Rio Grande silvery minnow Salvage
2011

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W. Jason Remshardt
Thomas P. Archdeacon
U.S. Fish and Wildlife Service
New Mexico Fish and Wildlife Conservation Office
3800 Commons Avenue NE
Albuquerque, New Mexico 87109

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Executive Summary

Between 25 June and 26 October 2011, a total extent of 40.0 miles of the main channel of the Middle Rio Grande became intermittent in the Isleta (12.9 miles) and San Acacia (27.1 miles) reaches. Including multiple drying events, 83.7 river miles were salvaged in the San Acacia reach, and 59.2 in the Isleta reach. A total of 8,244 Rio Grande silvery minnow were salvaged from isolated pools, transported, and released alive at locations within the same reach as they were salvaged. The take by mortality of 116 Rio Grande silvery minnow was attributed to water operations in the Middle Rio Grande during the 2011 irrigation season and assigned as incidental take. The level of estimated incidental take (observed multiplied by 50) was 5,800 and was well below the limits established under the determination of incidental take number of 459,077 individuals for the 2011 season. The loss of 336 Rio Grande silvery minnow was attributed to U.S. Fish and Wildlife Service permit activities. Going into the 2011 salvage season, lower pre-salvage catch rates meant that the allowed incidental take number was set lower in 2011 than 2010. Although we salvaged more miles and days in 2011, the number of fish observed both alive and dead was lower in 2011.

Introduction

Every year since 2001, with the exception of 2008, salvage activities were conducted on intermittent sections of the Middle Rio Grande for Rio Grande silvery minnow (RGSM) (Smith 2001, Smith and Munoz 2002, Smith and Basham 2003, U.S. Fish and Wildlife Service 2005; U.S. Fish and Wildlife Service 2006b, Remshardt 2008, Remshardt 2010, Remshardt and Archdeacon 2011). These activities were conducted under a variety of protocols and management actions to maximize effectiveness of RGSM salvage. The March 17, 2003 Biological Opinion (BO) described a Reasonable and Prudent Alternative, Reasonable and Prudent Measures, and Conservation Measures that served in part to secure baseline conditions for RGSM and Southwestern Willow Flycatcher (USFWS 2003). As part of the March 17, 2003 BO, the U.S. Fish and Wildlife Service (USFWS) established a protocol to determine allowable annual incidental take limits for RGSM (> 30 mm SL) for water operations in the Middle Rio Grande. That limit is now amended annually, incorporating a formula that includes October standard monitoring data, habitat conditions during the spawn (spring runoff), and augmentation. Federal Action agencies are apprised of the limit for incidental take by 1 April each year. Estimates of incidental take in the field are derived from surveys in which observed mortality is multiplied by 50, based on the assumption that the probability of observing a single mortality is 0.02. This value was an estimated value determined by USFWS Biologists (USFWS 2003). The amended incidental take limit for the 2011 irrigation season was 459,077 which would be equivalent to documented mortalities (USFWS 2011).

This report documents efforts during 2011 to reduce the mortality of post-larval RGSM when flow in the Middle Rio Grande became intermittent. Additionally, we related environmental parameters measured from isolated pools to the number of RGSM collected. We used time of day to describe diel and seasonal temperature changes. We related the amount of effort required to salvage a specified distance, while accounting for seasonal changes. The objective was to determine how many miles of river could be salvaged before pool temperatures exceed environmental thresholds for RGSM survival, with a reasonable crew size (4-6 persons) and work day (<12 h). Based on this information, we recommend changes that could be incorporated into a future BO and suggestions for research needs.

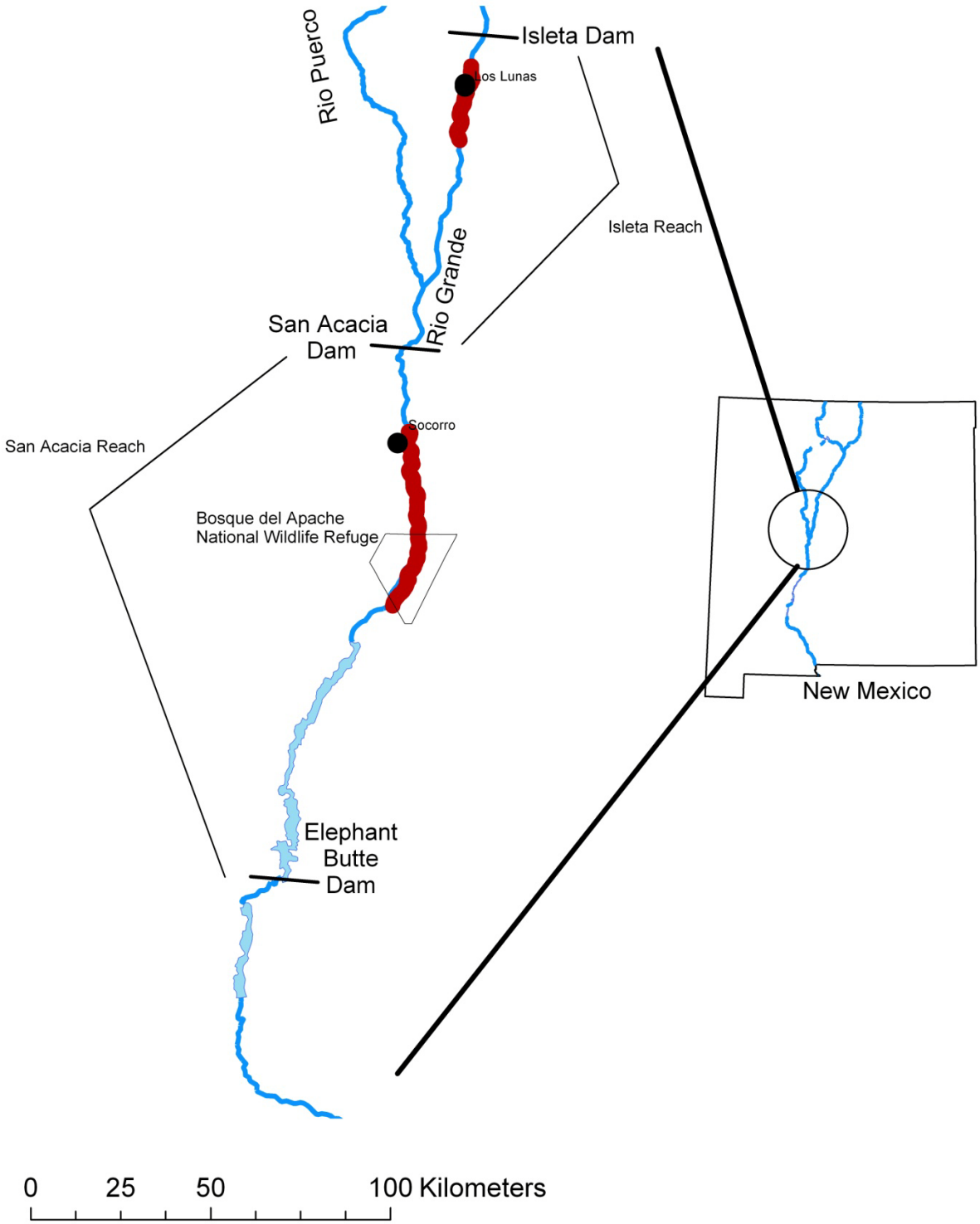

Figure 1-Reaches of the Middle Rio Grande in New Mexico. Salvage operations for Rio Grande silvery minnow were conducted in the Isleta and San Acacia reaches in 2011. Red areas indicate areas that experienced discontinuous flows.

Methods

Determination of Incidental Take

RGSM mortality can occur with channel drying resulting from seasonal conditions, and conditions resulting from federal water operations. In the recent past, intermittent conditions have existed in significant portions (e.g., up to 68.0 miles – approximately 45 percent of the RGSM's contemporary range) of the river between Isleta Diversion Dam and Elephant Butte Reservoir (Remshardt 2008; 2010; Remshardt and Archdeacon 2011; Smith 2001; Smith and Basham 2003; Smith and Muñoz 2002; USFWS 2005; 2006b). Salvage from intermittent reaches of river is intended to reduce RGSM mortality that occurs with channel drying. In addition, salvage is meant to reduce the probability that mortality associated with water operations will exceed the limit for incidental take.

Salvage operations progressed in synchrony with river recession, with priority given to reaches in which RGSM mortality due to federal water operations would be considered incidental take. Incidental take of post embryonic RGSM was defined for two size classes; those shorter than or equal to 30 mm SL and those longer than 30 mm SL. Individuals ≤ 30 mm SL are presumed to be taken when the river dries downstream of Isleta Diversion Dam (USFWS 2003), but no limit on the amount of incidental take was calculated.

Determination of incidental take for larger RGSM (> 30 mm SL) was conditional. Mortality of larger RGSM that occurred in portions of the river that rewetted due to forces that are not directly or indirectly related to federal water operations was not considered to be incidental take under the March 17, 2003 BO (USFWS 2003). In contrast, re-drying of river reaches that previously dried in violation of the BO and were rewet directly or indirectly related to federal water operations was regarded as incidental take. Mortality of RGSM > 30 mm SL that occurred outside of the active river channel was generally not considered to be incidental take. The exception to this generalization involved areas outside of the active channel that were wetted as a consequence of federal water pumping operations (i.e., water pumped from the low flow conveyance channel in an effort to maintain specified flows in the river) or river maintenance activities. Finally, RGSM > 30 mm SL that were "salvaged" and died in transit to relocation sites were not considered to be incidental take. Likewise RGSM that exhibited advanced clinical signs of poor health were deemed not salvageable and also (e.g., lethargy and hemorrhagic lesions) were excluded from incidental take.

Salvage of RGSM

Transport tanks were filled to near capacity (~50 gal) with municipal water filtered and dechlorinated from a Culligan® water filter system at the New Mexico Fish and Wildlife Conservation Office in Albuquerque. Infrequently, for example if we were salvaging multiple days in a row and not travelling back to Albuquerque, we would also use water from adjacent drains or flowing sections of river on the day of salvage. Salt (NaCl) was added to water in hauling vessels at the rate of 1.0 % NaCl solution, and Stress Coat® was added at the rate of 0.26 ml/L (1 ml/gal).

Using seines, we collected RGSM from isolated pools that formed as flow in the Middle Rio Grande became discontinuous. Prior to handling RGSM, personnel washed their hands to remove the residue of lotions (e.g., suntan lotions and mosquito repellant). Salvaged RGSM

were immediately placed into five-gallon buckets filled with transport tank water and subsequently transferred to 50-gallon transport tanks attached to utility terrain vehicles.

Pure oxygen was supplied to transport tanks through micro-bubble oxygen diffusers. Flow of oxygen was adjusted with varying water temperatures and loading rates of fish to maintain dissolved oxygen levels near 100% saturation. Salvaged RGSM were transported and released in the nearest section of perennial river within the reach they were salvaged. Prior to releasing RGSM, water in the transport tanks was tempered by slowly adding river water to the transport tanks until it was within 1° C of the river at the release site. We enumerated salvaged RGSM and noted relative abundances of other species of fish encountered daily.

Once a location was identified as a potential salvage site, a set of primary and secondary biological criteria were applied to determine whether salvage should occur. These criteria were defined by tolerance limits of RGSM to environmental variables (Cho et al. 2009), which were implemented in the salvage protocol in 2007. Documentation of conditions, incidental take (if appropriate), and preservation of individuals followed.

Criteria for Salvaging

Primary (Water Quality)	1. Water temperature < 34°C 2. Dissolved oxygen > 2.0 mg/liter 3. pH < 9.0
Secondary (Fish Health)	1. No dead fish (any species) in pool 2. No lethargy and/or hemorrhagic lesions noticed from fish (any species) in pool

In the instances where salvage was deemed necessary and feasible, effort was made to ensure that transported fish had the highest probability of survival.

Monitoring Activities

During salvage, a variety of data were collected to document environmental conditions at the pools, including those data necessary to determine whether or not salvage would occur. These parameters included visually-estimated size of pool (m^2), depth (nearest 0.1 m), dissolved oxygen (mg/L), water temperature (C°), pH, time of day, location (nearest 0.1 RM), and reach of river.

All RGSM were characterized as adult (estimated age 1 or older), young of year < 30 mm SL (typically early season), or young of year > 30 mm SL (late season). All adults were examined for Visible Implant Elastomer marks indicating their origin as a hatchery-released fish. Each RGSM was labeled as salvaged, dead, or sick. Dead fish were categorized as either incidental take or FWS permit fish. Rio Grande silvery minnow that exhibited advanced clinical signs of poor health (e.g., lethargy and hemorrhagic lesions) were counted as "sick" fish. Sick fish were not salvaged and were counted towards the FWS permit. Individuals < 30 mm SL were counted as incidental take, but were not included in reports of incidental take (USFWS 2003). Upon release, any fish that died during transport were subtracted from the appropriate size class of

salvaged fish and added to the FWS permit total, giving the final number of salvaged fish for that day and reach.

Analysis of Data

Reach-specific Data. We calculated reach and cumulative totals for all categories of RGSM encountered during salvage activities. We also summarized the temporal and spatial extent of each drying period.

Pool-Specific Data. We calculated the number of RGSM observed from each pool. Individual pools were not monitored over time, all relations between variables and time were from separate re-wetting events, e.g., pool size over time indicates size of pools after each re-wetting, not the size of an individual pool through time.

We examined counts of RGSM per pool to see how they varied by pool depth, date observed, distance to top of drying, and reach. We used general linear models with a negative binomial error structure as suggested for use with count data (Crawley 2007; O'Hara and Kotze 2010). Transformation (log+1 transformation) were applied to pool depth and area to meet the assumptions of the models.

We examined the change in isolated pool temperature and depth over time. To do this, we modeled both pool size and depth versus date observed. For statistical analyses, we used the Julian date with the origin set at 25 June 2011 (e.g., 25 June 2012 = 1).

We used multiple linear quantile regression to relate pool temperature to time of day and date (Koenker and Bassett 1978). Rather than estimating the slope for mean pool temperature during the day, quantile regression was used to estimate specified quantiles, e.g. the 50^{th} quantile would be the median. The regression line was the line of best fit for the specified quantile. We chose the 75^{th} quantile, which was defined as the time of day when 25% of the pools crosses 34º C. This allowed us to evaluate the temperature criteria for salvage, while still accounting for the effect of date. From this, we predicted the time of day when 25% of the pools exceeded 34º C for the 1^{st} and 30^{th} day of salvage, bracketing the time period when first drying occurs. We used this to estimate how many hours of salvage were possible before pools exceeded the maximum temperature threshold during the first drying.

Date-Specific Data. For daily data, we calculated the RGSM observed for each day of salvage, number of pools salvaged, number of river miles salvaged, and the amount of time required to salvage that distance. We used negative binomial models for count data relating RGSM to reach, date, and miles salvaged. We used multiple linear regression to relate number of miles salvaged to hours worked and date.

Relevance of Salvaged fish to Population. To estimate the relevant contribution that salvaged fish had on the population, we compared the amount of salvaged fish as a proportion of the population estimate for each reach salvaged (Dudley et al. 2012). To do this, we applied previously estimated values of survival for salvaged and wild RGSM (Caldwell, et al. 2010; Remshardt 2007). The Caldwell, et al. (2010) survival estimate of salvaged fish was used for day 1-10, and the Remshardt (2007) monthly survival estimate of wild RGSM was used for days

11-end, where "end" was noted as day of population estimate. These two estimates were combined and applied to each day's salvaged fish to obtain an estimated number of salvaged fish that survived to the average date the RGSM population estimation occurred for each reach (Isleta = 15 October 2011; San Acacia = 6 October 2011). Each reach was estimated separately for two reasons, 1) population estimates were available separately for each reach and 2) salvaged fish are moved to other sections of river within the reach they were salvaged.

Finally, in a post-hoc analysis, we predicted the number of miles that could be salvaged in each reach during six hours. We chose six hours because it represents the time from the first pool salvaged to when pool temperatures exceeded the salvage criteria (as estimated above), not the total work day. This represents approximately an 11-h work day including travel time, preparations, and transport and release of salvaged fishes. We used analysis of covariance to model how date and reach influence the amount of miles that can be salvaged per hour. We forced the regression through the origin, as zero hours salvaged must be zero miles salvaged.

We used program R for all statistical analyses (R Development Core Team 2011). We used package Quantreg (Koenker 2011) to perform quantile regression, and package MASS (Venables and Ripley 2002) for negative binomial modeling. A chronological summary of all collections appears in Appendix A.

Results

Documentation of Incidental Take of RGSM

In 2011, drying occurred in the Isleta Reach between the Peralta Wasteway and a point about four miles downstream of the Isleta Diversion Dam (Figure 1), and in the San Acacia Reach from the south boundary of Bosque del Apache National Wildlife Refuge to about Socorro, New Mexico (Figure 1). Multiple re-wetting and drying events were recorded in each reach, as re-wetting and re-drying occurs with monsoons, changes in irrigation demand, or through irrigation system maintenance.

Channel drying began 25 June 2011 and ended on 26 October 2011. Channel drying resulted in the incidental take of 116 RGSM (Table 1). The estimated level of incidental take was therefore 5,800 (observed multiplied by 50) and was below the limit established for the 2011 season, which was 459,077 (USFWS 2011).

Table 1-Summary of salvage operations for Rio Grande silvery minnow in the Middle Rio Grande, 2011. Total salvaged RGSM does not include transport losses. Age-0 <30 mm SL includes incidental take by mortality, FWS permit, dead/dying fish, and live fish.

Reach	Age-0 <30 mm SL	Age-0 >30 mm SL	Adults	Total Salvaged	FWS Permit	Incidental Take	Total Minnows
San Acacia	13	1216	3740	4956	255	111	**5335**
Isleta	205	2230	1058	3288	81	5	**3579**
Total	218	3446	4798	8244	336	116	**8914**

Channel Drying

During the 2011 irrigation season, 40 miles of the main channel of the Middle Rio Grande became intermittent, 27.1 in the San Acacia Reach and 12.9 in the Isleta Reach (Table 2). Channel intermittency in the San Acacia Reach occurred between the south boundary of Bosque del Apache National Wildlife Refuge and Socorro, and between the Peralta Wasteway and a point four miles downstream of the Isleta Diversion Dam during the 2011 irrigation season (Figure 1).

Salvage operations were conducted on 50 days during the 2011 irrigation season, 26 of which were in the San Acacia Reach, and 30 in the Isleta Reach (both reaches were salvaged on six days). Salvage occurred between 25 June and 26 October 2011, though many subsections re-wetted, which required additional salvage. In total, 83.7 river miles were salvaged in the San Acacia Reach, and 59.2 in the Isleta Reach (Table 2). For a chronological summary of salvage operations, see Appendix A.

Table 2-Number of days salvaged, pools evaluated, and miles salvaged and dried per reach during 2011 salvage operations. The number of miles dried is the longest section of discontinuous flow observed for the season. The miles salvaged include repeated drying and wetting events.

Reach	Number of Days	Pools	Miles Salvaged	Miles Dried
San Acacia	26	947	59.2	12.9
Isleta	30	1029	83.7	27.1
Total	56	1976	142.9	40.0

Salvage of Rio Grande silvery minnow

A total of 8,244 RGSM were captured in isolated pools in 2011 (Table 1). Of these, 8,073 were transported to flowing sections within the same reach and released alive (97.9% survival). The average daily number of miles salvaged was at or below the 8.0 miles/day rate allowed in the March 17, 2003 BO (USFWS 2003), as modified on June 15, 2006 (USFWS 2006a). This is a mean of 58 salvaged RGSM/ river mile.

A total of 336 Rio Grande silvery minnow was counted towards the FWS permit (Table 1). These individuals included those that perished during handling and transport, were preserved for salvage research, and those that were categorized as "sick".

Monitoring Activities

We selected a multiple regression model containing date, time of day, and the interaction to explain pool temperature. Pool temperature was related to date and time of day (Figure 2 Appendix B). Time of day when 25% of pools exceed 34º C was 1300 hrs for the first day of salvage, and 1430 hrs the 30th day of salvage, which would represent the approximate period of time for the first drying. After the 30th day, most salvage activities occurred in previously dried sections. Mean pool size and depth decreased over time (Figure 3 and Figure 4, respectively), but there was much unaccounted variability in the model (Appendix B).

Relevance of Salvaged fish to Population. The total number of salvaged fish released alive in 2011 prior to the population estimate was 7,836. When factoring in estimated survival of these salvaged fish, there were an estimated 1,180 RGSM at the time of the October 2011 population estimate in the Isleta Reach, or between 1.8 and 6.4% of the 18,356 – 66,318 (95% CI) estimated

population size (Dudley et al. 2012). There were an estimated 1,524 at the time of the October 2011 population estimate in the San Acacia Reach, or between 3.0 and 15.4% of the 9,894 – 51,187 (95% CI) estimated population size (Dudley et al. 2012).

The amount of river than could be salvaged per hour differed between reaches (Figure 5), and was greater for the San Acacia Reach (Appendix B). In the Isleta Reach, approximately 4.7 miles can be salvaged in six hours, while approximately 6.4 miles can be salvaged in six hours in the San Acacia Reach. However, the San Acacia Reach is more likely to dry earlier in the season. Earlier in the season, the amount of time available to salvage is reduced to about 5.5 hours because the temperature limit of 34° C is reached earlier in the day. This equates to an estimated 5.9 miles that can be salvaged during a normal work day.

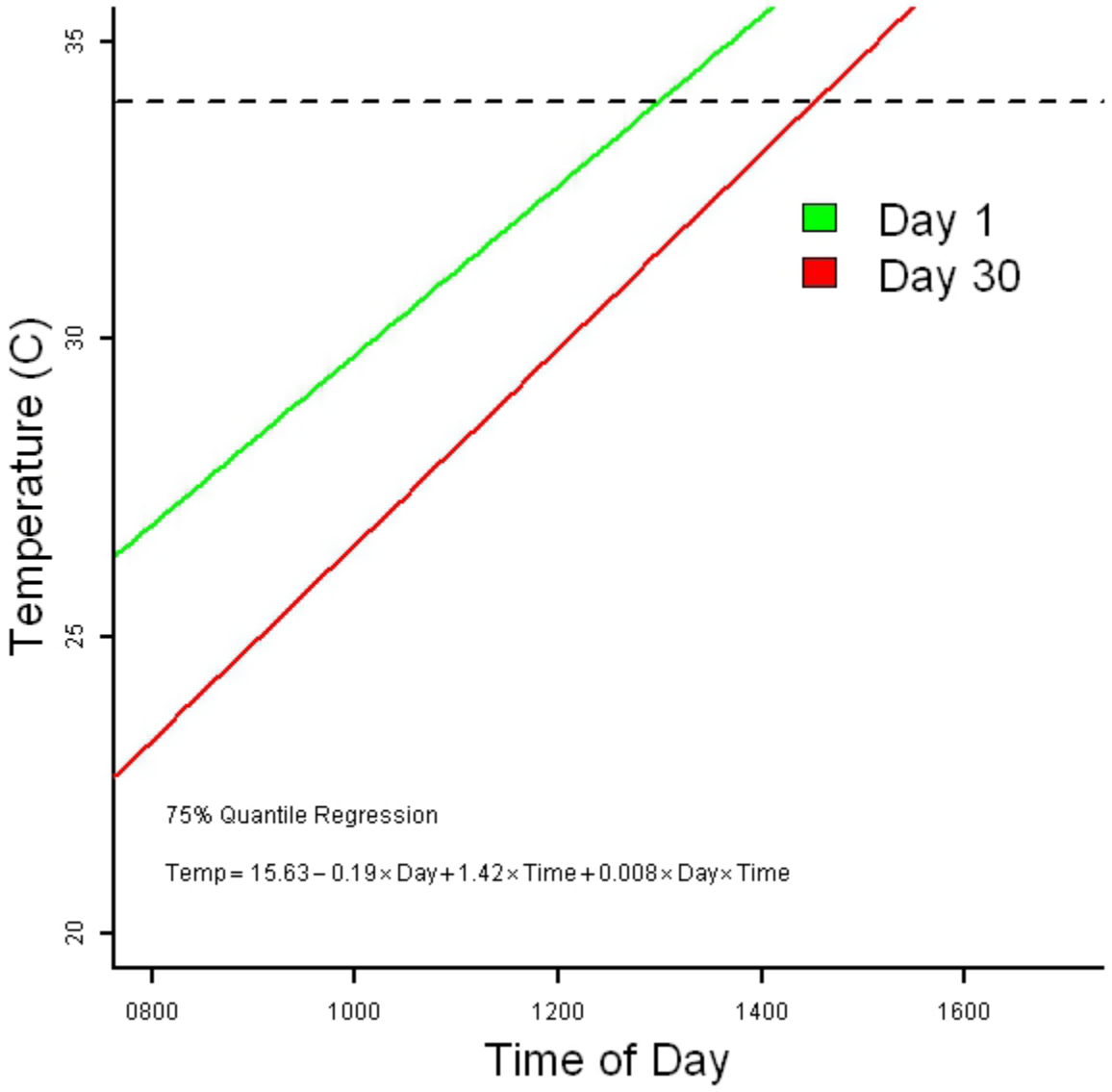

Figure 2-Quantile regression relating time of day to 75th quantile of measured pool temperatures in the Middle Rio Grande. The 75th quantile is the point where 75% of the data lies at or below the point. In the regression, 75% of

the pools are below the predicted temperature for a given time, while 25% exceed it. In contrast, a normal regression would show the predicted mean pool temperature at a give time of day. The two lines represent the first and 30th days of salvage, bracketing the time period for first drying of the Rio Grande during salvage operations.

The number of RGSM encountered in a pool was dependent on size, depth, and date (Appendix B). Reach was not statistically significant (P>0.10), and was removed from the model. The number of RGSM per pool increased with increasing pool depth and size, and decreased through the season, with depth being the most important predictor. The number of RGSM encountered per pool as increased as the distance to the top of drying decrease. This effect was small, but highly significant (Appendix B).

The number of RGSM encountered per day was dependent on number of miles salvaged and date, but was not statistically significantly related to reach (Appendix B). The number of RGSM encountered daily increased as river miles salvaged increased, but decreased slightly through the season.

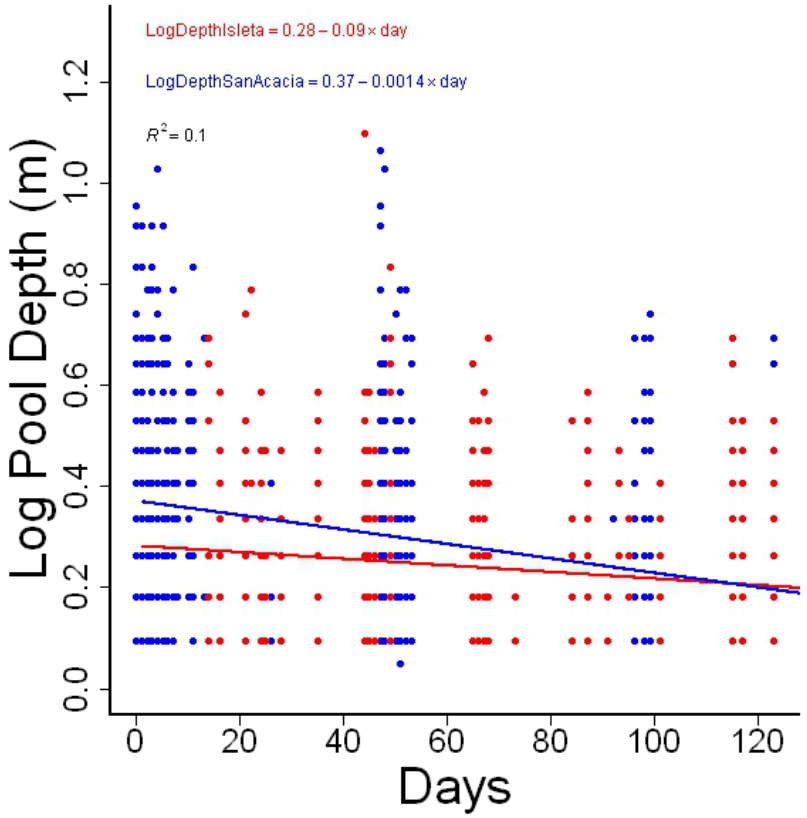

Figure 3-Relation between days since first drying and pool depth in the Middle Rio Grande, New Mexico. Blue points are pools from the San Acacia Reach, while red points are pools from the Isleta Reach. Pool depth was log-transformed.

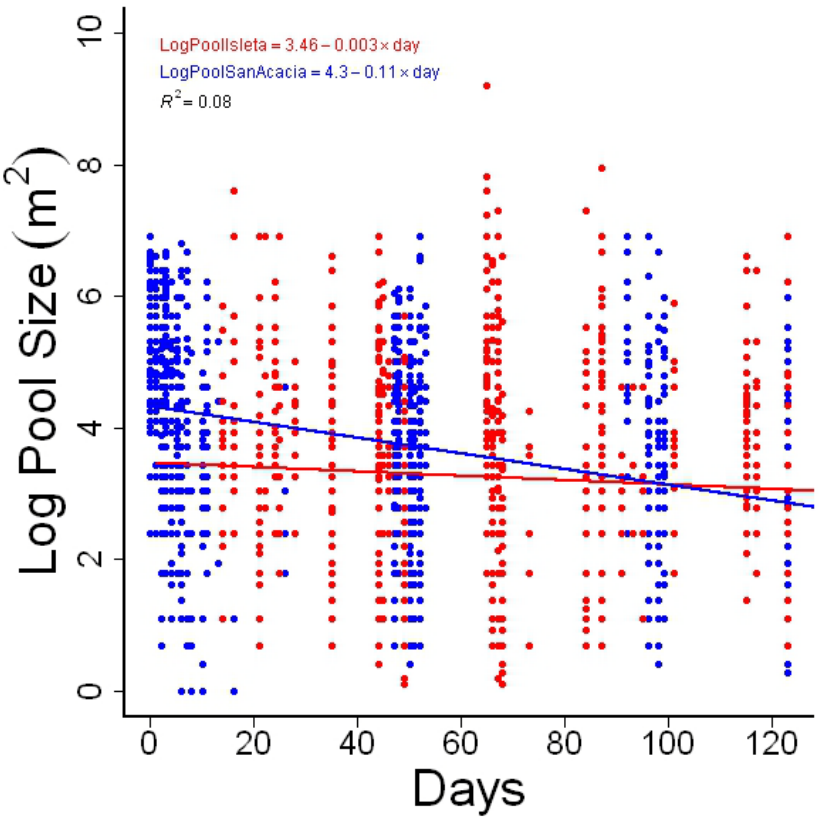

Figure 4-Relation between days since first drying and estimated pool size in the Middle Rio Grande, New Mexico. Blue points are pools from the San Acacia Reach, while red points are pools from the Isleta Reach. Pool size was log-transformed.

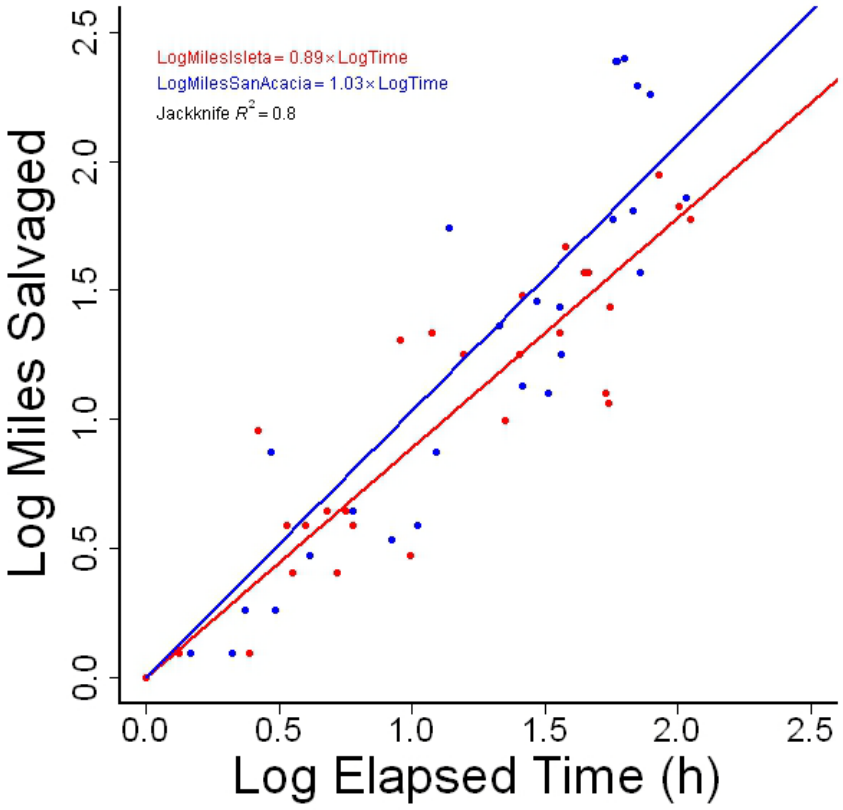

Figure 5-Estimated number of miles that can be salvaged per hour, by reach, in the Middle Rio Grande, New Mexico. Blue points are from the San Acacia Reach, while red points are from the Isleta Reach. Both axes are log-transformed. Because zero miles can be salvaged in zero hours, we forced the regression through the origin.

Discussion

Compared to 2010, we salvaged 10 more days and 7.7 more total miles. An estimated 4.1 more miles was not salvaged before rewetting occurred. We also sampled nearly double the amount of pools in 2011 compared to 2010, yet collected fewer RGSM (Remshardt and Archdeacon 2011). This resulted in an estimated average of 18 fewer RGSM per mile compared to 2010.

We were able to predict both the number of RGSM found in pools and found during each day (Remshardt and Archdeacon 2011). Both numbers decreased throughout the season. In each pool, number of RGSM increased with increasing pool size and depth. Both of those pool characteristics decreased during the season; however, it is not clear if fewer RGSM found per pool later in the season is directly related to pool size. Likely, pools are the same size when first formed, but dry more quickly later in the season, and are smaller when observed during salvage later in the season. These observations agree with observations that pool size and depth decrease through time, and is possibly due to decreased bank storage after repeated re-wetting and drying. The fact that fewer fish were found in pools as the year progressed may be correlated with the seasonally declining catch rates observed between June and October during population monitoring conducted throughout all reaches (Dudley and Platania 2012).

Another possibility for the decline, especially in late June and early July, could be the increased mobility of young juvenile fish as they grow. The June 15th start date for intermittency was designated to give young juvenile fish at least 30 days of growth before being susceptible to drying conditions. By giving these young juvenile fish time grow (up to ~ 20 mm SL), they might become more mobile and are able to navigate river velocities. In 2011, the largest RGSM spawn was noticeably late in the season, corresponding to a flow increase in late May. This was also reflected in the lack of juvenile RGSM in the June population monitoring survey (Dudley and Platania 2012). Typically, when the spawn occurs in early to mid-May, this is reflected in peak catch rates for juvenile RGSM in the June survey, but in 2011, this first occurred in the July survey (Dudley and Platania 2012).

Unlike 2010, we were able to predict the number of RGSM collected in a day based on the number of miles salvaged and the date. In 2010, several pools with hundreds to thousands of RGSM occurred on days with very little total drying, thus obscuring any relation between amount of river salvaged and total RGSM collected. In 2011, total numbers of RGSM collected each day decreased as the season progressed, while still accounting for the number of miles salvaged each day. This agrees with the observation that fewer RGSM are collected from each pool later in the season. Although the effect is small, fewer RGSM are present in dewatered sections of the river after periodic wetting and drying cycles.

In 2011, collection of time of day for each pool salvaged allowed us to estimate how many miles could be salvaged per day. The current BO allows for up to eight miles of river to be dried daily. Our data allow for a revised, more informed drying allowance, based on the feasibility of daily salvage operations. We found that for six hours on the river, about 11 hours are required for the entire day, which includes travel, tank preparations, in-channel travel to and from drying sites, transport of salvaged fishes, and equipment maintenance. Early in the season, 25% of the pools exceed the temperature criteria by 1300 hours. By the end of the first month of salvage, this moves to about 1430 hours. We estimate that about 4.7 miles can be salvaged in the Isleta Reach

during first drying, while about 6.4 miles (5.9 if you factor in early season temperature extremes) can be salvaged in the San Acacia Reach. The slower speed in the Isleta Reach reflects the more difficult conditions, where braided channels and jetty jacks are commonly encountered, and require more time to salvage. These estimates are best-case scenarios; we recommend that daily drying be limited to these amounts. We recommend either reach-specific allowances, 4.5 miles in the Isleta Reach and six miles in the San Acacia Reach, or a non-specific maximum of five miles per day for either reach, to allow for unusual situations (e.g. equipment failures). We also note that simultaneously salvaging in Isleta and San Acacia at the suggested rates would not be feasible without a crew of 8 or more.

The distance to the top of drying (e.g., the distance a pool lies from nearest upstream continuous flow) influenced the number of fish per pool. There were fewer YOY and adults in pools as the distance to the top of drying increased. This could be explained by a couple of factors; first, as salvage crews move closer to the top of drying and flowing sections of river, the time that any pool and fish would have been subject to declining water quality, crowding, and predation would be lessen, and second, it is hypothesized that as the river flows decrease, some RGSM (> 30 mm SL) move upstream following the receding river. Current management is designed such that river drying is limited daily to allow upstream movement of some RGSM out of drying sections of river. The fact that higher densities are observed as you move closer to the top of drying on any particular day suggests that some movement is happening, but what is unknown is what percentage of fish are moving out of drying sections of river versus those that remain, especially as this relates to the number of river miles dried in any particular day. While it appears that more fish are found in pools closer to the top of drying, the amount of river miles dried in one day is less of a predictor for number of fish salvaged. Future research on movement of RGSM and other species out of drying sections of river will be important to determine the effect rate of drying has on stranding fishes in isolated pools.

Acknowledgments

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Personnel of the New Mexico Fish and Wildlife Conservation Office served to plan and coordinate salvage operations, and represented the core of the salvage workforce, including Tristan Austring, Michelle Barnes, Sara Blocker, Andy Dean, Tim Mitchusson, Dustin Myers, Christine Stewart, and Cole Wolf. Field assistance was also provided by the Army Corps of Engineers staff including Sara Beck and Justin Reale. Special thanks to Bosque Del Apache National Wildlife Refuge for providing housing and logistical support.

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Appendix A: Chronology of Salvage Operations

Note: FWS permit includes those found dead that could not be attributed to incidental take including fish not salvaged due to health criteria, those sacrificed for research, or died prior to release. Salvaged fish are those released alive > 30 mm SL, number in parentheses is the number of adults. Release locations: [a]Isleta Diversion Dam, [b]Peralta Wasteway, [c]Highway 346 Bridge, [d]U.S. 60 Bridge, [e]1 mile below San Acacia Diversion Dam, [f]San Marcial Railroad Bridge, [g]Escondida Bridge, [h]Unrecorded location in San Acacia Reach.

25 June 2011	[f]San Acacia Reach	WJR11-1020
Rio Grande silvery minnow – Salvaged		175(175)
Rio Grande silvery minnow – FWS permit		15
Rio Grande silvery minnow – Incidental Take		3

26 June 2011	[f]San Acacia Reach	WJR11-1021
Rio Grande silvery minnow – Salvaged		152(152)
Rio Grande silvery minnow – FWS permit		1
Rio Grande silvery minnow – Incidental Take		12

27 June 2011	[e]San Acacia Reach	TPA11-060
Rio Grande silvery minnow – Salvaged		365(365)
Rio Grande silvery minnow – FWS permit		104
Rio Grande silvery minnow – Incidental Take		8

28 June 2011	[f]San Acacia Reach	WJR11-1022
Rio Grande silvery minnow – Salvaged		283(283)
Rio Grande silvery minnow – FWS permit		10
Rio Grande silvery minnow – Incidental Take		7

29 June 2011	[e]San Acacia Reach	TPA11-064
Rio Grande silvery minnow – Salvaged		170(170)
Rio Grande silvery minnow – FWS permit		2
Rio Grande silvery minnow – Incidental Take		2

30 June 2011	[f]San Acacia Reach	WJR11-1023
Rio Grande silvery minnow – Salvaged		295(295)
Rio Grande silvery minnow – FWS permit		20
Rio Grande silvery minnow – Incidental Take		34

1 July 2011	[e]San Acacia Reach	TPA11-065
Rio Grande silvery minnow – Salvaged		213(213)
Rio Grande silvery minnow – FWS permit		23
Rio Grande silvery minnow – Incidental Take		7

2 July 2011	[e]San Acacia Reach	TPA11-066
Rio Grande silvery minnow – Salvaged		209(209)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		6

3 July 2011	[e]San Acacia Reach	TPA11-067
Rio Grande silvery minnow – Salvaged		22(22)
Rio Grande silvery minnow – FWS permit		34
Rio Grande silvery minnow – Incidental Take		14

5 July 2011	[f]San Acacia Reach	TPA11-068
Rio Grande silvery minnow – Salvaged		278(278)
Rio Grande silvery minnow – FWS permit		2
Rio Grande silvery minnow – Incidental Take		8

6 July 2011	[f]San Acacia Reach	WJR11-1024
Rio Grande silvery minnow – Salvaged		117(117)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		2

8 July 2011	[f]San Acacia Reach	ATD11-013
Rio Grande silvery minnow – Salvaged		104(104)
Rio Grande silvery minnow – FWS permit		4
Rio Grande silvery minnow – Incidental Take		7

9 July 2011	[a]Isleta Reach	ATD11-014
Rio Grande silvery minnow – Salvaged		10(10)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0

11 July 2011	[e]San Acacia Reach	TPA11-069
Rio Grande silvery minnow – Salvaged		1(1)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		1

11 July 2011	[a]Isleta Reach	WJR11-1025
Rio Grande silvery minnow – Salvaged		30(30)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0

16 July 2011	[a]Isleta Reach	TPA11-071
Rio Grande silvery minnow – Salvaged		35(35)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0

17 July 2011	[a]Isleta Reach	TPA11-072
Rio Grande silvery minnow – Salvaged		2(2)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0

19 July 2011	[a]Isleta Reach	WJR11-1026
Rio Grande silvery minnow – Salvaged		11(11)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0

20 July 2011	[a]Isleta Reach	WJR11-1027
Rio Grande silvery minnow – Salvaged		260(260)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0

21 July 2011	[e]San Acacia Reach	WJR11-1028
Rio Grande silvery minnow – Salvaged		1(1)
Rio Grande silvery minnow – FWS permit		1
Rio Grande silvery minnow – Incidental Take		0

23 July 2011	[a]Isleta Reach	WJR11-1029
Rio Grande silvery minnow – Salvaged		2(2)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0

30 July 2011	[a]Isleta Reach	TJA11-071
Rio Grande silvery minnow – Salvaged		79(58)
Rio Grande silvery minnow – FWS permit		3
Rio Grande silvery minnow – Incidental Take		0

8 August 2011	[a]Isleta Reach	WJR11-1030
Rio Grande silvery minnow – Salvaged		966(174)
Rio Grande silvery minnow – FWS permit		8
Rio Grande silvery minnow – Incidental Take		0

9 August 2011	[a]Isleta Reach	TPA11-073
Rio Grande silvery minnow – Salvaged		305(93)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0

9 August 2011	[a]Isleta Reach	TPA11-073A
Rio Grande silvery minnow – Salvaged		32(17)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0

9 August 2011	[a]Isleta Reach	TPA11-073B
Rio Grande silvery minnow – Salvaged		89(8)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0

10 August 2011	[a]Isleta Reach	WJR11-1031
Rio Grande silvery minnow – Salvaged		12(7)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0

11 August 2011	[a]Isleta Reach	TPA11-076
Rio Grande silvery minnow – Salvaged		208(196)
Rio Grande silvery minnow – FWS permit		1
Rio Grande silvery minnow – Incidental Take		0

12 August 2011	[f]San Acacia Reach	WJR11-1032
Rio Grande silvery minnow – Salvaged		341(320)
Rio Grande silvery minnow – FWS permit		10
Rio Grande silvery minnow – Incidental Take		0

13 August 2011	[a]Isleta Reach	WJR11-1033
Rio Grande silvery minnow – Salvaged		286(74)
Rio Grande silvery minnow – FWS permit		3
Rio Grande silvery minnow – Incidental Take		5

14 August 2011	[f]San Acacia Reach	TJA11-072
Rio Grande silvery minnow – Salvaged		151(135)
Rio Grande silvery minnow – FWS permit		3
Rio Grande silvery minnow – Incidental Take		0

14 August 2011	[t]San Acacia Reach	TJA11-073
Rio Grande silvery minnow – Salvaged		630(177)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0

15 August 2011	[f]San Acacia Reach	TJA11-074
Rio Grande silvery minnow – Salvaged		399(144)
Rio Grande silvery minnow – FWS permit		23
Rio Grande silvery minnow – Incidental Take		0

16 August 2011	[f]San Acacia Reach	TJA11-075
Rio Grande silvery minnow – Salvaged		406(272)
Rio Grande silvery minnow – FWS permit		1
Rio Grande silvery minnow – Incidental Take		0

17 August 2011	[f]San Acacia Reach	WJR11-1034
Rio Grande silvery minnow – Salvaged		329(93)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0

29 August 2011	[a]Isleta Reach	WJR11-1040
Rio Grande silvery minnow – Salvaged		82(24)
Rio Grande silvery minnow – FWS permit		3
Rio Grande silvery minnow – Incidental Take		0

30 August 2011	[a]Isleta Reach	WJR11-1041
Rio Grande silvery minnow – Salvaged		217(87)
Rio Grande silvery minnow – FWS permit		4
Rio Grande silvery minnow – Incidental Take		0

31 August 2011	[a]Isleta Reach	WJR11-1042
Rio Grande silvery minnow – Salvaged		310(62)
Rio Grande silvery minnow – FWS permit		2
Rio Grande silvery minnow – Incidental Take		0

1 September 2011	[a]Isleta Reach	WJR11-1043
Rio Grande silvery minnow – Salvaged		147(26)
Rio Grande silvery minnow – FWS permit		1
Rio Grande silvery minnow – Incidental Take		0

2 September 2011	Isleta Reach	WJR11-1044
Rio Grande silvery minnow – Salvaged		0(0)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0

6 September 2011	[a]Isleta Reach	WJR11-1045
Rio Grande silvery minnow – Salvaged		23(1)
Rio Grande silvery minnow – FWS permit		38
Rio Grande silvery minnow – Incidental Take		0

17 September 2011	[a]Isleta Reach	WJR11-1046
Rio Grande silvery minnow – Salvaged		60(1)
Rio Grande silvery minnow – FWS permit		8
Rio Grande silvery minnow – Incidental Take		0

20 September 2011	[a]Isleta Reach	WJR11-1047
Rio Grande silvery minnow – Salvaged		23(1)
Rio Grande silvery minnow – FWS permit		3
Rio Grande silvery minnow – Incidental Take		0

24 September 2011	[a]Isleta Reach	WJR11-1048
Rio Grande silvery minnow – Salvaged		1(0)
Rio Grande silvery minnow – FWS permit		1
Rio Grande silvery minnow – Incidental Take		0

25 September 2011	San Acacia Reach	TPA11-084
Rio Grande silvery minnow – Salvaged		0(0)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0

26 September 2011	[a]Isleta Reach	TPA11-085
Rio Grande silvery minnow – Salvaged		4(0)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0

28 September 2011	[a]Isleta Reach	TPA11-089
Rio Grande silvery minnow – Salvaged		50(6)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0

29 September 2011	[h]San Acacia Reach	TPA11-090
Rio Grande silvery minnow – Salvaged		5(0)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0

1 October 2011	[g]San Acacia Reach	TPA11-095
Rio Grande silvery minnow – Salvaged		6(1)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0

1 October 2011	[g]San Acacia Reach	TPA11-096
Rio Grande silvery minnow – Salvaged		0(0)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0

2 October 2011	[h]San Acacia Reach	TJA11-076
Rio Grande silvery minnow – Salvaged		87(15)
Rio Grande silvery minnow – FWS permit		2
Rio Grande silvery minnow – Incidental Take		0

4 October 2011	[a]Isleta Reach	DJM11-078
Rio Grande silvery minnow – Salvaged		24(0)
Rio Grande silvery minnow – FWS permit		5
Rio Grande silvery minnow – Incidental Take		0

18 October 2011	[a]Isleta Reach	WJR11-1049
Rio Grande silvery minnow – Salvaged		147(66)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0

20 October 2011	[a]Isleta Reach	WJR11-1052
Rio Grande silvery minnow – Salvaged		77(3)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0

26 October 2011	[e]San Acacia Reach	TPA11-097
Rio Grande silvery minnow – Salvaged		9(2)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0

26 October 2011	[a]Isleta Reach	WJR11-1053
Rio Grande silvery minnow – Salvaged		4(0)
Rio Grande silvery minnow – FWS permit		1
Rio Grande silvery minnow – Incidental Take		0

25 June – 26 October	**Rio Grande**	**2011 Totals**
Rio Grande silvery minnow – Salvaged		**8244(4798)**
Rio Grande silvery minnow – FWS permit		**336**
Rio Grande silvery minnow – Incidental Take		**116**

Appendix B: R Model Output

Quantile regression for temperature

Call: rq(formula = temperature ~ date * time.dec, tau = 0.75, data = salvage)

tau: [1] 0.75

Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	15.62837	0.92180	16.95417	0.00000
date	-0.18658	0.02253	-8.27966	0.00000
time.dec	1.42168	0.07895	18.00826	0.00000
date:time.dec	0.00765	0.00195	3.91968	0.00009

Simple linear regression for pool size

Call:
lm(formula = log(size + 1) ~ date * reach, data = salvage)

Residuals:

Min	1Q	Median	3Q	Max
-4.2486	-1.0583	0.0514	1.0492	5.9642

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	3.462336	0.117996	29.343	< 2e-16 ***
date	-0.003325	0.001648	-2.017	0.0438 *
reachsa	0.857969	0.138360	6.201	6.84e-10 ***
date:reachsa	-0.008628	0.002036	-4.239	2.35e-05 ***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.544 on 1943 degrees of freedom
(27 observations deleted due to missingness)
Multiple R-squared: 0.07718, Adjusted R-squared: 0.07575
F-statistic: 54.16 on 3 and 1943 DF, p-value: < 2.2e-16

Simple linear regression for pool depth

Call:
lm(formula = log(depth + 1) ~ date * reach, data = salvage)

Residuals:

Min	1Q	Median	3Q	Max
-0.27587	-0.11602	-0.03454	0.07698	0.84499

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.2823154	0.0121780	23.182	< 2e-16 ***
date	-0.0006521	0.0001706	-3.822	0.000137 ***
reachsa	0.0888611	0.0144085	6.167	8.52e-10 ***
date:reachsa	-0.0007761	0.0002122	-3.657	0.000262 ***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.1567 on 1840 degrees of freedom
(130 observations deleted due to missingness)
Multiple R-squared: 0.1078, Adjusted R-squared: 0.1064
F-statistic: 74.13 on 3 and 1840 DF, p-value: < 2.2e-16

Non-linear regression for count of minnows per pool

Call:
glm.nb(formula = total.minnows ~ depth + date + dist.to.top,
    data = salvaged., init.theta = 0.2209297811, link = log)

Deviance Residuals:

Min	1Q	Median	3Q	Max
-1.7834	-1.0292	-0.8589	-0.1461	3.9981

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	1.354974	0.141293	9.590	< 2e-16 ***
depth	2.745189	0.224870	12.208	< 2e-16 ***
date	-0.015182	0.001521	-9.980	< 2e-16 ***
dist.to.top	-0.037339	0.008557	-4.364	1.28e-05 ***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for Negative Binomial(0.2209) family taken to be 1)

Null deviance: 1686.3 on 1681 degrees of freedom
Residual deviance: 1426.9 on 1678 degrees of freedom
(3 observations deleted due to missingness)
AIC: 6890.1

Number of Fisher Scoring iterations: 1

Theta: 0.2209
Std. Err.: 0.0104

 2 x log-likelihood: -6880.1320

Non-linear regression for count of minnows per day

Call:
glm.nb(formula = total.minnows ~ rm.salvaged + date + reach,
    data = sal.sum, init.theta = 0.6202584785, link = log)

Deviance Residuals:

Min	1Q	Median	3Q	Max
-2.3982	-1.3037	-0.2713	0.3253	1.5363

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	5.11718	0.38922	13.147	< 2e-16 ***
rm.salvaged	0.17911	0.06799	2.635	0.00842 **
date	-0.01403	0.00494	-2.840	0.00451 **
reachsa	-0.03963	0.37504	-0.106	0.91584

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for Negative Binomial(0.6203) family taken to be 1)

    Null deviance: 80.215 on 55 degrees of freedom
Residual deviance: 67.938 on 52 degrees of freedom
AIC: 661.7

Number of Fisher Scoring iterations: 1

              Theta: 0.620
          Std. Err.: 0.106

 2 x log-likelihood: -651.696