COLORADO PARKS & WILDLIFE

Present Distribution of Three Colorado River Basin Native Non-game Fishes, and Their Use of Tributaries

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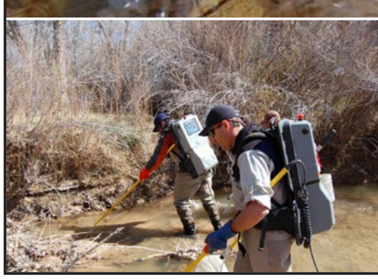

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COVER PHOTOS

Top: Bluehead Sucker (Zack Hooley-Underwood), Flannelmouth Sucker (Dan Kowalski), and Roundtail Chub (Kevin Thompson)

Bottom, left to right: 1) Electrofishing Yellowjacket Canyon (Kevin Thompson); 2) Cottonwood Creek weir site (Cole Brittain); 3) Submersible PIT tag antenna (Kevin Thompson); 4) Preparing the Roubideau Creek streambed for permanent PIT tag antenna placement (Kevin Thompson)

Back Cover: Sampling the Little Snake River

Present Distribution of Three Colorado River Basin Native Non-game Fishes, and Their Use of Tributaries

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Executive Summary

The objectives of this study were two-fold. First, to assess the currently occupied range in Colorado of Bluehead Sucker (*Catostomus discobolus*), Flannelmouth Sucker (*C. latipinnis*), and Roundtail Chub (*Gila robusta*). Second, we sought to control access to a spawning tributary used heavily by the sucker species in an effort to preclude participation in the spawning run on the part of non-native and non-native hybrid suckers, with the goal of achieving higher output of native sucker larvae.

Assessment of currently occupied range involved sampling (from 2012-2014) from sites that were randomly selected and spatially balanced across the landscape of historic native range for these species. The sites comprised those which were known to have previously been occupied by one or more of the study species (historic sites), and a those randomly selected point locations that had not been surveyed previously. Filtering the sites ensured that we focused mainly on tributary streams (because there is less information available on them), that streams of differing order were adequately represented, and that no site exceeded 8,500 feet elevation. Later sampling (2015-2017) focused primarily on historic sites, and included repeated visits to some sites within and across years.

The data set generated by the first three years of data were analyzed with occupancy models. Bluehead Sucker were estimated to occupy 62.6% of sites at which they had historically occurred. This species was also estimated to occupy 23.1% of randomly selected sites within suitable habitat at which they had not been previously sampled. Flannelmouth Suckers were estimated to occupy 37.1% of historic sites specific to this species when ignoring the effects of gradient on the probability of occupancy, and were rarely found at randomly selected sites. Gradient greatly affected Flannelmouth Sucker, with this species being much more likely to occupy sites of very gentle slope. Roundtail Chub were estimated to occupy 43.9% of species-specific historic sites when modeling on the average values of gradient and ordinal day of sampling covariates. Like Flannelmouth Sucker, Roundtail Chub were more likely to be found occupying historic sites of low gradient. They were also more likely to be found occupying sites at sampling dates later in the calendar year.

We found that surveys consisting of 2-pass electrofishing efforts over 500 feet or more of stream resulted in probabilities of detecting these species, given their presence at the site, of 0.95 or greater. Thus, 2-pass electrofishing over a suitable reach of stream carries a high probability of revealing whether any of the three species is present.

No formal occupancy analyses of the 2015 – 2017 data have yet been conducted, but occupancy by the three-species fishes was high over the 126 occasions represented, which included multiple visits per year at some sites. One or more of the study species were detected on 95% of sampling occasions in 2015, 89.5% of occasions in 2016, and 90.2% of occasions in 2017. Sampling occasions conducted during summer or fall months were likely to reveal three species occupancy by young-of-year or juvenile fishes rather than adults, which in many tributaries are only present during spring spawning season.

The conceptual basis for Chapter 2 of this report focused heavily on the native suckers and the predicament elicited by the introduction of non-native suckers on the Western Slope that both compete and hybridize with them. The continued spread of the non-native White Sucker (*C. commersonii*) and Longnose Sucker (*C. catostomus*) pose a threat to the genetic integrity of the native suckers that is both difficult to quantify and difficult to remediate. The likelihood of successfully stemming their spread via removal methods is small.

Instead, we sought to evaluate whether the control of a select spawning run would allow managers in the future to ensure that some tributaries in western Colorado would reliably allow the production of genetically pure native sucker larvae. We installed a weir and trap box in Cottonwood Creek, near Delta, over three spawning seasons (2015-2017) to attempt control of the sucker spawning run, allowing suckers we deemed to be native to pass while excluding those identified as non-native or hybrid. We also characterized the spawning population in a second tributary, Potter Creek, where no attempts to control spawning were made.

After the spawning season, sucker larvae were collected in each stream and subjected to genetic analysis using six microsatellite markers to determine their parentage.

In no study year were we entirely successful in controlling the spawning run. Primarily, failure of this objective was due to our inability to keep the picket weir fence clear of debris when runoff began in earnest. Thus, we were unable to demonstrate that controlling a spawning run resulted in the production of a greater proportion of genetically pure native sucker larvae. Moreover, oftentimes the genetic results of larval fish identification didn't meet our expectations that the larval fish population would generally reflect the adult spawning fish population composition. This was especially so in Cottonwood Creek where more species were encountered. In Potter Creek, very high proportions of both the spawning sucker population and the resulting larval sucker population were dominated by native species.

Potter Creek is 10 miles further up the Roubideau Creek drainage than Cottonwood. The differences in spawning population composition prompted further investigation of this phenomenon, and we found that further upstream in Cottonwood Creek and in Roubideau Creek, in limited sampling, genetically tested sucker larvae were more often found to be pure native suckers than in downstream locations. Given that non-native suckers have been present in the Gunnison River basin for at least 80 years, this may mean that certain tributary systems allow for spatial stratification that will benefit native suckers in the future, so long as such tributary systems remain open to fish access and their headwater areas remain uninvaded by non-native suckers.

During this study, many adult suckers were PIT tagged. Such fish allowed us to examine spawning fish fidelity to the Roubideau Creek tributary system and to our study streams within that drainage. We observed high rates of tributary fidelity to the Roubideau Creek drainage. For PIT-tagged native suckers detected entering Roubideau Creek during the spawning period in any given year, 69 to 78% of those fish (not adjusted for any annual mortality) were detected again the following year during the spawning period. Non-native and hybrid tagged suckers also tended to return to Roubideau Creek.

The fidelity demonstrated by tagged fish in this study enhances the probability of success in amplifying the proportion of native sucker larvae produced in tributary systems, provided a weir system suitable for high rates of stream flow and debris is in place. To that end, we recommend the testing of resistance board weirs in the Roubideau Creek drainage. We further recommend the identification of tributary systems in other river basins that may have similar characteristics with respect to the lack of non-native suckers in headwater areas as well as the lack of adult resident sucker populations.

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Chapter 1: Rangewide sampling

1.1 Introduction

Flannelmouth Sucker *Catostomus latipinnis*, Bluehead Sucker *C. discobolus*, and Roundtail Chub *Gila robusta* comprise an assemblage in the Colorado River Basin often referred to as the "three-species." Natives of the Colorado River Basin, the Flannelmouth Sucker and Roundtail Chub are endemic to the basin whereas the Bluehead Sucker is also found in portions of the Snake River Basin and Bonneville Basin (Minckley et al. 1986). Of the three, Roundtail Chub is considered a species of special concern by Colorado, whereas the two sucker species hold no special status. For all three, there is concern that populations are exhibiting downward trends. The Roundtail Chub was a candidate for Endangered Species Act listing as a threatened "distinct population segment" across the southern portion of its native range as recently as 2015 (Federal Register 2015), but has since been removed from proposed listing (Federal Register 2017). Collectively, the three-species are the subjects of a range-wide conservation agreement (UDWR 2006) to which Colorado is signatory, along with all other states claiming any portion of the native range of any of the three species.

In Utah, estimates of current occupancy are 47% of historic sites for the suckers and only 17% of historic sites for Roundtail Chub (Budy et al. 2015). More broadly, each species is estimated to occupy just 45 – 55% of its historic native range in the upper Colorado River basin (Bezzerides and Bestgen 2002; the upper basin includes the Colorado River and its tributaries from Glen Canyon Dam upstream). These authors estimated historic range from extensive searches of the historical literature, and gave greater weight to collection records supported by voucher specimens. Percentages of native range still occupied were derived by comparing data through 1979 to post-1979 data. The post-1979 era was chosen because these species overlap considerably with the habitat of the four Colorado River Basin endangered fishes, the subjects of intensive field research from 1980 onward. Therefore, a fair amount of ancillary information on the three-species was available for the post-1979 timeframe.

Unfortunately, for the three-species, the majority of this information has been restricted to mainstem rivers, the primary habitat for adults of the four endangered fish. The three-species fishes are more likely than the endangered fishes to be associated with tributary habitats that have not been widely sampled under endangered fish monitoring. Moreover, most other fish sampling in the Colorado River Basin is driven by sport fish management, and many of the smaller stream habitats where the three-species may feasibly exist are considered to be of low recreational fishery potential. As a result, much non-mainstem three-species habitat has never or rarely been sampled, a circumstance exacerbated by the possibility that such "rough fish" may not have been recorded even when encountered. An examination of these habitats is necessary to refine our understanding of the three-species' ranges in the basin, as well as to refine our assessment of the range-wide security of these fishes.

An effort to rigorously determine the present extent of the three-species' ranges in Colorado thus required sampling in areas other than mainstem channels. One way to accomplish such sampling in a scientifically defensible way is to pursue a form of "dual frame" occupancy sampling (Haines and Pollock 1998, Shyvers et al. 2018). This strategy couples sampling of historic sites where the species have previously been documented with sampling of randomly selected sites where it is possible the species may occur. Such a sampling strategy allows inference to the entire sampling frame (i.e., what is thought to be potential range of each species) within Colorado, as opposed to a strategy in which previously unvisited sites are selected non-randomly (perhaps based on convenient access).

1.2 Methods

In dual frame terminology, the two sampling frames are known as a list frame (historic sites, known point locations of previous species occurrence) and an area frame (in this study, the remainder of presumed potential range, from which randomly chosen point locations were surveyed). Our area frame was stratified into perennial and intermittent stream components. Our list frame was generated from the ADAMAS database of Colorado Parks and Wildlife, and comprised all sampling sites at which any of the three-species fishes had been observed. Over 80% of list frame sites were represented by data collected in 1980 and later. However, we chose not to exclude sites with data from before 1980 in order to make all historic sites available for sampling. In contrast, the composition of the area frame required the definition of what habitat we thought might be available to these fishes.

Our sampling was conducted with the objective of estimating site occupancy (Ψ). Our occupancy models also estimated the probability of detection (p) of the species of interest, given its presence at a site. Both Ψ and p may be influenced by various site characteristics, or covariates. Covariates we recorded and used in modeling were stream gradient at the site, ambient water conductivity on each sampling occasion, and day-of-year on which sampling occurred. All three covariates were considered to potentially influence Ψ, along with their squared terms since in each case there is likely an optimum value or range after which Ψ declines. Only stream conductivity was considered to influence p, since our chosen sampling method was electrofishing and it is well known that both high and low values of stream conductivity influence the effective-ness of electrofishing equipment.

We conducted occupancy analysis for each species separately. In addition to the influence of covariates on the estimated parameters, we modeled Ψ as a function of the type of site, grouped as random intermittent, random perennial, or historic. We further divided historic sites into two groups — those that were historic for the species for which occupancy was being modeled versus those that were historic for the three species in general (i.e., one or both of the other two species had been observed to historically occupy the site, but not the species that was the subject of analysis). We separated the historic sites this way because it isn't reasonable to consider a site as historic for a species that had never actually been documented at that site.

Finally, p was allowed to vary by site type (group) or by time. The latter corresponded to first or second electrofishing pass since each pass was considered a separate site visit. We kept first-pass fish in a holding pen, so p was likely to decrease because of behavioral avoidance responses and fewer fish available for encounter and capture on second passes. However, we also obtained an overall estimate of the probability of detection (p^*), given presence, using Bayesian methods. We generated Markov chain Monte Carlo (MCMC) files for the top model in each species analysis in MARK, using 4000 tuning samples, 1000 burn in samples, and 10,000 stored samples. These files were imported to Program R for analysis. In R, we used the 'mcmc' function in package 'coda' to generate 1000 estimates of p^*, then used the median value as our point estimate. Credible intervals around those point estimates were based on the values at 2.5% and 97.5% of the distribution of all p^* estimates.

Random Perennial or Intermittent sites — The area frame consisted of sites on both perennial and intermittent streams. These were selected using the reversed randomized quadrant-recursive raster (RRQRR) algorithm (Theobald et al. 2007). The algorithm facilitates the selection, within a GIS framework, of random sites that are spatially balanced with respect to availability across the landscape of interest. Filters were implemented to limit site selection (i.e., define the sampling frame) as follows:

- An upper elevation limit of 8,500 feet.
- No Strahler (1957) Order 1 streams.
- No lentic waters.
- No random sites in the mainstems of the Yampa River below Stagecoach Reservoir, White River, Colorado River, Gunnison River, Uncompahgre River, Dolores River below McPhee Reservoir, San Juan River, Animas River, and La Plata River.
- No sites in any stream above Blue Mesa Reservoir, Vallecito Reservoir, and Lemon Reservoir.
- The probability of including a given random site in the area frame increased in higher-order streams, to account for the smaller proportion of total stream mileage (Table 1.1).

Table 1.1. Inclusion probability for any potential site within a stream of a given Strahler (1957) order for perennial and intermittent streams.

Strahler	Inclusion probability	
Stream order	Perennial	Intermittent
1	0.0	0.0
2	0.1	0.1
3	0.1	0.1
4	0.1	0.2
5	0.1	0.4
6	0.2	1
7	0.5	---
8	1	---

This exercise resulted in ordered lists of UTM coordinates, NAD 83 projection, on streams in western Colorado. Separate lists of 200 random sites were selected for perennial and intermittent waters.

A restriction placed upon the RRQRR sampling scheme is that the random sites generated are to be visited in the order they appear on the list. We relaxed the restriction somewhat to make travel and sampling more efficient. We held to the restriction in the sense that, at the end of each sampling season, all sites on the list up to the highest-numbered visited site had actually been visited during that sampling season unless they were eliminated for legitimate reasons (e.g., de-watered, permission denied, excessively steep gradient, but not mere convenience).

Prior to planning field sampling events, we conducted reconnaissance on random sites in the office using topographic maps and Google Earth imagery. Sites situated on stream sections exceeding 4.0% stream gradient were excluded from consideration. This additional criterion was applied following the 2012 field season, when several random sites were sampled that clearly were un-suitable for the target species. Examination of 100 randomly selected historic data records from CPW's ADAMAS database revealed that 92% of these three-species records were obtained from stream sections with gradient less than 2.6%, and 98% from stream sections with gradient less than 4.0%.

Following the application of the stream gradient criterion, we determined land ownership. If situated on private land, contact with landowners occurred by phone, and we used a standardized presentation of our purpose for sampling to seek permission. If denied permission, the prospective site was simply struck from the visitation list.

Upon visiting a random site, the actual sampling station was selected. We attempted to keep the random coordinate near the midpoint of the sampling station while ensuring that a proper length of stream was sampled and appropriate start and stop points were selected to maximize the probability of population closure during sampling. Site photographs for future reference were taken at the midpoint and at the upper and lower station termini. Usually, an image of a small whiteboard with site number, coordinates, photo point location, and orientation on the stream was captured with each site photograph.

With rare exceptions, we sampled a minimum of 500 feet of stream, or 20 times the average stream width for streams greater than 25 feet average width. Sampling was conducted primarily with electrofishing equipment, usually backpack electrofishers. On rare occasions a bank electrofisher with multiple electrodes, or raft- or boat-mounted electrofishers were necessary. Two passes were conducted at each sampling station, again with rare exceptions. All fish from each pass were identified and enumerated. Since documenting presence or absence was our primary objective, if the catch was large only a portion of each species catch was measured and weighed.

At some sites a seine was also deployed as a second capture technique in 2012. This secondary method was used extensively with dual frame sampling efforts on the eastern plains because of conductivity levels that may compromise electrofishing effectiveness, as well as the species richness encountered there with the accompanying habitat segregation. The use of a secondary method was important in that context to avoid covariance issues between species detection and sampling gear (Ryan Fitzpatrick, CPW, personal communication).

Randomized Historic sites — Emphasis shifted in 2014 from random site (area frame) sampling to historic site (list frame) sampling. All historic sites at which any of the three species had ever been encountered (n = 377, including random sites from the previous two years' work at which three-species fishes were observed) were placed in a candidate pool and selected similarly to the random sites, using the RRQRR algorithm to ensure spatial balance. The previous filters were applied with regard to large streams, lentic waters, and upstream limits, but not site gradient (two of the first 100 randomly selected historic sites exhibited stream gradient exceeding 0.04 ft/ft) or stream order (we assumed that stream orders in non-mainstem habitats were already proportionately represented in historic data).

Sampling protocols remained the same as for random waters. However, since the database coordinates of the aquatic station number for each historic site is the downstream terminus, we made every effort to use those points as our re-sampling downstream terminus rather than the middle of the station. Also, we frequently sampled more stream length than was listed in ADAMAS for a historic site in order to meet sampling standards for this project.

In 2015, based upon consultation with CPW Aquatic Researcher Ryan Fitzpatrick and post-doctoral Research Associate Kristin Broms, emphasis shifted once again with respect to historic sites. From 2015 through 2017, we began to re-visit some sites across years and to re-visit some sites within years, and introduced fewer "new" sites to the sampling frame. The rationale for these adjustments was twofold — to better our understanding of year-to-year and seasonal variation in occupancy of these sites.

As a result of these sampling protocol adjustments, occupancy analyses of the dual-frame data set was initially limited to the 2012-2014 time frame. Analyses were conducted in Program MARK (White and Burnham 1999) for each species separately using "single season" occupancy models (MacKenzie et al. 2002, 2006). Thus, all sampling conducted over the initial three years of the project was considered as one "season" of sampling for each species, and the analyses herein represent a "snapshot" of species occupancy over that three year period.

Models that best explained the data were selected by Akaike Information Criterion adjusted for potential small-sample bias

(AICc, Burnham and Anderson 2002). We also considered whether $\hat{c}$ – a variance inflation factor – was necessary in adjusting model selection results. The use of the variance inflation factor results in "quasi-AICc" model selection, or QAICc. Program MARK contains just one method to estimate the value of $\hat{c}$ for occupancy models (a bootstrap routine and the use of the resulting median value) but the method unfortunately is incompatible with model sets that incorporate covariates. Thus, the value of $\hat{c}$ provided in the model output for the most parameterized model without covariates was used to adjust model selection for each species' candidate set. If $\hat{c}$ > 1, the estimated value was used. When $\hat{c}$ < 1, no adjustments were made (i.e., $\hat{c}$ = 1, no variance inflation, model selection by AICc).

Historic sites, 2015 – 2017 — In addition to the repeated sampling of historic sites conducted in the latter half of this study, we collated surveys from the CPW's ADAMAS database in which any of the three species fishes were detected from 2011 through 2017. We limited these surveys to active sampling methods (e.g., removed fish ladder records), but did not apply any further restrictions such as elevation, gradient or stream size in order to obtain the most complete picture of recent detection. For both the research sampling results and the ADAMAS survey results, we combined survey locations and catch data by HUC12 watershed units to get a count of surveys (where any three-species fishes were present for ADAMAS records, and of all dual frame records), and an average number of individuals present of each species per survey within each hydrologic unit. These results were compared in graphic format to yield a picture of where each of the species is consistently found within each river basin of Western Colorado.

1.3 Results and Discussion

From 2012 through 2017, 72 unique random and 93 unique historic sites were sampled over a total of 73 and 182 occasions, respectively (Table 1.2). All waters sampled under this project from 2011 through 2017, including those sampled apart from formal distribution assessment, are listed in Appendix A, Tables A.1 and A.2.

Seining was removed from the three-species sampling protocol after 2012 because the target fish are all suitably vulnerable to capture by electrofishing and on only one occasion in 2012 did seining result in the capture of a species not captured with electrofishing. Seining efforts were not considered in occupancy modeling.

Random Perennial, Intermittent and Historic sites, 2012 - 2014 — A total of 71 randomly selected sites on perennial and intermittent streams (area frame) and 56 randomly selected three-species historic sites (list frame) were sampled from 2012 to 2014 (Table 1.2). Those sites sampled in 2012 that exceeded 4.0% stream gradient (n = 6) were excluded from occupancy analysis so that the gradient criterion was consistent among years for random sites, leaving 121 sampled sites in the 3-year analysis.

Table 1.2. Sites ("Ran" = random sites, "His" = historic sites) sampled each year from 2012 through 2017, and number of total sampling occasions represented.

Year	Ran	Occasions	His	Occasions
2012	29	29		
2013	42	42		
2014			56	56
2015			29	40
2016	1	1	39	38
2017	1	1	29	48

Bluehead Suckers were captured at 26 of 45 species-specific historic sites (naïve occupancy rate 26/45 = 0.578) and one of 11 sites that were historic only for one or both of the other three-species fishes. The top 15 models for Bluehead Sucker are listed in Table 1.3. The most-supported model estimated Bluehead Sucker occupancy at 0.626 (SE = 0.106) for species-specific historic sites, and at 0.231 (SE = 0.075) for the other three groups combined. The top model estimated p = 0.876 (SE = 0.091) on the first pass of a sampling effort and 0.588 (SE = 0.122) on the second pass. The overall probability of detecting Bluehead Suckers, given their presence, during an electrofishing event was p^* = 0.973 (SE = 0.0217, credible interval = 0.913, 0.995). Using the second-ranked model, which modeled all groups separately, estimated occupancy was 0.090 (SE = 0.119) in non-species-specific historic waters, 0.132 (SE = 0.167) in random intermittent waters, and 0.268 (SE = 0.088) in random perennial waters. The estimate given by this model for species-specific historic sites was substantially the same as that given by the top model.

Most well-supported models show that water conductivity influenced probability of detection, which is reasonable given that electrofishing was the survey method and both very low and very high conductivity reduces electrofishing efficiency. Elevated conductivity is common in three-species waters, more so than excessively low conductivity. Site gradient was an important covariate predicting site occupancy, and the likelihood of Bluehead Sucker occupancy of species-specific historic sites diminished with increasing gradient, whether estimated by the top-ranked model or by model averaging among 30 models (Figure 1.1).

Table 1.3. Model selection results for 15 Bluehead Sucker occupancy models fit to data from 2012-2014 sampling, with $\hat{c}$ = 1.74. K is the number of estimated parameters in the model, ΔQAICc is the difference in QAICc values, w is the model weight, and -2l is twice the negative log-likelihood. In model descriptions, ψ = occupancy, p = detection probability, t = time (i.e., electrofishing pass), g = group (of which there were four relating to the type of site: species-specific historic [when group is described as “g1”, the species-specific historic sites were modeled in contrast to the other three groups in combination], non-species-specific historic, intermittent, and perennial), cond = specific conductivity, grad = site gradient, and day = day-of-year. A ‘+’ indicates an additive effect.

Model	K	ΔQAICc	w	-2l
ψ(g1 + grad) p(t + cond)	6	0.00	0.534	192.192
ψ(g + grad) p(t + cond)	8	3.52	0.092	190.405
Ψ(g) p(t)	6	3.91	0.076	198.997
ψ(g + day) p(t + cond)	8	5.25	0.039	193.406
ψ(g + cond) p(t + cond)	8	5.25	0.039	193.408
ψ(g + cond + grad) p(t + cond)	9	5.51	0.034	189.791
ψ(g + grad + grad^2) p(t + cond)	9	5.61	0.032	189.967
ψ(g + grad) p(t + cond + cond^2)	9	5.74	0.030	190.194
ψ(g + grad + day) p(t + cond)	9	5.75	0.030	190.210
ψ(g) p(.)	5	6.13	0.025	206.705
ψ(g_historic groups together) p(t)	5	7.20	0.015	208.566
ψ(g + grad + day + day^2) p(t + cond)	10	7.46	0.013	189.062
ψ(g + cond + day) p(t + cond)	9	7.58	0.012	193.405
ψ(g + cond + grad + day) p(t + cond)	10	7.84	0.011	189.722
ψ(.) p(t)	3	8.83	0.006	218.921

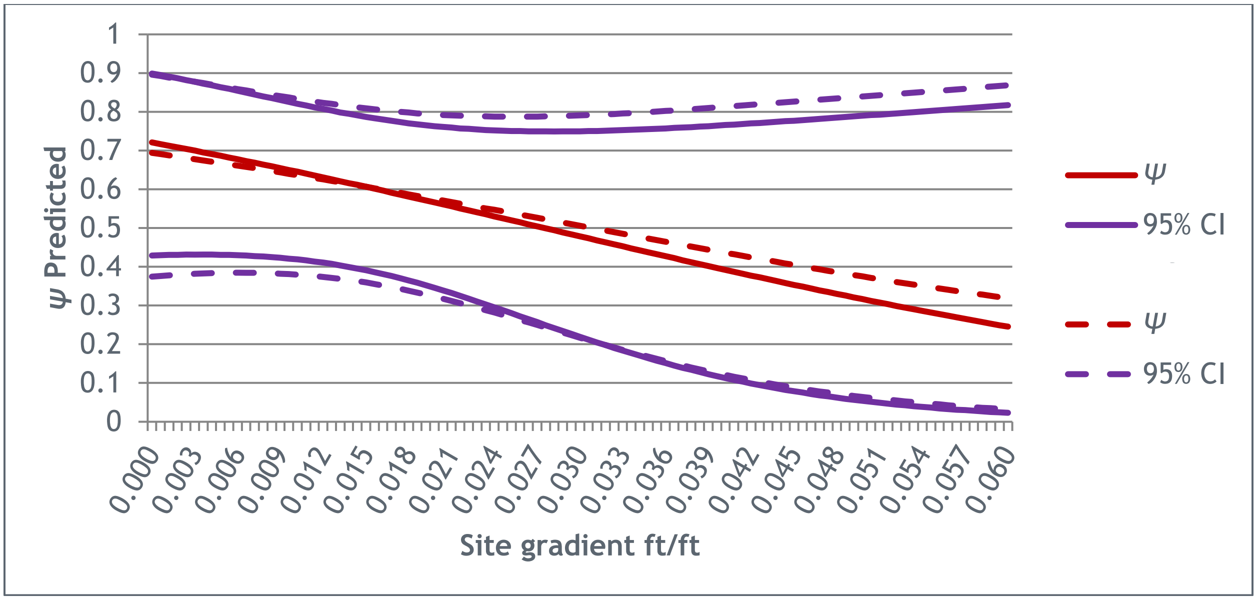


Figure 1.1. Predicted occupancy and 95% confidence intervals produced by the top-ranked Bluehead Sucker model (solid lines) and by model averaging (30 models, dashed lines) for species-specific historic sites over the range of site gradient potential.

Flannelmouth Suckers were physically captured at 11 of 30 species-specific historic sites (naïve occupancy rate 11/30 = 0.367). They were not captured at non-species-specific historic sites or intermittent sites, but were captured at four of 62 randomly chosen perennial sites. Once again, the top models indicated that site gradient was an important predictor of site occupancy (Figure 1.2) and that conductivity influenced capture probability measurably (Table 1.4). The top model for this species estimated species-specific historic site occupancy at 0.166 (SE = 0.099), considerably less than the naïve estimate, but these estimates were modeled on the mean value for the gradient covariate for all sites sampled (0.0127). In contrast, the mean gradient for the 30 Flannelmouth Sucker historic sites was 0.0076, and the mean gradient of sites where they were detected was 0.005. Covariate plot data from this model generated occupancy estimates of 0.72 (SE = 0.152) for stream gradient on the low end of the range sampled (0.0002) and 0.25 (SE = 0.107) for stream gradient of 0.01. Model {ψ(g) p(.)}, using no covariates, generated a Flannelmouth Sucker occupancy estimate at species-specific historic sites of 0.371 (SE 0.089), close to the naïve estimate. The probability of detection estimated in the top model was 0.920 (SE = 0.072) on the first pass of a sampling effort and 0.869 (SE = 0.091) on the second pass, leading to p^* = 0.987 (SE = 0.0214, credible interval = 0.921, 0.999) of detecting Flannelmouth Suckers during a 2-pass electrofishing event.

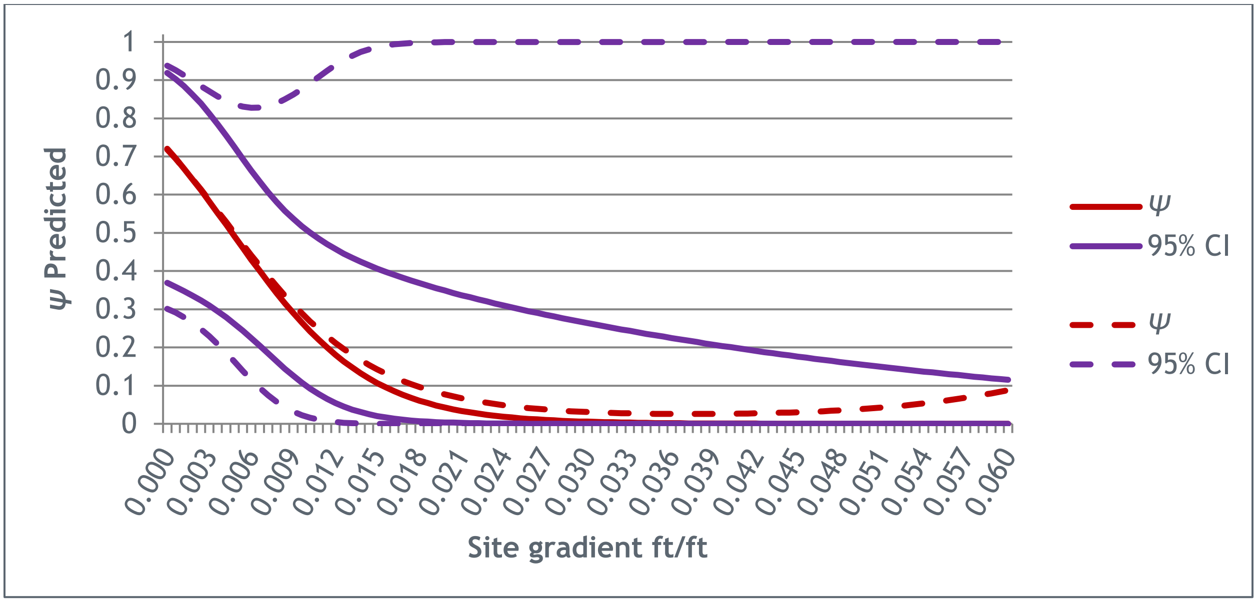


Figure 1.2. Predicted occupancy produced by the top-ranked Flannelmouth Sucker model (solid lines) and by model averaging (dashed lines, 30 models) for species-specific historic sites over the range of site gradient potential.

Table 1.4. Model selection results for 15 Flannelmouth Sucker occupancy models fit to data from 2012-2014 sampling, with $\hat{c}$ = 1.00. Model descriptive components are as in Table 1.3, except that ΔAICc is used rather than ΔQAICc since there is no evidence of overdispersion in this data set. When group is described as “g1”, the species-specific historic sites were modeled in contrast to the other three groups in combination.

Model	*K*	ΔAICc	*w*	-2l
ψ(g1 + grad) *p*(t + cond)	6	0.00	0.218	80.326
ψ(g + grad) *p*(t + cond + cond^2)	9	0.56	0.164	74.005
ψ(g + grad) *p*(t + cond)	8	0.95	0.135	76.730
ψ(g + grad + day) *p*(t + cond)	9	1.59	0.098	75.029
ψ(g1 + grad + grad^2) *p*(t + cond)	7	1.87	0.085	79.943
ψ(g + cond + grad) *p*(t + cond)	9	2.06	0.078	75.499
ψ(g + cond + grad + day) *p*(t + cond)	10	2.52	0.062	73.584
ψ(g + grad + grad^2) *p*(t + cond)	9	2.86	0.052	76.299
ψ(g + grad + day + day^2) *p*(t + cond)	10	3.67	0.035	74.734
ψ(g) *p*(.)	5	4.83	0.019	87.374
ψ(g + grad + grad^2 + day + day^2) *p*(t + cond + cond^2)	12	5.02	0.018	71.192
ψ(g + grad + grad^2 + day + day^2) *p*(t + cond)	11	5.69	0.013	74.335
ψ(g) *p*(t)	6	6.72	0.008	87.049
ψ(g + day) *p*(t + cond)	8	7.42	0.005	83.194
ψ(g + cond + cond^2 + grad + grad^2 + day + day^2) *p*(t + cond)	13	7.89	0.004	71.546

Roundtail Chub were physically captured at 11 of 15 species-specific historic sites (naïve occupancy rate 11/15 = 0.73). In addition, they were found at two of 41 non-species-specific historic sites and four of 56 random perennial sites, but not at any random intermittent sites. Site gradient and the day-of-year when sampling occurred were important covariates influencing site occupancy (Table 1.5). The most-supported model, which evaluated occupancy for species-specific historic sites against the

Table 1.5. Model selection results for 15 Roundtail Chub occupancy models fit to data from 2012-2014 sampling, with $\hat{c}$ = 1.00. Model descriptive components are as in Table 1.4. An asterisk indicates an interactive effect. When group is described as "g1", the species-specific historic sites were modeled in contrast to the other three groups in combination.

Model	*K*	ΔAICc	*w*	-2l
ψ(g1 + grad + day) *p*(t + cond)	7	0.00	0.612	74.953
ψ(g1 + grad) *p*(t + cond)	6	3.56	0.103	80.767
ψ(g + grad + day) *p*(t + cond)	9	3.80	0.092	74.118
ψ(g + day) *p*(t + cond)	8	5.67	0.036	78.328
ψ(g + grad + day + day^2) *p*(t + cond)	10	6.08	0.029	74.019
ψ(g + cond + grad + day) *p*(t + cond)	10	6.17	0.028	74.109
ψ(g + grad) *p*(t + cond)	8	6.88	0.020	79.539
ψ(g + cond + day) *p*(t + cond)	9	7.67	0.013	77.988
ψ(g + grad + day) *p*(g*t + cond)	15	8.21	0.010	63.582
ψ(g + cond + grad) *p*(t + cond)	9	8.48	0.009	78.798
ψ(g + grad + grad^2 + day + day^2) *p*(t + cond)	11	8.50	0.009	74.019
ψ(g + grad + grad^2) *p*(t + cond)	9	9.04	0.007	79.360
ψ(g + grad) *p*(t + cond + cond^2)	9	9.19	0.006	79.514
ψ(g + day) *p*(g*t + cond)	14	9.75	0.005	67.732
ψ(g + grad + day) *p*(g + t + cond)	12	9.89	0.004	72.946

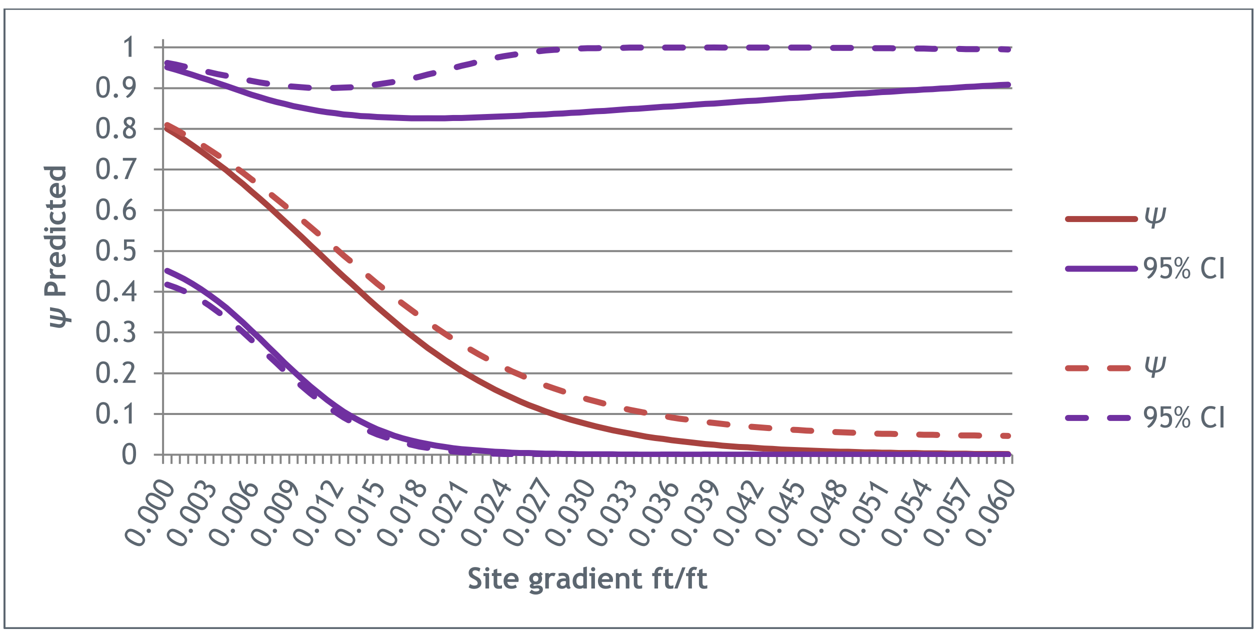


Figure 1.3. Predicted occupancy produced by the top-ranked Roundtail Chub model (solid lines) and by model averaging (dashed lines, 35 models) for species-specific historic sites over the range of site gradient potential.

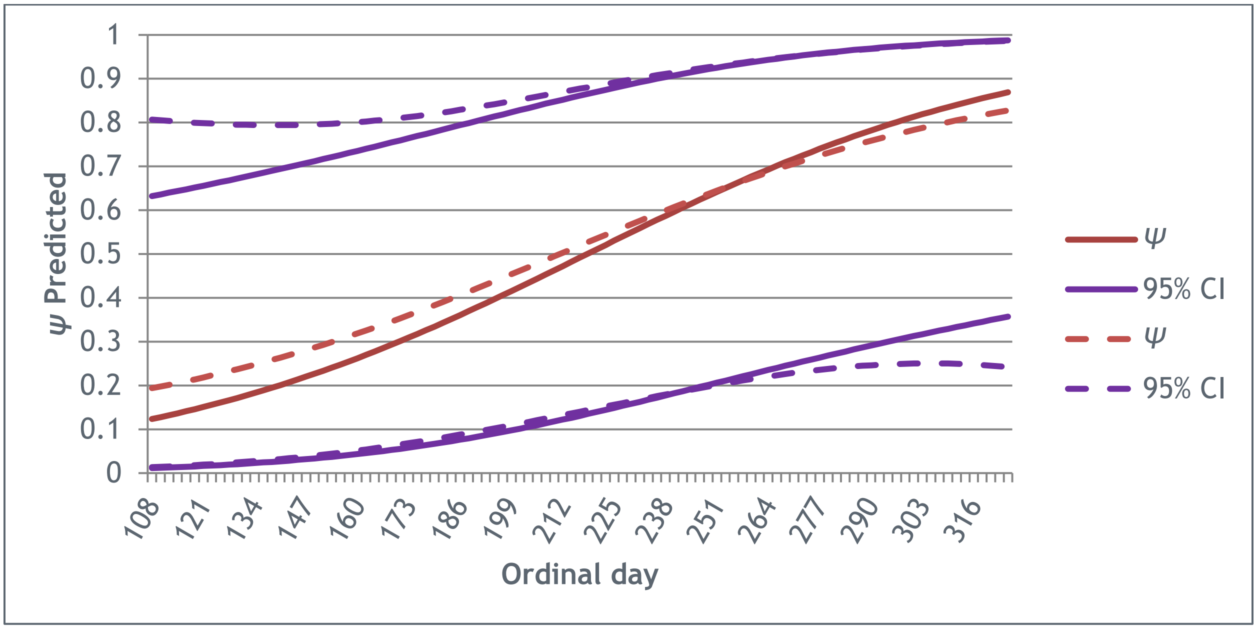


Figure 1.4. Predicted occupancy produced by the top-ranked Roundtail Chub model (solid lines) and by model averaging (dashed lines, 35 models) for species-specific historic sites over the range of days-of-year sampled.

other three site types combined, yielded an estimate of Ψ = 0.439 (SE 0.2352) using mean covariate values for site gradient and day-of-year of sampling. However, plotting predicted occupancy versus site gradient shows that low gradient sites were more likely to be occupied (Figure 1.3). Day-of-year was also an important predictive covariate for Roundtail Chub, with later sampling dates more likely to reveal occupied sites (Figure 1.4). The probability of detecting Roundtail Chub, given presence at a site, was 0.972 (SE = 0.036) on the first pass and 0.692 (SE = 0.130) on the second pass. The overall probability of detecting Roundtail Chubs on a 2-pass electrofishing event was p^* = 0.953 (SE = 0.0469, credible interval = 0.817, 0.994).

The application of a stream gradient filter in 2013 removed many sites from consideration, but did not greatly increase the rate at which random sites were found to be occupied. Considering perennial and intermittent sites, three-species fishes were found at 24% of randomly selected sites sampled in 2012, and 26% in 2013. Considering only perennial sites, three-species fishes were found at 28% of sites in 2012 and 31% in 2013. In contrast, three-species fishes were found at 55% of randomly chosen historic sites sampled in 2014 (Appendix A, Table A.1).

The 56 historic sites sampled in 2014 were historic for one or more of the three-species since 1980, with the exception of five that were limited to data from 1974 – 1977. Considering that Bezzerides and Bestgen (2002) used a 1980 demarcation to distinguish historic from recent data, the fact that we caught three-species fishes at just 55% of the sites that would have been considered "still occupied" by those authors may suggest that these fish species are still losing ground. However, a caution to accompany this viewpoint is that the sampling reported here was focused on tributary streams and hence on waters that are more prone to seasonal occupancy than the totality of the three-species range under consideration in Bezzerides and Bestgen (2002), much of which encompassed mainstem habitats.

The likelihood of detecting the three species fishes, given their presence at a site and the sampling of a suitably long reach (500 ft or 20 times the average stream width in these smaller tributary streams), is high if two passes of electrofishing effort are conducted. The overall probabilities of detection (*p**) met or exceeded 0.95 for all three species. Thus, investigators can have high confidence that a 2-pass electrofishing occasion will most often reveal whether any of the subject fishes are present.

Occupancy versus gradient trends indicate that Bluehead Sucker is more tolerant of higher gradient stream sites than Flannelmouth Sucker and Roundtail Chub. The latter two species appear to prefer very mild gradients, and future efforts to locate previously unknown occupied sites should bear this in mind. However, during spawning periods all three species are capable of negotiating steeper sections of stream in order to access spawning habitats. Indeed, those spawning habitats themselves may well be generally steeper stream sections than those occupied for other life stages.

Historic sites, 2015 - 2017 — The number of sites visited and the number of occasions for the sampling efforts in 2015 through 2017 are summarized in Table 1.2, and results by occasion are listed in Appendix A, Table A.1. The sampling represents 127 occasions across 52 unique sites. Bluehead Suckers were encountered on 79.7% of sampling occasions, Flannelmouth Suckers on 62.1%, and Roundtail Chub on 46.4%. When the sites sampled are split into species-specific subsets, the percentages rise with respect to recent historic data or all historic for all species (Table 1.6). Considering only pre-1980 species-specific historic sites, it would initially appear that Flannelmouth Sucker and Roundtail Chub have lost significant ground in tributary habitats, but these results were driven by the paucity of pre-1980 historic sites for Flannelmouth Sucker (n = 10) and Roundtail Chub (n = 7) that were included in sampling.

Table 1.6. The percentage of occasions on which species-specific historic sites were found to be occupied in comparison to three different periods of historic data (Period).

Period	BHS	FMS	RTC
Pre-1980	80.0	50.0	12.5
1980-2013	84.1	75.0	62.0
All years	83.6	73.6	58.9

Seasonal occupancy by adult fish has been evident in the sampling. Locations such as Coal, Cottonwood, Escalante, Piceance, Potter, Roubideau, and Tabeguache creeks are heavily used by spawning adult fish in the spring, but most of these locations are abandoned by adult fish the remainder of the year. Detections of PIT tags in Coal Creek (White River) reveal this phenomenon well (Fraser 2015, Fraser et al. 2017). Likewise, in Roubideau Creek, a channel-spanning passive interrogation array (PIA) installed to detect passing PIT-tagged fish revealed heavy use by adult native suckers from mid-March through early June each year, after which detections diminish greatly through the remainder of the summer and fall. In four winters of operation, the Roubideau PIA did not register any tag detections between mid-November and early March. Moreover, mobile antennas deployed for about two weeks in likely winter holding habitat in Roubideau Creek near its mouth, after a season in which numerous fish were tagged in Roubideau Creek at that location, yielded no detections of tagged fish. These results suggest that adult fish migrating into tributary systems for spawning do not use tributary habitats at all for winter habitat, and only lightly for summer and fall habitat.

In such tributaries, spring occupancy most often is predominated by adult spawning fish, whereas summer and fall occasions often reveal occupancy only by young-of-year and juvenile fish. These results point to the importance of these tributary habitats for the life history of the three-species fishes. Although larvae, young-of-year and juveniles can be found in mainstem habitats (Fraser 2015, Fraser et al. 2019), many resort to suitable tributary habitats for significant portions of the year. Additionally, it is evident from work conducted in Cottonwood Creek (Chapter 2 of this report) that some important tributaries are ephemeral or intermittent. Cottonwood Creek only runs reliably during snowmelt, yet many hundreds to thousands of spawning adult three-species fishes were found using that tributary during runoff periods in 2014 – 2017 (Hooley-Underwood et al. 2019).

No formal occupancy analyses of the 2015 – 2017 data have yet been conducted, but occupancy by the three-species fishes was high over the occasions represented, which included multiple visits per year at some sites. Historic sites were found to be occupied by one or more of the three-species on 95% of sampling occasions in 2015, 89.5% of occasions in 2016, and 90.2% of occasions in 2017. Sampling occasions conducted during summer or fall months were likely to reveal three species occupancy by young-of-year or juvenile fishes rather than adults, which comports with the use of such habitats by adults primarily for spawning. Intensive sampling during spawning season and afterward in tributary streams of the Gunnison River Basin showed this phenomenon, with abundant adults present for 6 – 8 weeks primarily during April and May, but rare or absent otherwise.

Yampa River and Green River Drainage — Research sampling in the Yampa River and Green River basins revealed that of the sampled tributary waters, the Little Snake River, the Williams Fork of the Yampa, and Milk Creek were the only ones where three-species fishes were detected (Figure 1.5 — figures for the river basin narratives are fold-out pages beginning on page 18). Each of these tributaries also contained all three species, but only the Little Snake River consistently hosted high densities of all three species. Each of the three-species fishes were collected at all of the sampled HUC12 units on the Little Snake River, but in the Williams Fork River and Milk Creek drainages, Roundtail Chub were found only in the downstream most HUC12 units sampled. In Milk Creek, both sucker species were found near the mouth as well as in the headwaters, with Flannelmouth Sucker being more common in the former, and Bluehead Sucker in the latter. Sampling records from ADAMAS confirmed that these three tributaries are the primary non-mainstem waters where three-species fishes occur, and also showed an expanded distribution of Bluehead Sucker and Flannelmouth Sucker in both the Little Snake River and Milk Creek Systems (Figure 1.6). Bluehead Suckers were found in near-headwater reaches of the Little Snake River, and both suckers were found in tributaries to Milk Creek. Additionally, several Bluehead Suckers were found in the Elkhead Creek drainage, and several Roundtail Chub were found in Trout Creek (near Steamboat Springs) and two tributaries. These Roundtail Chub are far removed from their nearest neighbors (located downstream near the Williams Fork – Yampa confluence) and may represent an isolated tributary population, but our sampling did not produce any Roundtail Chub in the system during similar time frames, so densities appear to be quite low. Mainstem sampling records from ADAMAS show that the highest densities of the three-species occur in the Yampa River downstream of the Williams Fork River confluence. High densities are repeatedly sampled near the Little Snake River confluence in particular, and near the mouth of the Yampa. Interestingly, only Flannelmouth Sucker are found at relatively high densities in the Green River, perhaps because they are more tolerant of the temperature moderation imposed by the Flaming Gorge Dam upstream. The sucker species are occasionally found much higher up the mainstem Yampa than Roundtail Chub, with several records of both species in the Steamboat Springs area.

White River Drainage — The three-species fishes were infrequently found in White River tributaries under the three-species research sampling program in the White River Basin

(Figure 1.7). Flannelmouth Sucker were found in five tributaries while Bluehead Sucker were found only in two, and Roundtail Chub were only found in the mainstem of the White River. Tributaries occupied by either of the sucker species included Douglas Creek, Crooked Wash, Piceance Creek, Flag Creek, and Coal Creek. Douglas Creek was sampled one time each at two locations, and of the three-species fishes, only four Flannelmouth Sucker were found at the downstream sampling location. Piceance Creek was sampled multiple times at several sites and both sucker species were found repeatedly. Bluehead Sucker were found regularly at moderate densities (5-10 fish per sampling event) in the lowest reach sampled, while Flannelmouth Suckers were found in abundance at the most upstream mainstem sampling location. Interestingly, Mountain Sucker (presumably native here) were also abundant in Piceance Creek. Crooked Wash was sampled twice, and Flannelmouth Sucker were relatively abundant (n = 9) on one occasion, but were not present on the other. Both sucker species were numerous in Coal Creek at times, as were Flannelmouth Sucker in Flag Creek, but in both streams the species were absent in many surveys as well, resulting in overall low abundance for the HUC. This highlights the seasonality of sucker use of many of these tributaries, and it should be noted that most other streams were visited only once, limiting our ability to identify seasonal occupancy. Some research program sampling did occur on the White River mainstem between Meeker and Kenny Reservoir, and indicated that all three species are present at moderate to high densities in sections of the river, with Flannelmouth Sucker being the most ubiquitous. Records from ADAMAS indicate a similar distribution of the sucker species in both tributaries and the mainstem, though with greater overall distribution in the White River itself (Figure 1.8). Roundtail Chub were not sampled in tributaries in either data set. The mainstem White River sampling records in ADAMAS indicate that occupancy for both sucker species is highest in reaches downstream from Meeker, and around Rangely, both upstream and downstream of Kenney Reservoir. Reaches near Rangely likewise support an abundance of Roundtail Chub. Lower numbers of Roundtail Chub have also been sampled downstream of Meeker, but their distribution appears to be mostly limited to reaches below the confluence of Piceance Creek with perhaps occasional exceptions. Fraser et al. (2019) found Roundtail Chub larvae in the White River above Piceance Creek in 2012 at just one site on one occasion.

Coal Creek is used by the sucker species for spawning (Fraser et al. 2017, 2019), and Piceance Creek may be also in exceptional runoff years. The status of Crooked Wash as a spawning tributary is uncertain. It may also host some spawning activity in exceptional runoff years, but is much smaller than the other known spawning tributaries. Both Flag Creek and Douglas Creek are limited as potential spawning habitat by barriers near their mouths. The barrier on Flag Creek allows access to only a few hundred feet of stream. Douglas Creek may be further limited for spawning purposes by sedimentation.

Colorado River Drainage — Three-species research sampling suggests that tributary occupancy by three-species fishes is limited to streams in the basin from the Roaring Fork River confluence downstream (Figure 1.9), with the exception of a survey on Dry Fork Cabin Creek in which Bluehead Suckers were present (discussed later). Down-basin, tributary densities of all three fishes were low or non-existent until Roan Creek, with the exception of West Divide Creek, which had abundant Bluehead Sucker at several locations, and less numerous Flannelmouth Sucker and Roundtail Chub only at the most downstream site. Roan Creek was occupied by all three-species, but only the suckers were found at densities above five fish per site. All three species were relatively abundant in the lower reaches of Plateau Creek, and both suckers were found high in the drainage although only Bluehead Suckers were ever abundant. Downstream of Grand Junction, all species were found at low to moderate densities in all of the notable tributary systems with the exception that no Bluehead Suckers were found on the one sampling occasion in Persigo Wash. Sampling records from ADAMAS indicate similar tributary occupancy (Figure 1.10). The only major differences between the ADAMAS and research data sets are that both suckers have been occasionally found in the Eagle River, that an abundance of Roundtail Chub have been sampled in the Muddy Creek drainage near Kremmling, Colorado, and that Bluehead Suckers were found on an additional occasion in the Dry Fork of Cabin Creek near Burns, Colorado. The Muddy Creek records are representative of an anomalous isolated population of chub in Wolford Mountain Reservoir and Muddy Creek upstream. The authenticity of the Dry Fork Cabin Creek records is questionable, as suckers sampled in the stream have been identified as either Bluehead or Mountain suckers at different times. Connectivity to the Colorado River and a source of Mountain Suckers in lakes in the Derby Creek headwaters (Derby Creek via a diversion and ditch supplies the majority of the Dry Fork Cabin Creek water) indicates possible occupancy by either species, so additional sampling is needed to definitively determine which species is present (if not both). In the mainstem Colorado River, the ranges of the three-species fishes vary greatly, with Bluehead Sucker having been found nearly all the way upstream to Granby, and Flannnelmouth Sucker upstream nearly to Gore Canyon, while Roundtail Chub were not found above Glenwood Springs. Areas with particularly high occupancy of all three species occur between Parachute and Rifle, and from Debeque Canyon to the Colorado-Utah border.

Gunnison River Drainage — Tributary systems to the Gunnison River that were deemed occupied by all of the three-species fishes under the research sampling regime included Escalante Creek, Roubideau Creek (both downstream of the Uncompahgre River), and the North Fork of the Gunnison River (Figure 1.11). Additionally, Dry Creek (tributary to the Uncompahgre River) contained all three species, but the Uncompahgre River basin did not have three-species fishes elsewhere. Importantly, Dry Creek is tributary to the Uncompahgre River downstream of all major irrigation diversion structures on the river, the lowermost of which is just upstream of the Montrose-Delta County line. Thus, three-species fishes from the Gunnison River have access to Dry Creek but not the upper reaches of the Uncompahgre River. The Roubideau Creek drainage was sampled numerous times, and in many instances all three fishes were abundant. However, densities per HUC12 are generally low as presented, which is reflective of the highly seasonal use of the system. The removal of an irrigation diversion in Roubideau Creek in 2017 eased access to upper portions of the drainage for all fish, but especially for Flannelmouth Sucker (see Chapter 2). In Escalante Creek, across 29 sampling occasions, the mean capture numbers of each species were relatively high, reflective of the perennial nature of occupancy of all species in the creek above a barrier, keeping sub-populations of all three species isolated from the Gunnison River. In the North Fork of the Gunnison River, Bluehead Suckers followed by Flannelmouth Suckers were the most abundant of the three species, while Roundtail Chub were relatively scarce. The two sucker species also occupied upstream sites near Paonia Reservoir where Roundtail Chub were absent. Bluehead Suckers were present both above (in Muddy Creek immediately above Paonia Reservoir and in its headwaters) and below the reservoir while Flannelmouth Suckers were present above the reservoir only and were scarce. The above-reservoir occupancy of the two species has not been reconfirmed since a chemical removal of Northern Pike from Paonia Reservoir in 2014, prior to which many Bluehead Suckers were relocated from Muddy Creek to below the Reservoir. Flannelmouth Suckers were not found in any other tributaries in the basin, but Bluehead Suckers and Roundtail Chub were both found in Big Dominguez Creek (tributary to the mainstem Gunnison River downstream of Escalante Creek), and Bluehead Sucker alone were found in Kannah Creek (tributary to the mainstem Gunnison River near Grand Junction, Colorado) and in the Cimarron River drainage (tributary to the mainstem Gunnison River downstream of Blue Mesa Reservoir). Big Dominguez Creek descends a substantial waterfall near its mouth that limits its useable length for fish to approximately 600 ft and therefore should not be considered an occupied tributary as a whole. In the Cimarron River drainage, several Bluehead Suckers have been sampled in both the Cimarron and Little Cimarron rivers indicating that a population has persisted despite isolation from the Gunnison River Bluehead Sucker population that resulted from the construction of the Aspinall Unit dams (constructed 1966-1976). Their scarcity there suggests they will not persist in perpetuity. In addition to tributary sampling, some mainstem Gunnison River sampling was also completed under the three-species research program. An abundance of both sucker species and, to a lesser degree, Roundtail Chub were found in the section between the Uncompahgre River and Roubideau Creek confluences, and in the section immediately downstream from the North Fork of the Gunnison River confluence. Records from ADAMAS show a minimal difference in tributary occupancy in the basin, mainly that all three species were sampled in Kannah and Big Dominguez creeks, that both sucker species were present in East Creek (tributary to the Gunnison River near Grand Junction, Colorado), and that occupancy of the upper part of the North Fork of the Gunnison River drainage was more widespread for both sucker species (Figure 1.12). ADAMAS records do indicate widespread presence and abundance of the three fishes in the Gunnison River from near the Smith Fork of the Gunnison River (just above the North Fork of the Gunnison River) to the confluence of the Gunnison River with the Colorado River in Grand Junction, Colorado.

Dolores River Drainage — The only Dolores River tributary sampled under the three-species research program that repeatedly had an abundance of all three-species fishes was the San Miguel River, but in the lowest reach only (Figure 1.13). The suckers were abundant on the one San Miguel River sampling occasion above Naturita, but Roundtail Chub were absent. All three fishes were found repeatedly in low numbers in multiple stretches of the San Miguel tributary Tabeguache Creek. Removal of an obsolete water diversion from Tabeguache Creek opened access for spawning activity by the three-species fishes, and possibly to greater perennially occupied habitat. Another tributary, Naturita Creek, had low densities of both suckers, but Roundtail Chub were not detected. The San Miguel River contributes the majority of the flow to the lower Dolores throughout much of the year due to operations of McPhee Reservoir, and as such, may be functionally as much mainstem habitat as the Dolores River. Because of this relationship, Dolores River sampling sites (above the San Miguel River Confluence) were included in the sampling regime. We found Bluehead Suckers in one HUC only, and at very low densities, in the Dolores River upstream of the San Miguel River, but they were present and, in some locations, relatively abundant in La Sal Creek. Roundtail Chub were also present in low numbers in the lowermost section of La Sal Creek sampled. Flannelmouth Suckers were not detected in La Sal Creek, but were present in low numbers in the mainstem Dolores River above and below Disappointment Creek and in Disappointment Creek proper. Roundtail Chub were more widely detected (but also at low densities) in the Dolores River than Flannelmouth Sucker, being found in reaches near the La Sal Creek confluence. Likewise, several Roundtail Chub were found on one sampling occasion in Disappointment Creek. The only other sampling occasions during which any three-species fishes were found occurred on West Creek, near the Colorado-

Utah border, in which two juvenile Bluehead Suckers were captured, on Roc Creek, below the San Miguel confluence, in which Flannelmouth Sucker were found on one of two occasions, on the North Fork of Mesa Creek in which a single Bluehead Sucker was found, and on the West Fork of the Dolores River in which a lone adult Bluehead Sucker was captured. While the three-species are widely considered extirpated upstream of McPhee Reservoir in the Dolores River Basin, this occurrence of a Bluehead Sucker in the West Fork indicates that they may still exist above the reservoir in very low numbers. The addition of ADAMAS records indicates a similar distribution of three-species fishes but with more widespread occupancy of the Dolores River (Figure 1.14). Most notably, the Dolores River in Slick Rock Canyon, near La Sal Creek, had all three species, and Roundtail Chub and especially Flannelmouth Suckers were abundant. Additionally, the three fishes were all found farther upstream (Bluehead Sucker and Roundtail Chub nearly to McPhee Dam), and the river section above Disappointment Creek had a high density of Roundtail Chub. Downstream of the San Miguel, the Dolores River was also occupied at varying densities by all three species. Occupancy of the San Miguel River portion of the drainage was similar to the research sampling, with the river section above the mouth having the greatest abundance of all three fishes. Bluehead Suckers were also found farther upstream. Densities of all three species were found to be higher in portions of Tabeguache Creek, and Bluehead Suckers were found to occupy more sections of the Naturita Creek drainage. The ADAMAS records include several surprising occurrences of the two sucker species. In the San Miguel River, one Bluehead Sucker was sampled nearly at 8,000 ft, near Telluride. In the upper Dolores River drainage, both sucker species have been repeatedly sampled at low densities in McPhee Reservoir, and numerous Flannelmouth Suckers were sampled in gravel-pit ponds just off the Dolores River at the Twin Spruce Ponds State Wildlife Area.

San Juan River Drainage — Three-species research sampling resulted in a stark contrast in occupancy between Bluehead Sucker and the other two species in tributaries of the San Juan and Animas rivers (Figure 1.15). Bluehead Suckers were sampled in the drainages of McElmo Creek and the Mancos, La Plata, Los Pinos, Piedra, Rio Blanco, and Navajo rivers. Roundtail Chub were only found in two tributary systems, and Flannelmouth Suckers in three. Of the drainages containing Bluehead Sucker, the streams with the highest densities when sampled were McElmo Creek, Yellowjacket Canyon (a McElmo Creek tributary), the Mancos River near Mancos, Cherry Creek (a La Plata River tributary), and the Rio Blanco River. The only sampling location with all three species was the lower end of McElmo Creek, but Bluehead Sucker and Roundtail Chub numbers were low. The only other locations where Flannelmouth Suckers were captured were in the Mancos and Rio Blanco rivers. Roundtail Chub were captured, in addition to McElmo Creek, in the Mancos River and its tributary, Weber Canyon Creek. ADAMAS records did not indicate Bluehead Sucker occupancy of additional tributary systems, but did show an expanded range of occupied HUCs in nearly all drainages (Figure 1.16). Additionally, mainstem habitats on the San Juan and Animas rivers were occupied with sections near Pagosa Springs (San Juan River), and Durango (Animas River) having high densities of the suckers. The ADAMAS data set did show greatly expanded occupancy of Flannelmouth Sucker and Roundtail Chub. Flannelmouth Sucker were found throughout the McElmo Creek drainage, and were abundant at many localities, consistent with the findings of Cathcart et al. (2015). They were also found to occupy sites in the Mancos, La Plata, Los Pinos, and Navajo river drainages – drainages where they were not detected when sampled under the three-species research program. At several sites in these drainages (Mancos, La Plata, and Los Pinos rivers) they were even found to be relatively abundant. Like Bluehead Suckers, Flannelmouth Suckers were found in the mainstems of the Animas and San Juan rivers, but at lower densities. The only tributary in which Roundtail Chub were found in addition to those indicated by the three-species research sampling was the La Plata River where they were relatively abundant in the lowest reach in Colorado. However, they were also found to be more widespread and abundant in the McElmo Creek and Mancos River drainages. Overall, sampling suggests that McElmo Creek (along with Yellowjacket Canyon), the Mancos River, and the lower segment of the La Plata River currently support the healthiest three-species populations, and that the Rio Blanco is also an important stream when just the two suckers are considered.

1.4 Conclusions and Recommendations

The three-species fishes appear to be retaining much of their recent historic range, and 2-pass electrofishing efforts over a suitable reach of probable habitat yields a high probability of detecting juvenile or adult individuals of any of the species if they are present. A concern is that, while overall range may seem stable, some mainstem areas of historic habitat are increasingly populated by invasive suckers and their hybrids, and fewer native suckers are encountered. Such a situation appears to exist in the Yampa River drainage, where strongholds of native sucker habitat are more isolated to downstream reaches. Surveys in the important Little Snake River in recent years have revealed non-native White Sucker in new locations, a troubling circumstance. The proliferation of non-native suckers and their hybrids is a serious problem that is dealt with more in Chapter 2 of this report, but it is clearly a danger to the persistence of Bluehead and Flannelmouth suckers.

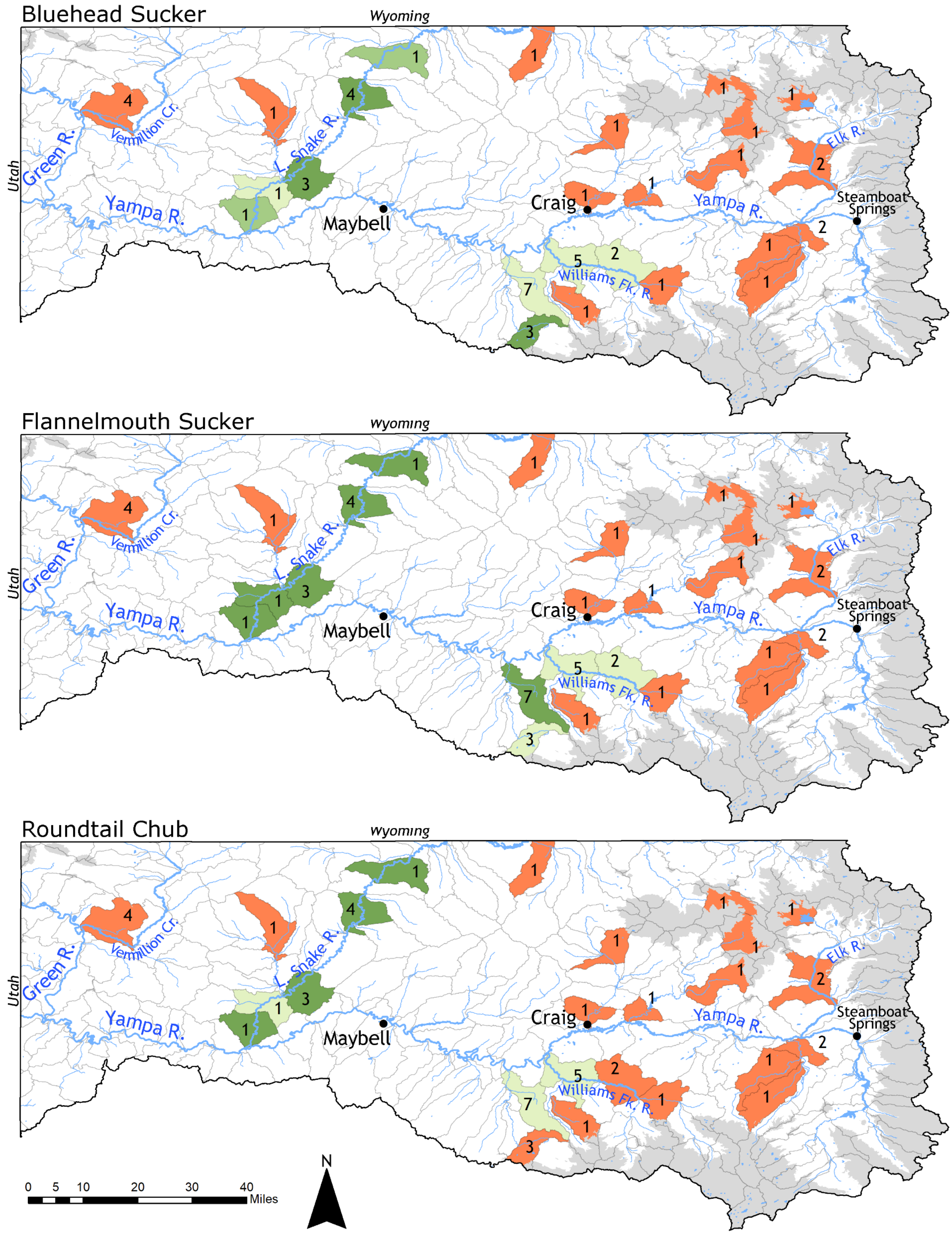
Roundtail Chub, while still found to be occupying much of their recent historic range, have been documented in far fewer historic locations. This, in combination with the assessment of Budy et al. (2015) that Roundtail Chub are the most imperiled of the three-species fishes in neighboring Utah, indicates that this species should be diligently monitored in the future.

Future efforts to identify new occupied habitats should heed the relationship identified in this study between stream gradient and the likelihood of three-species occupancy, and especially so for Flannelmouth Sucker and Roundtail Chub. These two species are more likely to inhabit reaches of very low gradient than those of even moderate gradient.

The removal or remediation of diversions or other barriers, two of which were accomplished in recent years on Roubideau Creek and Tabeguache Creek, will likely help the three-species maintain and enhance presence on the landscape. However, with respect to the native suckers, such opening of habitat may sometimes be accompanied by the danger of allowing greater access to non-native and hybrid suckers as well. Such evaluations will need to occur on a case-by-case basis, with managers weighing the potential benefits against the possibility of undesired consequences. In general, though, these fish thrive when large reaches of habitat are open to them, and opening additional habitat should be pursued.

Figures 1.5 - 1.16 are paired maps for each of six major river basins in Western Colorado. In each case, the odd-numbered figure presents information gathered via the three-species research program from 2011 to 2017, and the even-numbered figure presents information based on all ADAMAS records for three-species fishes from 2011 to 2017.

Yampa & Green River Basin



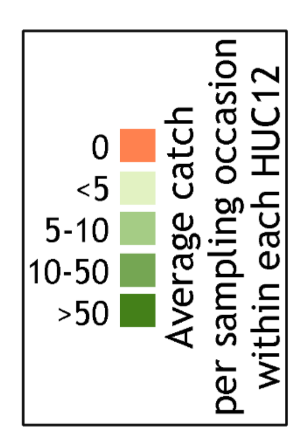
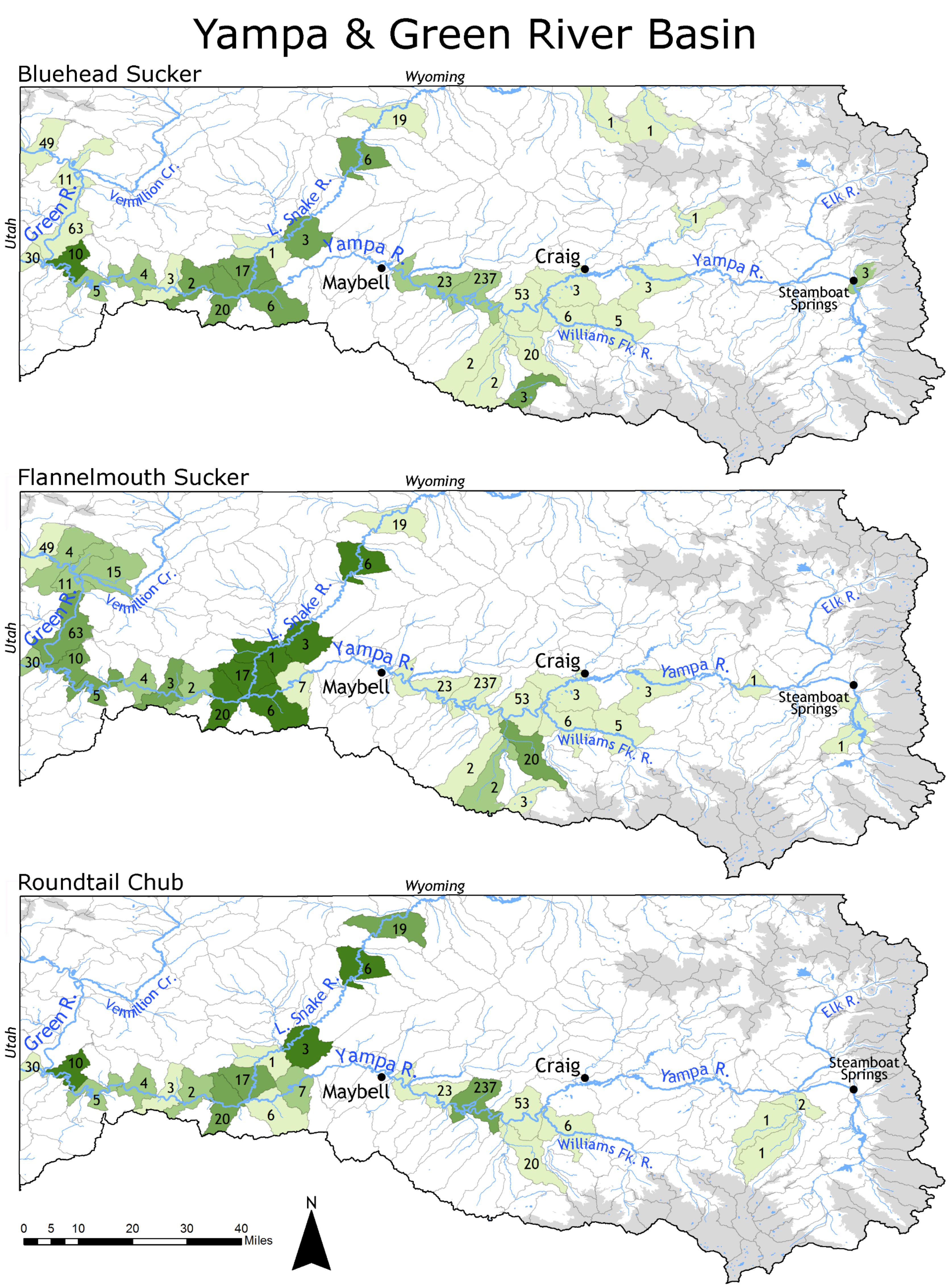


Figure 1.5. Sampling by HUC12 watershed of historic and random waters associated with the three-species research sampling program between 2011 and 2017. Numbers of surveys conducted within each HUC12 are indicated by the numbers on each map, and the coloration indicates the average number of individuals of the target species that were captured among all surveys in each HUC12. Sampling sites above 8,000 ft were excluded from the sampling program and are shaded grey on the maps.



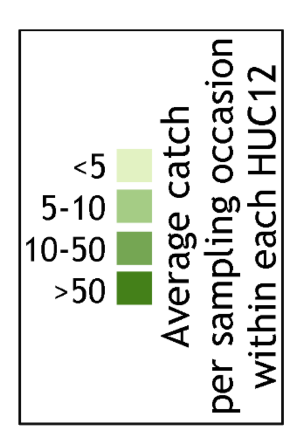


Figure 1.6. All survey records in the ADAMAS database where each of the three-species were physically collected between 2011 and 2017. Numbers of three-species-present surveys conducted within each HUC12 are indicated by the numbers on each map, and the coloration indicates the average number of individuals of the target species that were captured among all surveys in each HUC12. Sampling sites above 8,000 ft were excluded from the three species research sampling program and are shaded grey on these maps for continuity with figure 1.5.

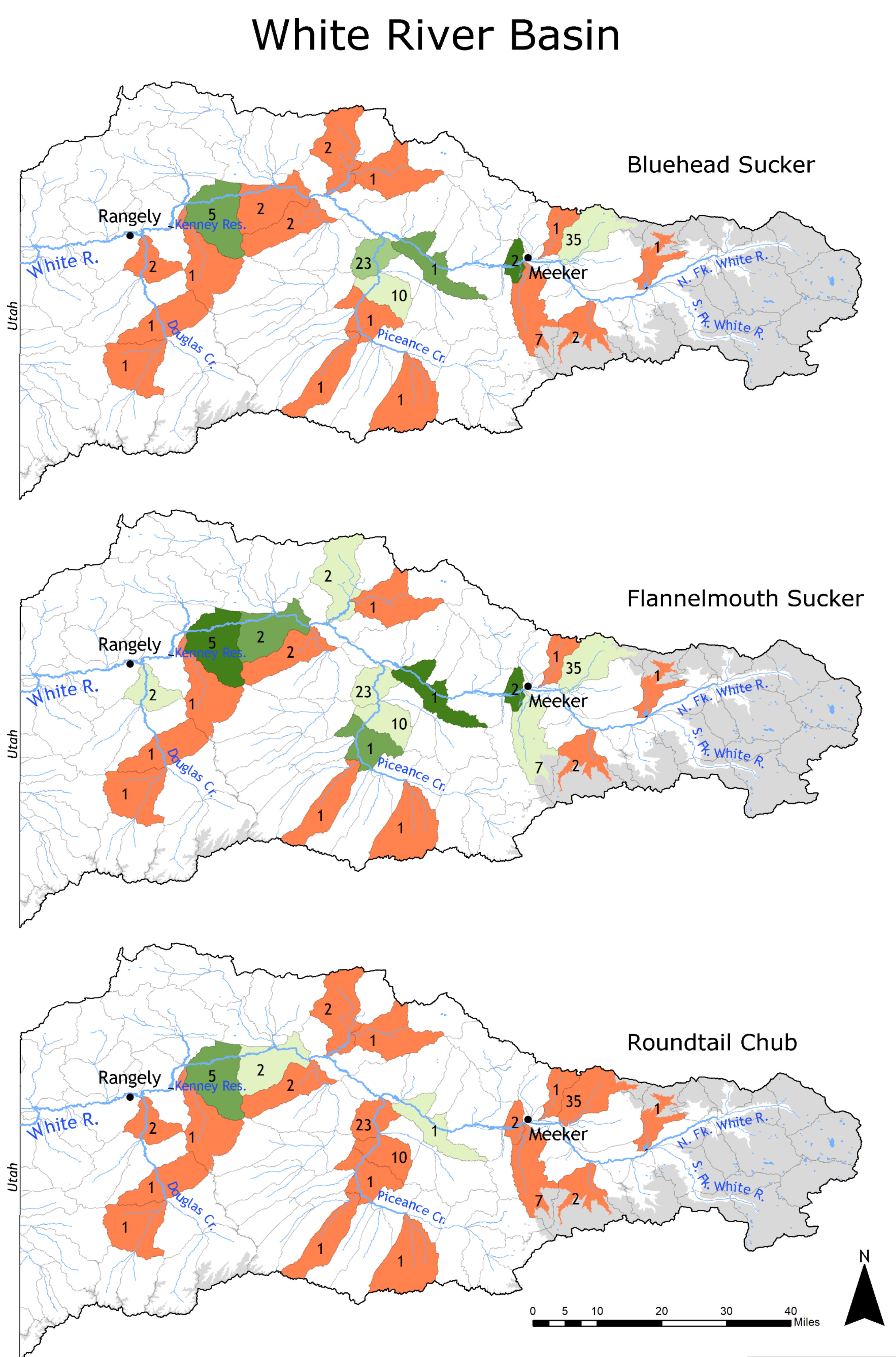
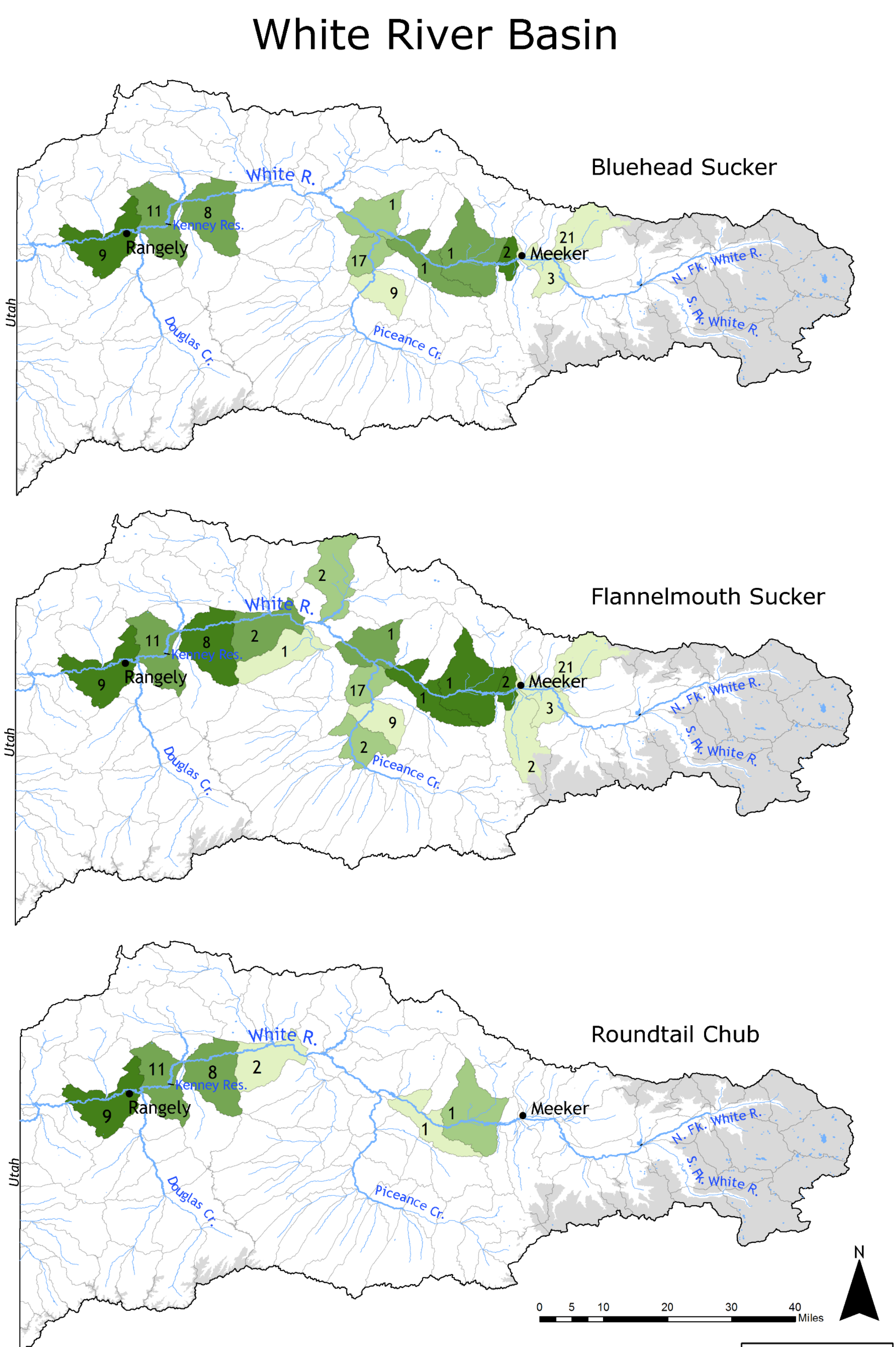


Figure 1.7. Sampling by HUC12 watershed of historic and random waters associated with the three-species research sampling program between 2011 and 2017. Numbers of surveys conducted within each HUC12 are indicated by the numbers on each map, and the coloration indicates the average number of individuals of the target species that were captured among all surveys in each HUC12. Sampling sites above 8,000 ft were excluded from the sampling program and are shaded grey on the maps.



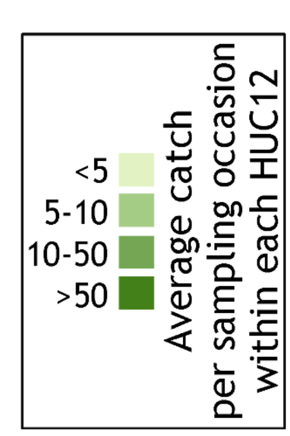


Figure 1.8. All survey records in the ADAMAS database where each of the three-species were physically collected between 2011 and 2017. Numbers of three-species-present surveys conducted within each HUC12 are indicated by the numbers on each map, and the coloration indicates the average number of individuals of the target species that were captured among all surveys in each HUC12. Sampling sites above 8,000 ft were excluded from the three species research sampling program and are shaded grey on these maps for continuity with figure 1.7.

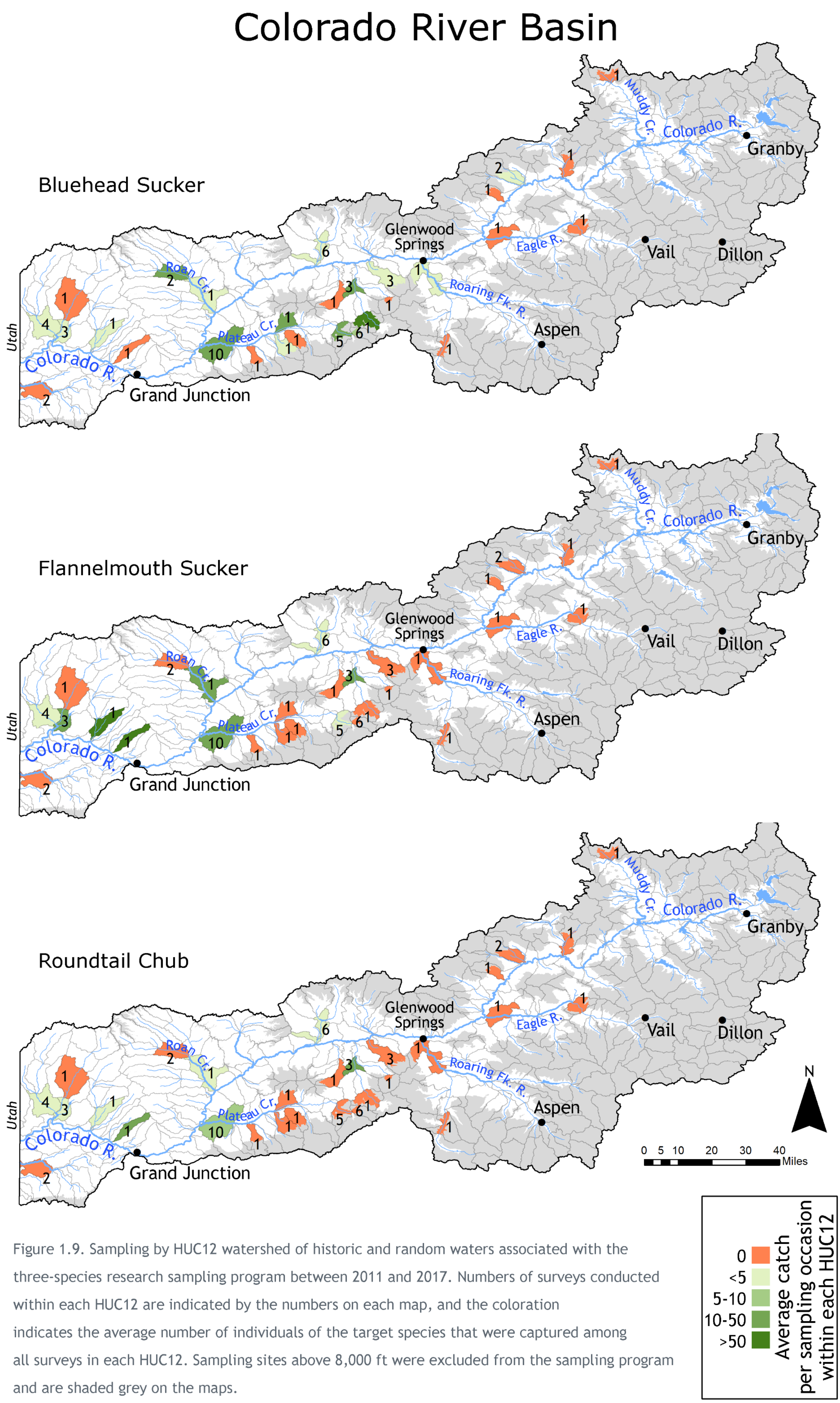
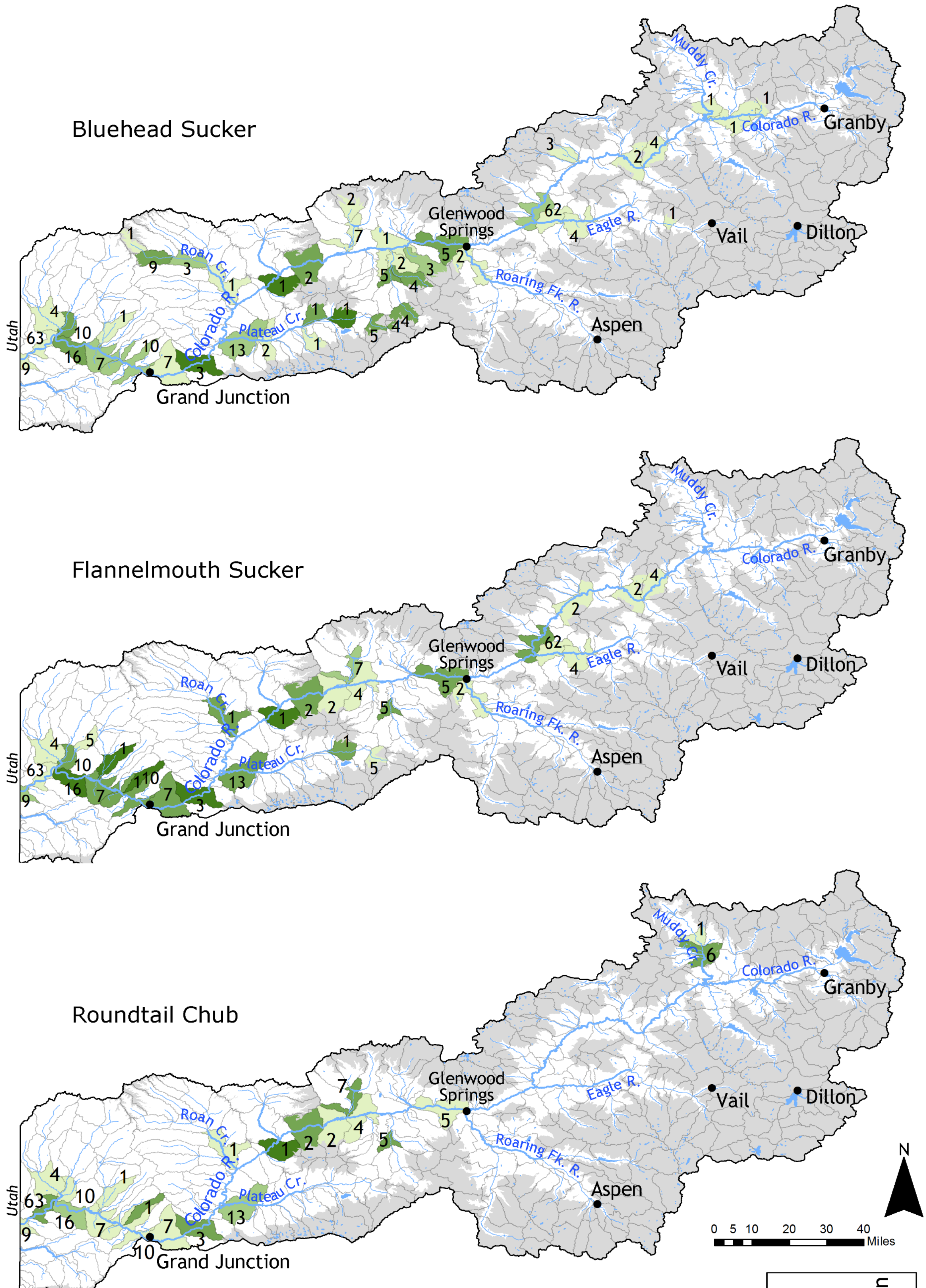


Figure 1.9. Sampling by HUC12 watershed of historic and random waters associated with the three-species research sampling program between 2011 and 2017. Numbers of surveys conducted within each HUC12 are indicated by the numbers on each map, and the coloration indicates the average number of individuals of the target species that were captured among all surveys in each HUC12. Sampling sites above 8,000 ft were excluded from the sampling program and are shaded grey on the maps.

Colorado River Basin



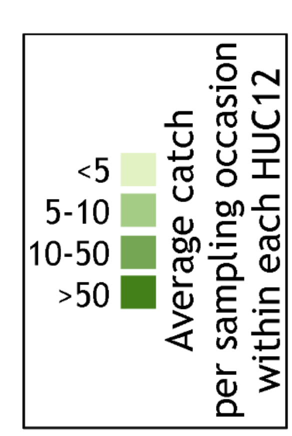


Figure 1.10. All survey records (not including fishway passage records; e.g. the Grand Valley Diversion Dam fish ladder) in the ADAMAS database where each of the three-species were physically collected between 2011 and 2017. Numbers of three-species-present surveys conducted within each HUC12 are indicated by the numbers on each map, and the coloration indicates the average number of individuals of the target species that were captured among all surveys in each HUC12. Sampling sites above 8,000 ft were excluded from the three species research sampling program and are shaded grey on these maps for continuity with figure 1.9.

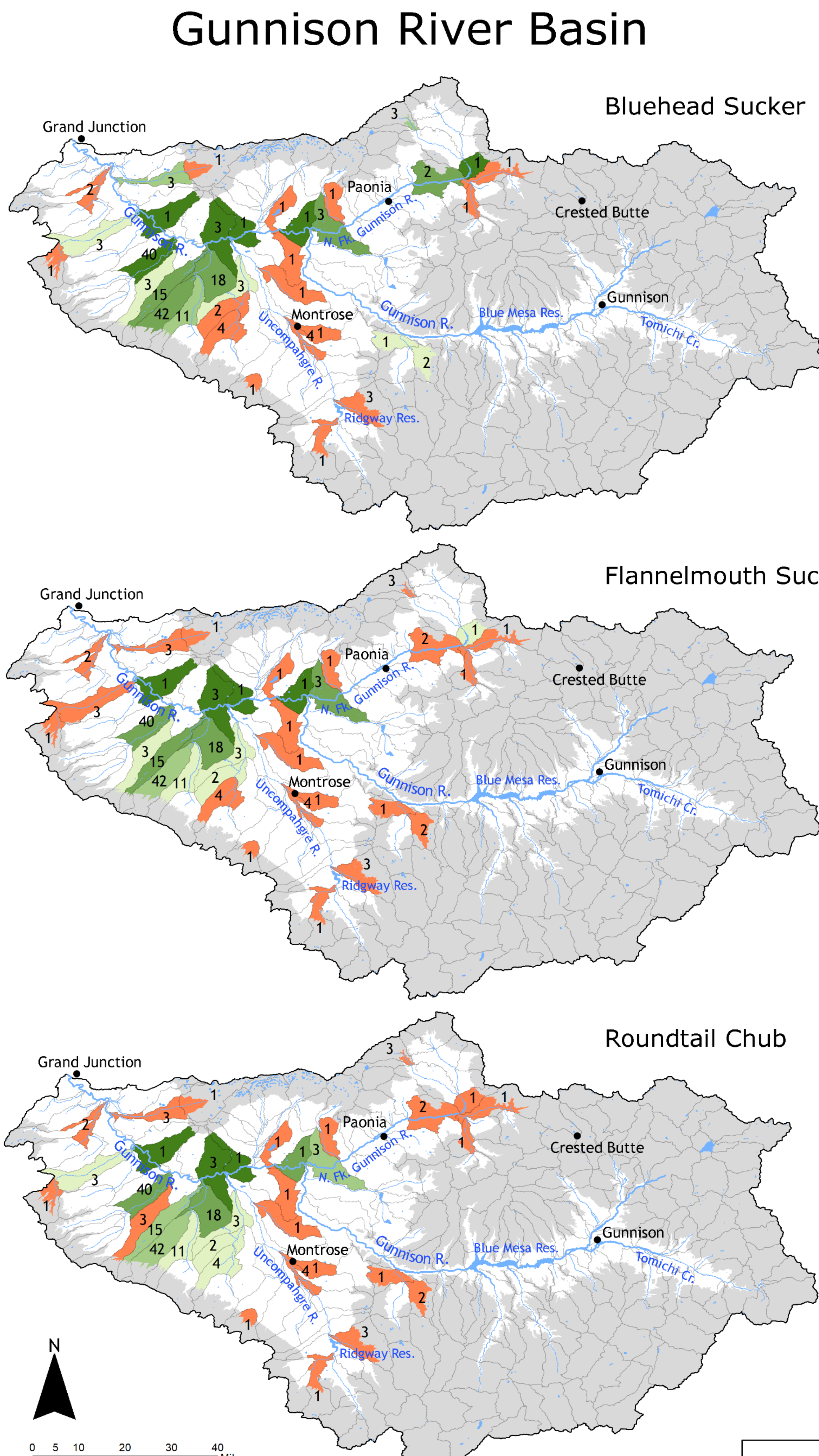
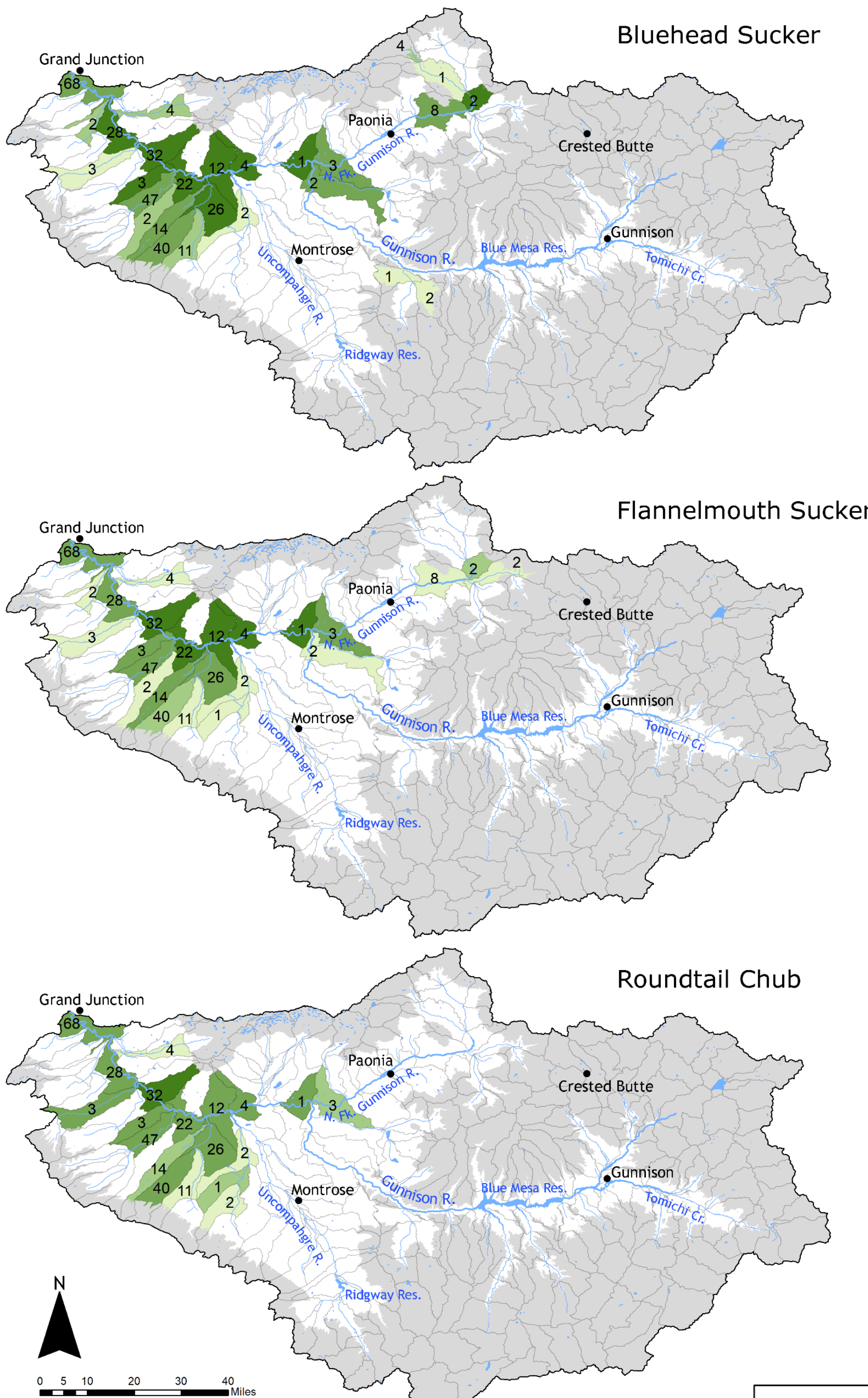


Figure 1.11. Sampling by HUC12 watershed of historic and random waters associated with the three-species research sampling program between 2011 and 2017. Numbers of surveys conducted within each HUC12 are indicated by the numbers on each map, and the coloration indicates the average number of individuals of the target species that were captured among all surveys in each HUC12. Sampling sites above 8,000 ft were excluded from the sampling program and are shaded grey on the maps.

Gunnison River Basin



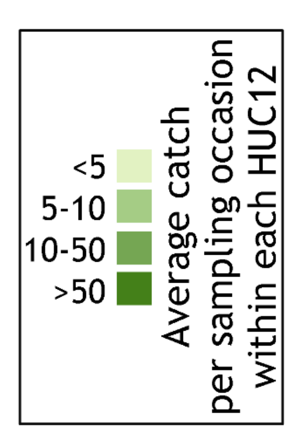
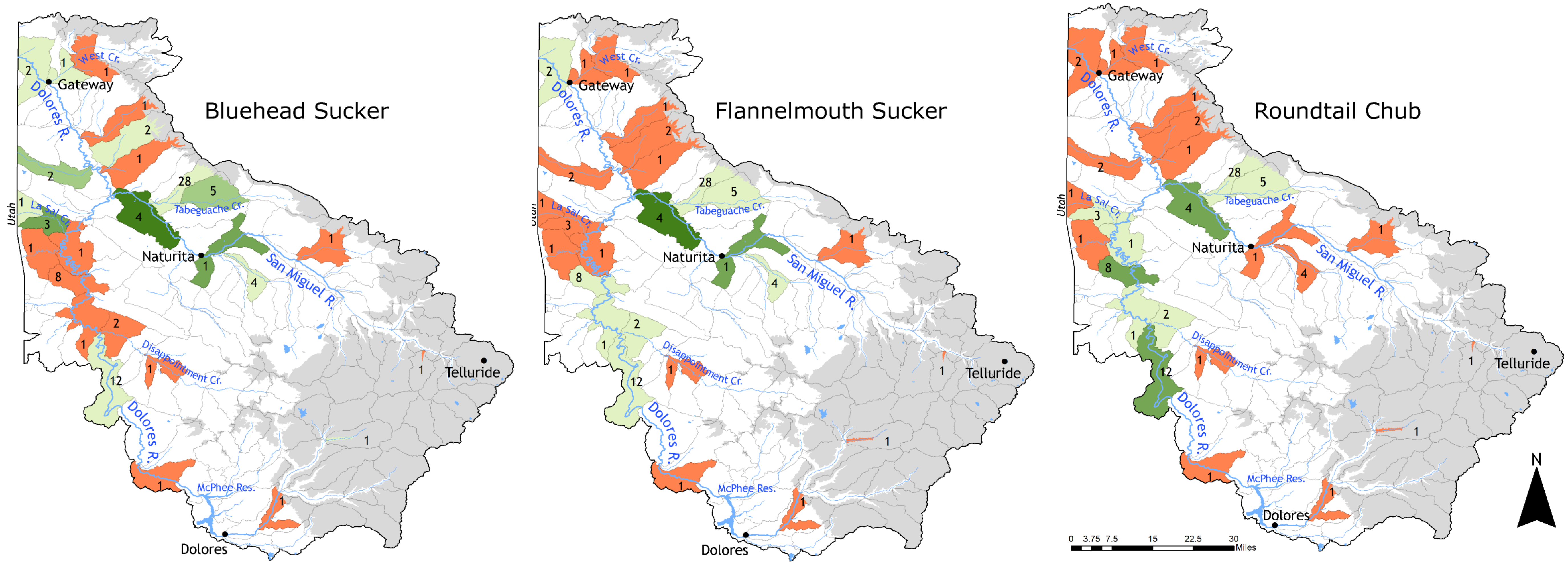


Figure 1.12. All survey records (not including fishway passage records; e.g. the Redlands Diversion Dam fish ladder) in the ADAMAS database where each of the three-species were physically collected between 2011 and 2017. Numbers of three-species-present surveys conducted within each HUC12 are indicated by the numbers on each map, and the coloration indicates the average number of individuals of the target species that were captured among all surveys in each HUC12. Sampling sites above 8,000 ft were excluded from the three species research sampling program and are shaded grey on these maps for continuity with figure 1.11.

Dolores River Basin



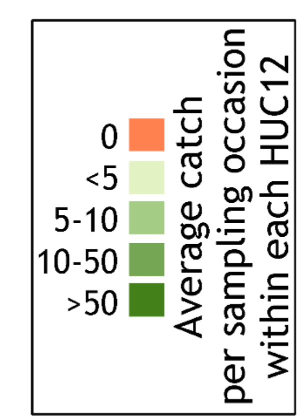
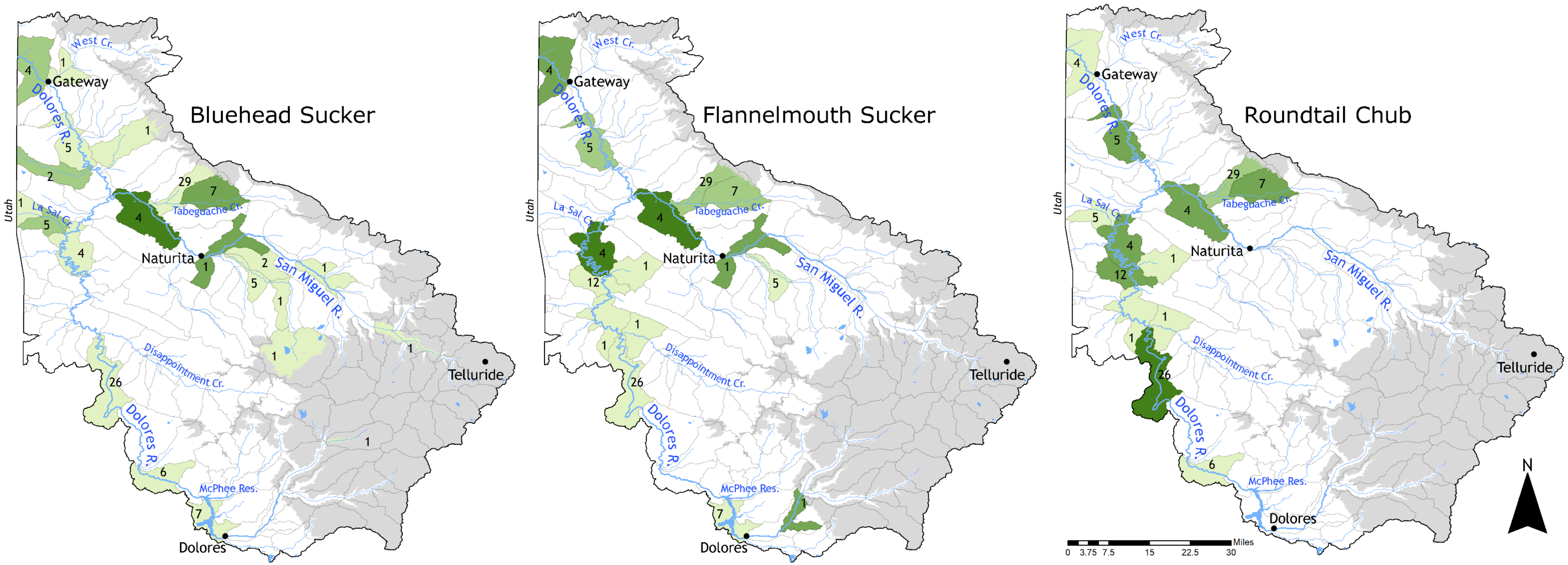


Figure 1.13. Sampling by HUC12 watershed of historic and random waters associated with the three-species research sampling program between 2011 and 2017. Numbers of surveys conducted within each HUC12 are indicated by the numbers on each map, and the coloration indicates the average number of individuals of the target species that were captured among all surveys in each HUC12. Sampling sites above 8,000 ft were excluded from the sampling program and are shaded grey on the maps.

Dolores River Basin



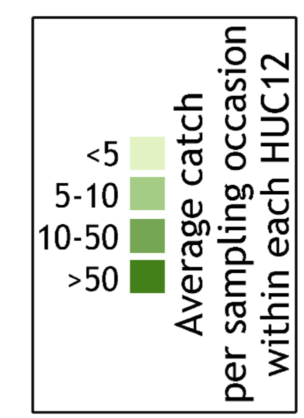


Figure 1.14. All survey records in the ADAMAS database where each of the three-species were physically collected between 2011 and 2017. Numbers of three-species-present surveys conducted within each HUC12 are indicated by the numbers on each map, and the coloration indicates the average number of individuals of the target species that were captured among all surveys in each HUC12. Sampling sites above 8,000 ft were excluded from the three species research sampling program and are shaded grey on these maps for continuity with figure 1.13.

San Juan River Basin

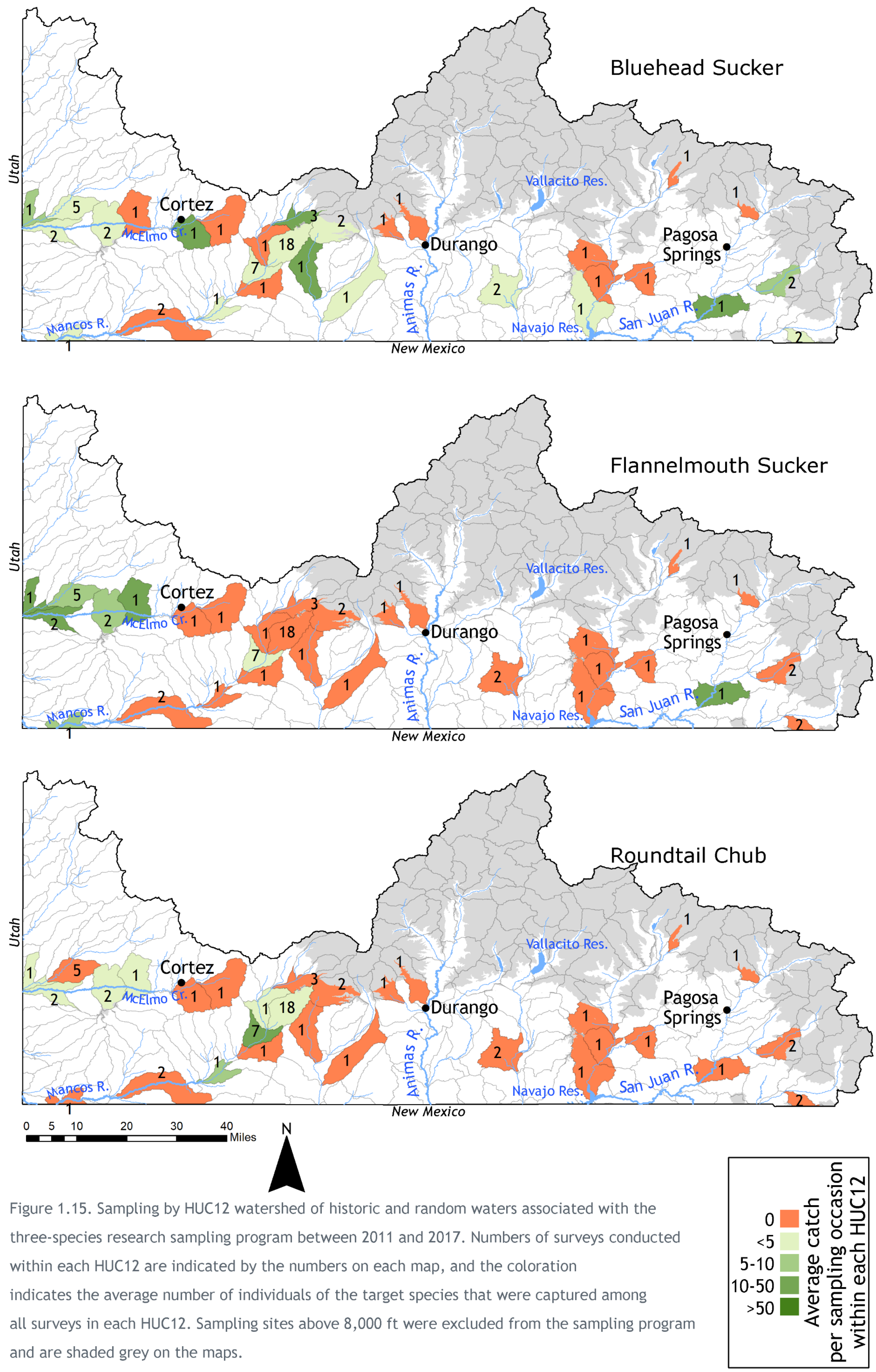
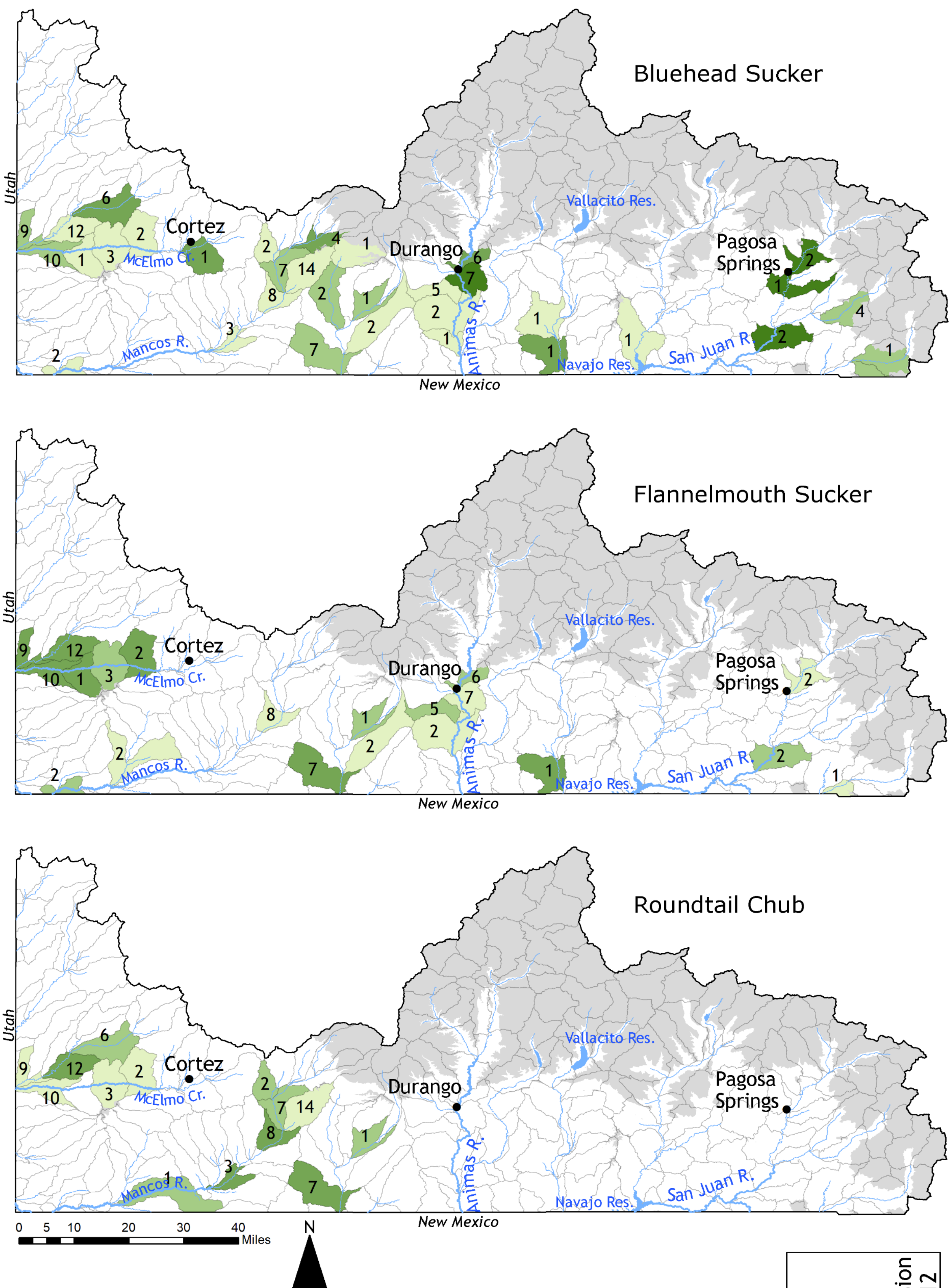


Figure 1.15. Sampling by HUC12 watershed of historic and random waters associated with the three-species research sampling program between 2011 and 2017. Numbers of surveys conducted within each HUC12 are indicated by the numbers on each map, and the coloration indicates the average number of individuals of the target species that were captured among all surveys in each HUC12. Sampling sites above 8,000 ft were excluded from the sampling program and are shaded grey on the maps.

San Juan River Basin



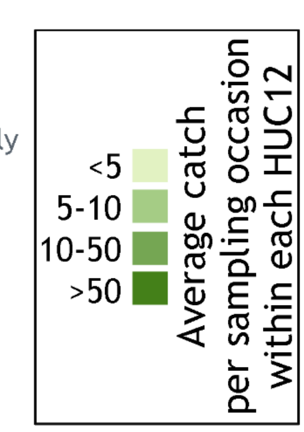


Figure 1.16. All survey records in the ADAMAS database where each of the three-species were physically collected between 2011 and 2017. Numbers of three-species-present surveys conducted within each HUC12 are indicated by the numbers on each map, and the coloration indicates the average number of individuals of the target species that were captured among all surveys in each HUC12. Sampling sites above 8,000 ft were excluded from the three species research sampling program and are shaded grey on these maps for continuity with figure 1.15.

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Chapter 2. Improving genetic integrity of sucker spawning runs by mechanical removal of non-native and hybrid spawners

2.1 Introduction

With loss of range and declines in abundance among three-species populations well documented, mitigating the underlying causes of these trends is a priority of Colorado River Basin fishery managers and conservationists. Negative three-species population effects largely result from the construction and operation of water infrastructure (e.g. dams and irrigation diversions) and from introductions of non-native fishes (Bezzerides and Bestgen 2002). Water infrastructure fragments available habitat and alters natural flow, temperature, and sediment transport regimes to which the three-species are specially adapted. Non-native fishes prey upon, compete with, and hybridize with three-species fishes. Perhaps the most insidious threat to the integrity of the remaining Bluehead Sucker *Catostomus discobolus* and Flannelmouth Sucker *C. latipinnis* populations in Colorado is the presence and spread of non-native sucker species with which the native suckers hybridize. Primarily, these non-natives are White Sucker *C. commersonii* and Longnose Sucker *C. catostomus* in Colorado, but also such species as Utah Sucker *C. ardens* in other parts of the upper Colorado River Basin. The range of these non-native suckers has greatly expanded in western Colorado over the last 40 years and hybrid suckers are becoming increasingly common (CPW aquatic database; Appendix B, Figure B.1 and Figure B.2). Wilson (1992) suggested that 38% of North American freshwater fish could be threatened by hybridization, and certainly these native western suckers should be counted among them. Continued hybridization and introgression could result in the eventual extinction of the native species as we know them today (*sensu* Rhymer and Simberloff 1996, Todesco et al. 2016).

Once present in a river basin, it is very difficult to prevent movement and range expansion of non-native suckers, and mitigating management options are limited. Because the native suckers are for the most part “big river” fish, opportunities to segregate pure populations of native suckers from invading non-natives, à la the cutthroat trout model, by translocation or barrier erection will be very limited. Habitat disturbance has been identified as a pathway to hybridization in the aquatic realm (Allendorf et al. 2001, Witte et al. 2013, Grabenstein and Taylor 2018). Habitat disturbance within the native range of the three-species fishes (dams, irrigation withdrawals, temperature and sediment regime changes, conversion of lotic to lentic habitats) have paved the way for thriving populations of non-native suckers (Martinez et al. 1994, Collier et al. 1996). Most such habitat disturbances are unlikely to be reversed because they are the foundation of societal infrastructure in the arid west.

A lack of opportunities for segregation or habitat restoration leads to consideration of a third option – removal of non-native suckers and hybrids. However, such an approach is unlikely to be executed on a scale as broad as the present range of non-native suckers in Upper Colorado River Basin. Moreover, attempts to suppress fish populations may result in demographic or life history responses on the part of the removal target species that counter the removal efforts (Brodeur et al. 2001, Zipkin et al. 2009). Removals to benefit three-species fishes have been suggested or attempted in smaller drainages (Rawson and Elsey 1948, Compton 2007, Garner et al. 2010). While attempts to remove non-native suckers in a large river basin are unlikely to be successful and may even be counter-productive, perhaps focusing on the spawning run in a smaller tributary would allow success on a smaller scale that would have implications for the larger river basin.

The long-term effectiveness of such a removal strategy would be dependent upon at least a degree of spawning tributary fidelity in the suckers. A high propensity for fish to return year-after-year to their natal stream or chosen tributary system would ensure that the genetic integrity of the specific tributary-spawning population could be maintained even if non-native and hybrid suckers predominate basin-wide in the future. Likewise, if the non-native suckers exhibit tributary fidelity, the effectiveness of removing them from spawning runs would be increased as fewer numbers would be expected after multiple years of culling. Evidence exists that suggests that catostomids both have the capacity for natal homing (Werner and Lannoo 1994) and are known to return to the same spawning tributary year after year (Cathcart et al. 2017, Fraser et al. 2017).

Our overall objective here was to test the hypothesis that mechanical removal of non-native suckers and their hybrids from an important spawning tributary of the Gunnison River would result in detectable changes in the proportion of pure native larval suckers produced in the tributary. If non-natives can be successfully suppressed to the advantage of native suckers, progeny produced in that stream would result in more pure fish in the Gunnison River. While such a strategy would not result in the disappearance of non-native suckers from the entire Gunnison basin, it may provide an avenue toward ensuring that the native species persist there. If successful, this strategy could be implemented in other river basins on appropriate tributaries as well.

Specific Objectives:

1. Exclude non-native and hybridized suckers from the spawning run in Cottonwood Creek, a tributary to Roubideau Creek, over three years to assess the effect on genetic purity of the larval drift. Compare results to those obtained in Potter Creek, an un-manipulated stream.
2. Determine, via longitudinal larval genetic sampling, if native suckers travel farther upstream than non-native suckers in Cottonwood and Roubideau creeks.
3. Compare tributary usage and fidelity of PIT-tagged three-species and non-native suckers in Roubideau Creek and its tributaries through Roubideau passive interrogation array detections and the deployment of multiple mobile, submersible PIT readers in order to gauge the potential long term effectiveness of non-native exclusion.

2.2 Methods

2.2.1 Non-native exclusion study

Two tributaries of Roubideau Creek (itself a tributary of the Gunnison River) were selected as study streams. Potter Creek was chosen to serve as the unmanipulated control stream, and the intermittent Cottonwood Creek as the treatment stream (Figures 2.1 and 2.2).

Uniquely identifiable fish were necessary to accomplish some of the longer-term objectives of this study, specifically assessment of spawning stream fidelity. Therefore, commencing in 2014, during select electrofishing surveys in the Gunnison River basin and all sampling efforts associated with the exclusion study, suckers ≥ 150 mm in total length (TL) were tagged with a PIT tag measuring 12.5 mm long and 2 mm in diameter. New tags were inserted intraperitoneally or into the abdominal musculature slightly left of the abdominal midline and about 50-60% the length of the pelvic fin behind the left pelvic fin insertion.

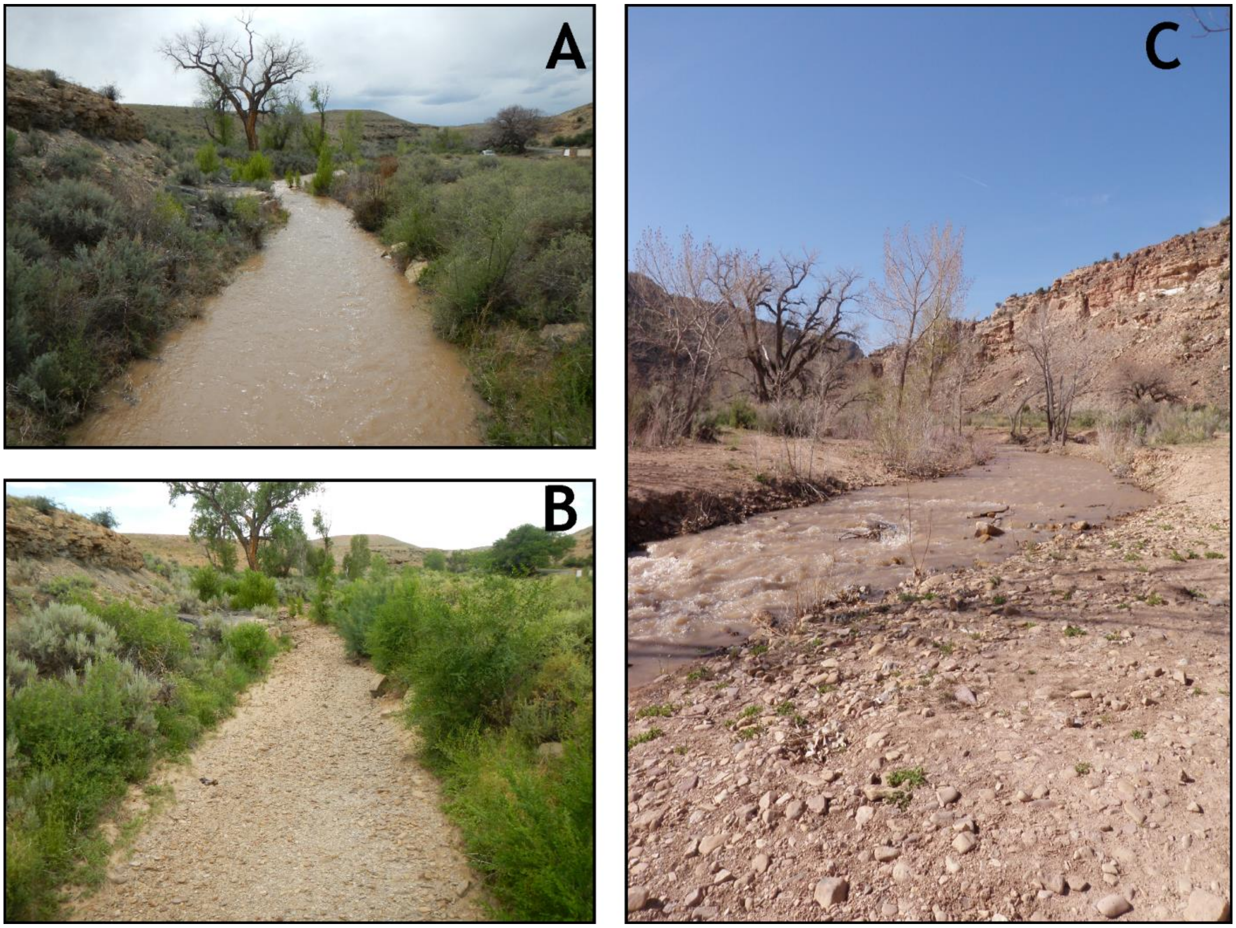

Figure 2.1. Intermittent Cottonwood Creek near its mouth in April (Panel A) and June (Panel B) of 2016. Potter Creek (pictured at its mouth in April 2014; Panel C) is a similarly sized stream but maintains flow throughout most or all of the year under normal snowpack conditions.

Although we favored the muscular insertion approach as we expected no tag expulsion with eggs compared to tags inserted all the way into the abdominal cavity, in practice most tags came to rest intraperitoneally. All fish were identified to species or suspected hybrid combination and measured (mm TL and gm weight), prior to release. The number of PIT tags deployed was limited by budget, and in 2016 and 2017 we encountered more fish than we were able to tag.

In addition to the PIT tags implanted in fish at the Cottonwood Creek weir, numerous tags were implanted elsewhere in the basin by us and by other CPW biologists or researchers (Table 2.1). The implantation procedure was generally as described for fish implanted at the weir. These fish were captured by boat, bank, and backpack electrofishing in 2005, and in 2014-2017. Three-species fishes tagged in waters outside of the Gunnison River basin (primarily the Colorado River) or by other agencies were infrequently encountered in the Roubideau Creek drainage, and while they may appear in fidelity analyses and figures, we do not report total numbers tagged.

A fish weir was used to conduct the spring fish trapping commencing in 2015. The weir consisted of two stream-spanning aluminum fences (with 2.22 – 2.86 cm spaces between vertical bars) that funneled fish into two trap boxes (Figure 2.3). One trap captured

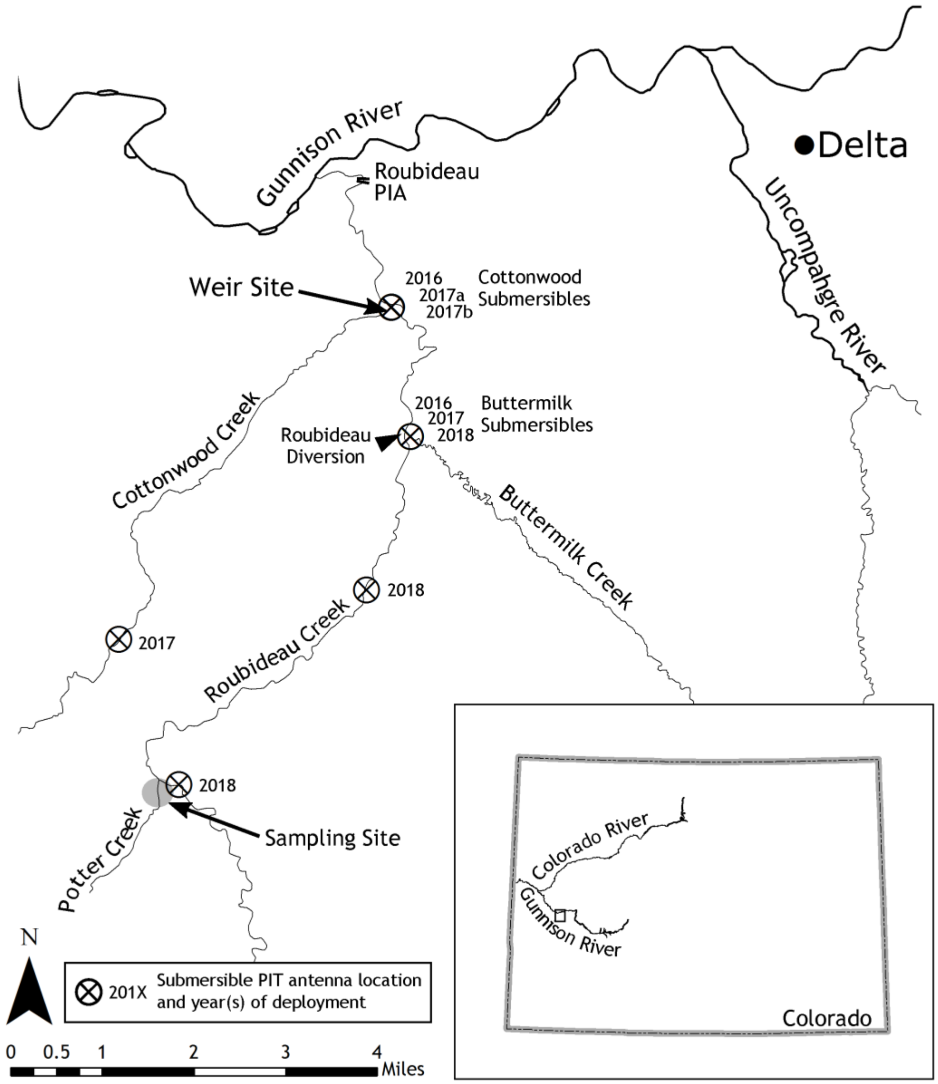

Figure 2.2.The Roubideau Creek system is a network of important spawning streams for Gunnison River Three-Species fishes. We attempted to limit entry of non-native suckers into Cottonwood Creek (Weir Site) and compared the genetic purity of larvae produced in the stream to the un-manipulated Potter Creek (Sampling Site). Also shown are the locations of a permanent passive interrogation array (PIA) and mobile submersible antennas deployed (by year) to detect movements of PIT-tagged fish. The inset map locates the study area (black rectangle) in relation to the State of Colorado.

upstream migrants, and one trap captured downstream migrants. The traps were aluminum box frames (76.2 × 76.2 × 152.4 cm) with 2.54 × 1.27 cm PVC-coated 14 gauge wire mesh panels, and funneled entrances 7 – 7.5 cm wide. Vertical bar spacing was designed to preclude passage of fish measuring about 220 mm total length or longer through 2016 (the narrower bar spacing), and 250 mm total length or longer in 2017 (the wider bar spacing), based on measurements of head width over a range of fish lengths. We sought to install the fish weir early enough to capture the earliest spawning immigrants, and intended to operate it throughout the spawning run.

Table 2.1. Numbers of PIT tags deployed by Colorado Parks and Wildlife in waters throughout the Gunnison River basin by year and by species. All suckers identified as non-native or hybridized with non-natives are grouped.

Tagging year	Cottonwood Cr.	Escalante Cr.	Gunnison R.	Potter Cr.	Roubideau Cr.	Other	Total
			Bluehead Sucker				
2005			540				540
2014	63	364	100	211	406		1144
2015	570	123	479	87	356	7	1622
2016	2243	201		110	3		2557
2017	1250	156		182		4	1592
			Flannelmouth Sucker				
2005			286				286
2014	175	123	66	169	90		623
2015	4	50	228	2	27		311
2016	399	71		10	1		481
2017	331	75		135		1	542
			Bluehead Sucker x Flannelmouth Sucker hybrid				
2014	1	28	4	9	12		54
2015	13	6	12	1	5		37
2016	53	23		1			77
2017	11			6			17
			Roundtail Chub				
2005			136				136
2014	42	43	13	5	50		153
2015	77	88	162	14	20	1	362
2016	2	71		2	10		85
2017	64	1		25	5		95
			Non-native and non-native hybrid suckers				
2014	57	81	39	8	3		188
2015	7	30	187				224
2016	189	44					233
2017	None tagged. All captured (with or without PIT tag) were culled.						

2.2.2 Effects of exclusion on larval species composition

Every migrating sucker entering the trap was identified morphologically to putative species or hybrid mix using published resources (Baxter and Stone 1995, Snyder et al. 2004) and a matrix of morphological characteristics and accompanying photographs assembled by staff from Colorado State University's Larval Fish Laboratory, the Upper Colorado River Endangered Fish Recovery Program, and CPW (unpublished data). Those deemed to be pure Flannelmouth Sucker or Bluehead Sucker were released upstream of the weir after work-up. Those deemed to be hybrids or pure non-native White Sucker or Longnose Sucker were released downstream of the trap in Roubideau Creek if they were PIT tagged (either historically or on the present occasion), but most often removed from the population if not PIT tagged. In 2016 and 2017, we randomly selected putative pure native suckers for genetic analysis in order to determine the accuracy of identification and the level of cryptic non-native sucker genetic influence due to introgression, because the genetic purity of individuals allowed to proceed upstream to spawning areas would

Figure 2.3. The Cottonwood Creek fish weir under a variety of conditions. Panel A shows the fully operational weir in 2016 when flows were low but ascending. In panel B, the 2016 weir is shown fully functional, but at flows approaching damaging levels. Leaf matter and woody debris had to be cleaned nearly continuously at these levels. High flows forced the removal of pickets or fence sections in both years (panel C; 2017 pictured here) to preserve the integrity of the overall structure. Fish had free access to the creek under these conditions. In 2016 especially, the outmigration occurred in such mass that fish threatened the integrity of the weir as can be seen in panel D - the damming effect seen on the upper fence is the result of several hundred fish attempting to pass the weir simultaneously.

affect the purity of larval drift from Cottonwood Creek.

Larval fish produced in the spawning runs in both tributaries were collected near the mouth of each tributary (in Cottonwood Creek, only upstream of the weir location) with a combination of drift nets and hobby aquarium hand nets. Larval fish were preserved in 95% non-denatured ethanol and shipped to the Museum of Southwestern Biology, Fishes, at the University of New Mexico (UNM) for curation and genetic analysis. In 2016 and 2017, larval fish were identified to genus level and shipments of fish to UNM were limited to putative *Catostomus* to reduce the incidence of *Gila* in the collections. Our goal was to provide 120-150 specimens from each study tributary for genetic analyses each year.

Genetic analyses used microsatellite DNA markers to evaluate the genetic identity of larval drift specimens in the two streams.

Genomic DNA was isolated using the E.Z.N.A.® Tissue DNA Kit (Omega-biotek) according to the manufacturer's instructions. Individuals were assessed for microsatellite variation at four loci (year 2014; Dlu4184, Dlu4235, Dlu482, Dlu456) and six loci (years 2015-2017; Dlu4184, Dlu4235, Dlu482, Dlu456, Dlu409, Dlu4300) developed for catostomids by Tranah et al. (2001). Conditions for polymerase chain reaction (PCR) amplification of DNA followed Tranah et al. (2001) with slight modifications. Early species contribution assessments were based on comparison to microsatellite data from reference samples of 12 Mountain Sucker and 25 each from Flannelmouth Sucker, Bluehead Sucker, White Sucker, and Longnose Sucker (Carson et al. 2016). In the final analysis of larval genetic data, reference samples only for Flannelmouth, Bluehead and White suckers were included because earlier efforts utilizing the remaining species' reference samples indicated virtually no representation of those species in either adult or larval samples (Schwemm et al. 2018). The same methods were used to assess purity of the randomly collected putative pure adult native suckers sampled at the Cottonwood Creek weir in 2016 and 2017.

Incidence of hybridization within and among populations was evaluated with Structure 2.3.4 (Pritchard et al. 2000, Falush et al. 2007, Hubisz et al. 2009). Run parameters included 200,000 iterations with 25% burn-in, correlated allele frequencies, and population information included as priors. Structure runs were replicated 10 times, combined, and visualized using CLUMPAK (Kopelman et al. 2015). Individual specimens were deemed "pure" when the proportional assignment to a single species was ≥ 90%.

2.2.3 Short term PIT tag retention

One future goal in this research program is to estimate apparent annual survival of native suckers in the Gunnison River basin. Such survival estimates can be obtained with Cormack-Jolly-Seber models utilizing tagged individuals (Lebreton et al. 1992). However, a critical assumption of such models is that marks or tags are not lost. The weir operations offered an ideal opportunity to assess short-term tag retention through a spawning event.

We used full-duplex, 134.2 kHz PIT tags measuring 12.5 x 2.1 mm (Biomark, Boise, Idaho). Deployment occurred via single-use hypodermic needles, and tags were inserted posterior to the left pelvic fin. Most tags were inserted into the body cavity, but some came to rest in musculature near the pelvic fin. Workers with varying levels experience were involved with implantation, but all were instructed beforehand in proper technique and supervised by an experienced tagger.

In 2016 and 2017, all fish receiving a newly implanted PIT tag as they ascended Cottonwood Creek were also given a second mark consisting of a 6.35-mm hole punch in the dorsal lobe of the caudal fin. After exhausting the supply of tags designated for Cottonwood Creek in these years, additional immigrant fish received hole punches in the ventral lobe of the caudal fin to differentiate them from PIT-tagged fish. Fish ascending Cottonwood Creek that carried PIT tags implanted in previous years were given no hole punch marks since they were already identifiable as having passed the weir and were not part of short-term tag retention evaluations. Thus, as emigrating fish were encountered, any fish exhibiting a dorsal lobe hole punch but revealing no PIT tag when scanned were assumed to have lost their tag. Retention was evaluated by sex and species of fish. For a more detailed explanation of these methods, see Hooley-Underwood et al. (2017).

2.2.4 Longitudinal larval genetic sampling

The first years of this study revealed that Potter Creek consistently hosted a higher proportion of adult native suckers in the spawning population than did Cottonwood

Creek. As Potter Creek is further from the Gunnison River than Cottonwood Creek, we hypothesized that this phenomenon of increased purity would be displayed in more upstream locations in Cottonwood and Roubideau creeks. Additionally, we wished to know how far upstream in the intermittent Cottonwood Creek these native fish were ascending in order to spawn. Therefore, in 2017, larval samples were obtained from Cottonwood Creek at two additional locations about 8 and 13 miles upstream of the mouth and a total of 62 specimens were genetically assessed. Cottonwood Creek did not deliver any water to the stream mouth in 2018, so longitudinal samples were restricted to Roubideau Creek, representing four locations spaced from the mouth to 24.5 miles above the mouth, nearly to the boundary of U.S. Forest Service property. All longitudinal larval samples were tested at a private lab (Pisces Molecular, LLC, Boulder) rather than University of New Mexico, but with similar methodology.

2.2.5 Spawning tributary fidelity

A passive interrogation array (PIA) consisting of four antennae was installed in Roubideau Creek in February 2015. The antennae, in pairs, span the entire channel in two locations, allowing increased detection probability and the potential for discerning direction of movement of individual fish. Data were downloaded about weekly during annual spawning seasons from mid-March to late June to ensure the system continued to operate properly, and less frequently throughout the rest of the year. The PIA operates continuously and year-round. Additionally, two to four portable, 1-m diameter submersible PIT-tag readers (hereafter SPR; Biomark, Boise, ID) were used throughout the Roubideau Creek drainage in 2016, 2017, and 2018 (see Figure 2.2 for specific deployment locations by year) in order to assess specific tributary usage and adult spawning tributary fidelity. Submersible PIT readers were deployed in strategic locations where they could be anchored flat to the substrate in stream sections where fish were likely to pass directly over. Such locations were usually constricted runs where water velocities were not likely to dislodge antennas even at high flows. We suspected that suckers, being benthic-oriented fish, would continue to pass close to the antennas even if increased discharge resulted in increased depth. Antenna data were downloaded, and batteries were changed, every two weeks during seasons of deployment unless high water prohibited access.

Data obtained from the PIA and the SPRs were used to assess stream fidelity in two ways. First, we determined whether any PIT tags detected on the PIA in any year were detected again the following year, without regard to the original tagging location. This revealed whether PIT-tagged fish that visited the Roubideau Creek drainage tended to re-visit in succeeding years. Second, we used the data from SPRs to determine whether fish tended to return to the same tributary in which they were originally tagged. Both assessments were accomplished without adjusting for any tag loss or fish mortality, hence fidelity rates are underestimated.

2.3 Results and Discussion

2.3.1 Non-native sucker exclusion study

Here we present results of stream sampling and weir operations as they pertain to the effectiveness of this study to prevent non-native suckers from entering Cottonwood Creek, and the accompanying results from Potter Creek. Primarily we present sampling timelines, numbers of fish present, and species composition. This study also provided a great deal of insight into the spawning ecology of the three-species, and a detailed investigation of these results is presented in Hooley-Underwood et al. (2019).

2014 –This was the preliminary year of study in which we documented use of both streams by the three-species fishes. Snowpack in 2014 was below the median (Figure 2.4), but both study streams were flowing on all sampling occasions. Both streams were repeatedly electrofished. Cottonwood Creek was sampled on May 5, 6, and 19. Potter Creek was sampled on April 9 (no spawning fish present) and on May 2, 12, and 19. Of those occasions, the most fish in spawning condition were found on May 5 and 6 in Cottonwood Creek and on May 12 in Potter Creek. We tagged all appropriately sized fish encountered; 397 suckers and five Roundtail Chub in Potter Creek, and 296 suckers and 42 Roundtail Chub in Cottonwood Creek (Table 2.1). Of the suckers, Flannelmouth Suckers were most common (60% of catch) in Cottonwood Creek, while Bluehead Suckers were only slightly more common than Flannelmouth Suckers in Potter Creek (Figure 2.5). White Suckers and their hybrids made up nearly 20% of the catch in Cottonwood Creek, while only a handful were captured in Potter Creek.

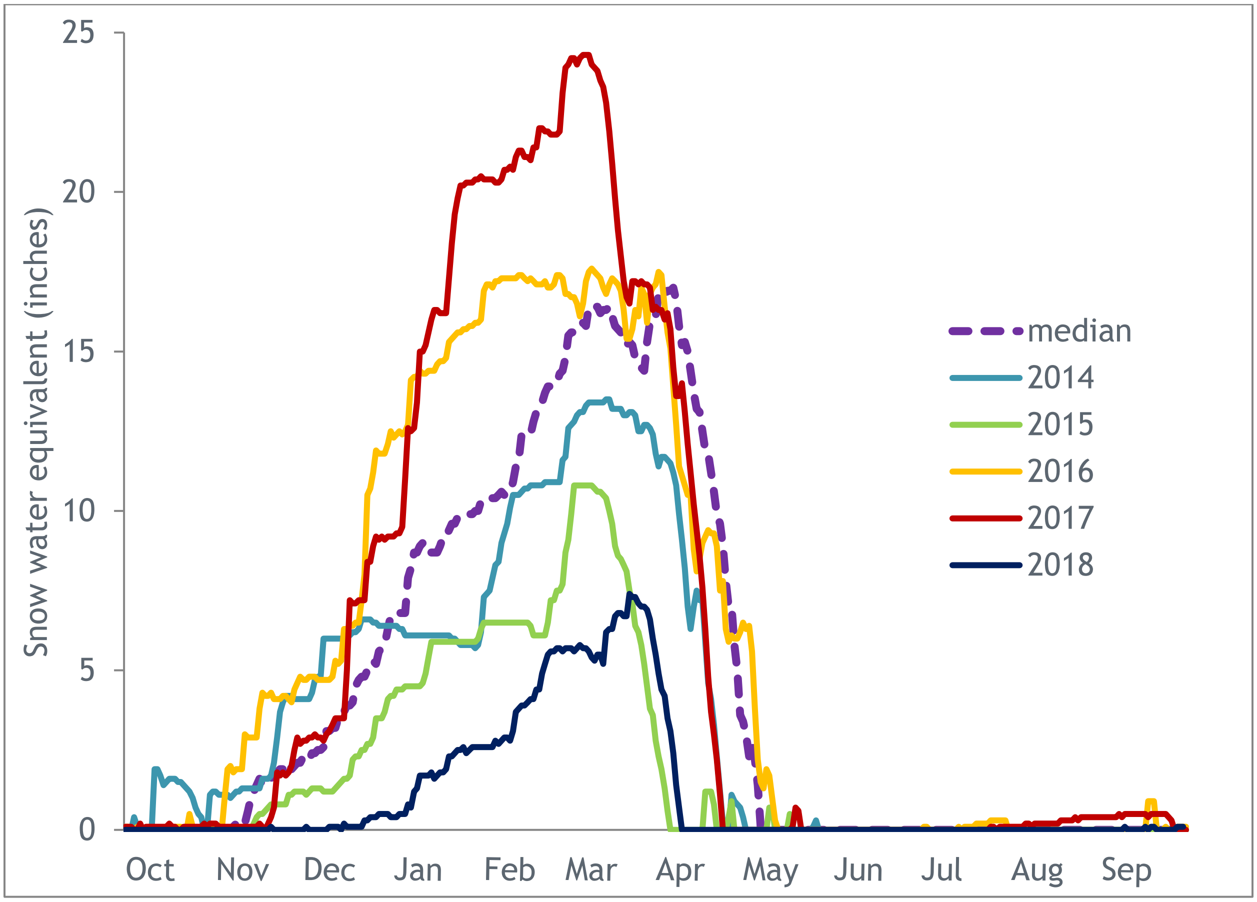

Figure 2.4. Columbine Pass (Uncompahgre Plateau) snow telemetry data chart showing long term average snow water equivalent along with the individual water years 2014 – 2018. Data were downloaded on 1/3/2019 from: https://www.cbrfc.noaa.gov/lmap/lmap.php?interface=snow

2015 - Our intentions to conduct the first year of the exclusion study on Cottonwood Creek were thwarted by very low snowpack and runoff conditions. Cottonwood Creek was still dry at its mouth in early April, and the only snow telemetry site informing runoff from the Uncompahgre Plateau was at that time reporting snow water equivalent near zero at the site (Figure 2.4). Consequently, we deployed the trap in Roubideau Creek on April 20, 2015, 1.25 miles downstream of the Potter Creek confluence.

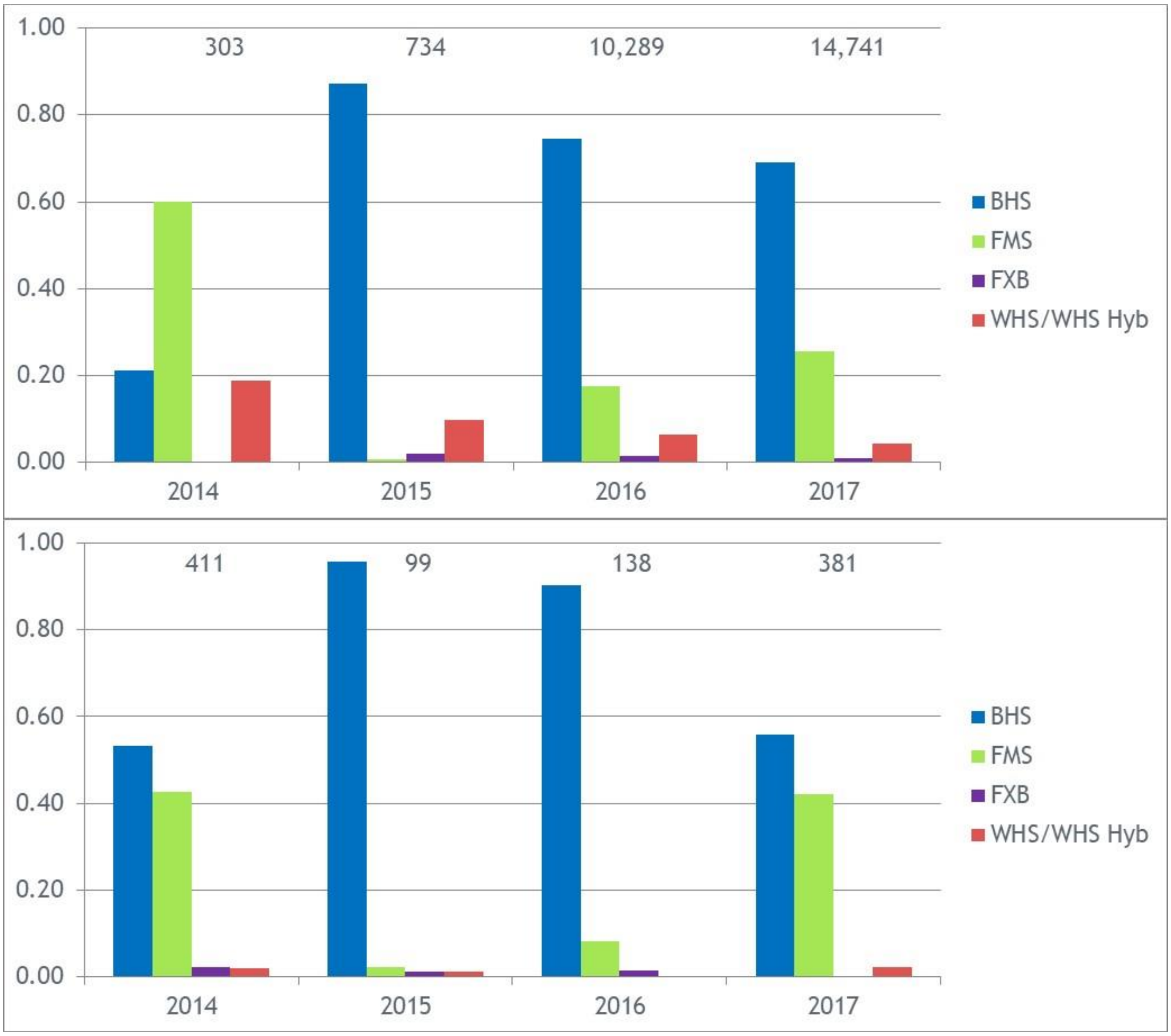

Figure 2.5. Relative species and hybrid composition of all suckers sampled by weir and electrofishing combined from 2014 – 2017 in Cottonwood Creek (top panel, treatment stream) and Potter Creek (bottom panel, control stream). Sample sizes (including recaptured fishes) are displayed above the columns for each year. Abbreviations are for Bluehead Sucker (BHS), Flannelmouth Sucker (FMS), Flannelmouth x Bluehead hybrid (FXB), and combined White Sucker and all White Sucker hybrids (WHS/WHS Hyb).

In late April, the rains commenced that later gave rise to the moniker “miracle May” with respect to the effects on Colorado’s runoff experience that year. These heavy rains necessitated the removal of the weir on May 6. It was deployed in Cottonwood Creek on May 11 and removed on May 22. Officials at the adjacent Delta Correctional Center indicated that Cottonwood Creek began to flow at the mouth on May 6, the same date the weir was rendered nonfunctional in Roubideau Creek. This resulted in missing the first five to six days of flow in Cottonwood Creek; the majority of the fish captured there in 2015 were exiting, not entering the stream (Table 2.1). Bluehead Sucker and Roundtail Chub predominated the catch (Figure 2.5). Flannelmouth Sucker, which generally spawn at cooler temperatures than the other two species and therefore earliest, were poorly represented in Cottonwood Creek in 2015, likely indicating that they had already accomplished spawning elsewhere in the Roubideau Creek drainage.

A second factor impacting this study in 2015 and 2016 was an irrigation diversion in Roubideau Creek 6.8 miles downstream of Potter Creek that was rebuilt prior to spring 2015 runoff (Figure 2.2; Figure 2.6). Notably, the electrofishing catch rate in Potter Creek plummeted from 3.0 fish/minute in 2014 to 0.44 fish/minute in 2015, and the proportion of Flannelmouth Sucker was greatly diminished, dropping from 41.9% of the catch in 2014 to 1.3% in 2015 (Figure 2.5). Only later did we discover the rebuilt diversion, constructed with 27 interlocking concrete barrier blocks, which resulted in a very formidable fish passage obstacle. The diminished catch rates during the sucker spawn in Potter Creek suggest strongly that fish passage in general was inhibited. Further, that the passage of Flannelmouth Sucker was particularly strongly inhibited.

Figure 2.6. The irrigation diversion (A) that was in place in Roubideau Creek between the confluences of Cottonwood and Potter creeks during 2015 and 2016, and the location of the diversion following removal (B) prior to the 2017 spawning season.

The combined trapping and electrofishing efforts resulted in the PIT tagging of 594 suckers in Cottonwood Creek, 388 suckers in Roubideau Creek, and 90 suckers in Potter Creek (compared to 397 in Potter Creek in 2014; Table 2.1). Species composition was dramatically different in both tributaries compared to 2014 (Figure 2.5). Flannelmouth Suckers were nearly absent from both tributaries, a circumstance likely explained by the diversion in Roubideau Creek and its effect on Potter Creek access, and by the lateness of the runoff with respect to Cottonwood Creek access. Cottonwood Creek was dominated by Bluehead Suckers in 2015, which usually spawn a little later than Flannelmouth Sucker. White Sucker specimens were not encountered in Cottonwood Creek in 2015, whereas they were fairly common in 2014. White Sucker hybrids however were present, though overall proportional abundance was less than observed in 2014.

2016 – The snowpack in 2016 was much higher than in 2015 and produced ample runoff in Cottonwood Creek (Figure 2.4). Prior to the installation of the weir and trap boxes, a SPR was placed in Cottonwood Creek between the weir site and the mouth of the stream to detect potential early arrival of tagged fish. None were detected before weir placement.

The weir and traps were installed in

Cottonwood Creek on April 5 in low, clear water. Migrating suckers arrived at the weir on April 8 with increasing discharge (and turbidity). The weir was in place until May 6, but there were a number of occasions when debris load compelled the removal of picket rods from parts of the weir resulting in the loss of control over hybrid and non-native sucker immigration. This, of course, defeated the primary objective of excluding all such fish from participating in the spawning run. The weir was re-deployed in Cottonwood Creek from May 23 to 25, during which time 4,433 emigrating suckers were captured. Included in this number were both White Suckers and hybrid suckers — 212 fish that had not been previously handled and 42 fish that had been encountered attempting the upstream migration while the weir was in place. The latter group had been tagged and released back into Roubideau Creek downstream of the Cottonwood confluence, but they subsequently returned to Cottonwood Creek.

Fish-trapping and electrofishing efforts in 2016 resulted in the PIT tagging of 2,893 suckers in Cottonwood Creek and 120 suckers in Potter Creek (Table 2.1). The numbers of suckers ascending Cottonwood Creek were much higher than anticipated based upon the 2015 experience, and in fact 2,660 native suckers were passed upstream without having a PIT tag implanted, but rather a ventral lobe caudal fin batch mark. On the outmigration from May 23 – 25, 3,046 unmarked suckers were handled in addition to recaptured fish with both dorsal and ventral lobe caudal fin punches. Therefore, about 8,599 individual suckers were handled during the trapping operation, and many more than that were in the stream as evidenced by the numbers of fish we were unable to handle during outmigration. Tagged suckers continued to be detected on the SPR following the removal of the weir until June 7.

In comparison to 2015, fewer Roundtail Chub were handled at the weir (Table 2.2). Only three Roundtail Chub were caught on the upstream migration, but 92 were captured during the downstream migration, suggesting that this species commenced upstream migration at a later date than the sucker species, after weir removal on May 6.

Catch rates and overall numbers of fish captured in Potter Creek remained substantially reduced from 2014, with the rebuilt diversion in Roubideau Creek still in place. The CPUE for suckers sampled in Potter Creek totaled over five occasions from May 3 to June 1, 2016 was 0.51 fish per minute, compared to 0.44 in 2015.

2017 – The 2017 snowpack was greater than in 2016, and runoff started earlier and proceeded more precipitously. Warm weather in early March resulted in PIT-tagged fish being detected by SPR ascending Cottonwood Creek by March 17, a full three weeks earlier than in 2016 and two weeks prior to having a crew to set up and monitor the weir. Consequently, control of the spawning run was lost from the outset. In addition, we encountered the same problems as previous years that resulted in removal of pickets for portions of days from April 12 - 24. Typically, pickets were removed during high debris events and in daylight periods when fish migration was minimal. When debris loads were heavy overnight, pickets were removed after the evening migration abated, usually between 11:00 pm and 1:00 am.

The picket weir frame and trap boxes were in place continuously from March 31 – May 19. During that time, we handled 11,280 individual suckers a total of 14,753 times (Table 2.2). After removal of the picket weir and trap boxes, the latest documented emigrants detected by SPR occurred on May 24 for Flannelmouth Sucker, May 27 for Bluehead Sucker, and May 31 for Roundtail Chub. Counting only first captures of all suckers, 91.8% were morphologically identified as pure Bluehead or Flannelmouth suckers. As in past years, all suckers deemed to be natives were released upstream of the trap if they were immigrating. In contrast to

Table 2.2. Numbers of fish trapped at the Cottonwood Creek Weir in 2015, 2016, and 2017. Numbers in the "US" and "DS" columns refer to all fish caught traveling upstream and downstream, respectively. Counts in the "Ind. Fish" columns are the total number of individual fish handled during each season (i.e. the number of unique PIT tag IDs + fish with no batch mark at time of capture).

2015			2016			2017		
US	DS	Ind. Fish	US	DS	Ind. Fish	US	DS	Ind. Fish
			Bluehead Sucker					
93	547	604	4279	3412	6349	3422	6756	7540
			Flannelmouth Sucker					
0	5	5	919	875	1678	802	2962	3112
			White and hybrid White suckers					
11	63	74	450	210	532	379	259	628
			Roundtail Chub					
40	273	-	4	90	91	10	65	74

past years, all non-native and non-native hybrid suckers were removed from the population (n = 665, of which 78 were PIT tagged).

Notable observations - Over three years of operation of the Roubideau PIA from 2015 to 2017, the first tagged fish detections occurred on March 14 or 15. Over those same three years, the first entries into Cottonwood Creek were May 6 (inferred from personal communication of sufficient discharge by Delta Correctional Facility officials), April 8 (physically handled fish at the trap), and March 17 (PIT-tagged fish detected on the SPR at the mouth of Cottonwood Creek). The remarkable consistency of entry into Roubideau Creek (including March 13 for 2018) is in stark contrast to the first entry into Cottonwood Creek. Largely, the use of Cottonwood Creek is a matter of water availability, with access to the creek becoming feasible for these large native suckers at about 5 cfs. Once flows permit access, it is clearly a favored stream, possibly due to vast resources of clean gravel and cobble substrate, and native suckers ascending a minimum of 13 miles of this stream to engage in spawning activity. Compton et al. (2008) also observed these same sucker species accessing for spawning purposes an intermittent tributary that offered sediment-free riffles that were rare in the perennial stream.

Following the removal of the irrigation diversion from Roubideau Creek, catch rates and overall numbers of fish captured in Potter Creek improved. The CPUE for suckers sampled in Potter Creek totaled over seven occasions from May 1 to June 7, 2017 was 1.55 fish/minute, compared to 0.51 in 2016 and 0.44 in 2015 when the diversion was in place. Flannelmouth Suckers particularly benefited from the removal of the diversion, with CPUE increasing to 0.58 fish per minute in 2017 compared to 0.05 in 2016 and 0.01 in 2015. Flannelmouth Sucker catch rate was 1.3 fish/minute on three occasions in the first three weeks of May 2014 prior to the construction of the diversion, demonstrating that the diversion in Roubideau Creek had a profound impact on access to Potter Creek for this species.

A SPR was also deployed in Buttermilk Creek, tributary to Roubideau Creek just downstream of the irrigation diversion site, in 2016 and 2017. As further evidence that the diversion was preventing native fish from accessing preferred spawning habitats, the antenna detected 910 unique PIT tags in 2016 when the diversion was in place, but only 25 unique tags in 2017 after diversion removal. Of the 910 tags detected in 2016, 622 were originally deployed in Potter Creek and Roubideau Creek. These fish presumably were unable to reach preferred habitat and thus settled for Buttermilk Creek in 2016.

2.3.2 Effects of exclusion on larval species composition

We were successful in collecting larvae from both creeks and completing genetic analyses on sets of larvae in all four years of study.

2014 – Both streams were sampled for drifting sucker larvae in 2014. Successful amplification of microsatellite markers was achieved for 157 larval fish specimens from Potter Creek and 79 from Cottonwood Creek. Admixture analyses revealed that the tributaries differed greatly in the genetic identity of the tested larvae (Figure 2.7). Potter Creek larvae were predominated by pure native suckers and hybrids thereof (98.7%), with very little White Sucker representation (n = 2 Flannelmouth x White sucker hybrids, 1.3%). Cottonwood Creek larvae were predominated by White Sucker (n = 34, 43%) and their hybrids (n = 28, 35%), followed by Flannelmouth Sucker (n = 12, 15%), Flannelmouth x Bluehead hybrids (n = 3, 3.8%) and Bluehead Sucker (n = 2, 2.5%). There was no evidence of Longnose or Mountain Sucker in the samples.

It was unexpected that a majority of larvae sampled in Cottonwood Creek were genetically determined to be non-native and hybrid suckers, in contrast to less than 20% of

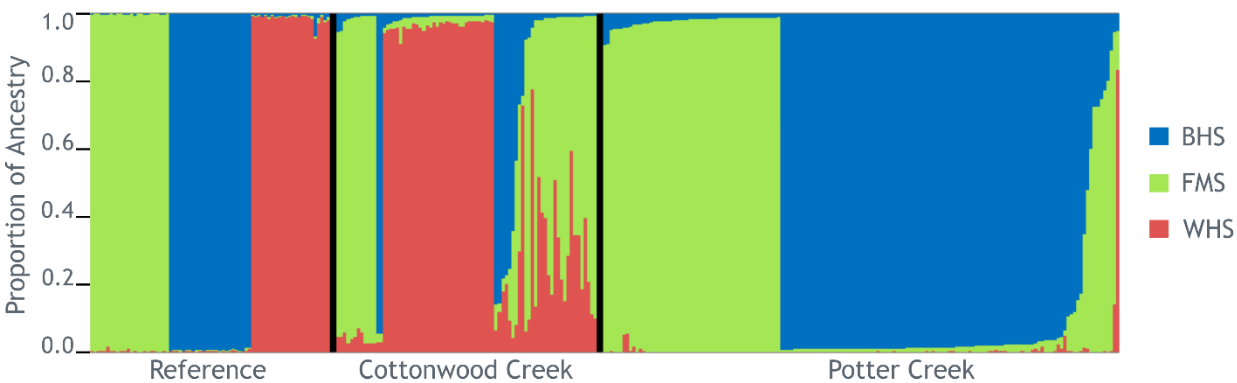

Figure 2.7. Structure analysis of species admixture for larval samples collected from Potter (n = 157) and Cottonwood (n = 79) creeks in 2014, and reference samples for three species of sucker tested for in the analysis. Colors represent each species' genetic contribution (based on four microsatellite markers) in a fish specimen, and each column of the chart displays the results for a single fish. BHS = Bluehead Sucker *C. discobolus*, FMS = Flannelmouth Sucker *C. latipinnis*, and WHS = White Sucker *C. commersonii*.

adult suckers identified morphologically as non-native or non-native hybrids. Many of the Cottonwood Creek larvae were collected on a single occasion and in a single location, leading to speculation over the possibility of having sampled a sibling group. However, given the life history activity of larval drift in these fishes, self-mixing should alleviate such concerns. It is also possible that by sampling larvae on one occasion only, we sampled a non-native-heavy wave of drifting larvae, which may have occurred due to temporal or spatial differences in spawning behavior of the different species. Another explanation is that we grossly misidentified adults, but genetic testing of adults in this study and elsewhere has shown that we are very accurate at visually determining the pure species involved in this study and first-generation hybrid mixtures of adult suckers. A final explanation could be that White Suckers are able to produce a much greater number of viable, drifting larvae per capita, which is why we saw a greater proportion of non-native genetics in the larval population than in the adult population. Regardless, the high density of non-native sucker larvae resulted in a situation where we anticipated creating an effect in following years by excluding non-native and hybrid adult fish from the spawning run. In contrast, Potter Creek contained a high proportion of native sucker larvae.

During the remaining years of study, the locations and timing of larval collections in both streams were more diversified to minimize the potential for repeating the incongruent results observed in 2014. We limited the number of larvae collected at any one location to 10-12 fish, and ensured that numerous locations in the lower 0.3 mile of stream above the mouth (Potter Creek) or above the weir site (Cottonwood Creek) were represented. We also ensured that two or more different dates of collection were represented.

2015 – Larvae were collected from both creeks with drift and dip netting. We collected numerous larvae and submitted 150 from each stream to UNM. A total of 84 larvae from Potter Creek and 124 larvae from Cottonwood Creek were identified as catostomids based on microsatellite genetic analyses. Potter Creek larvae were exclusively Bluehead Sucker by the ≥ 90% standard (Figure 2.8). Cottonwood Creek larvae were comprised of Bluehead Sucker (n = 95, 77%), Flannelmouth Sucker (n = 7, 6%), White Sucker (n = 12, 10%), and White Sucker hybrids (n = 10, 8%), with a total White Sucker and White Sucker hybrid representation of 18% among larvae.

2016 – We collected drifting larvae and visually targeted larvae with dip nets on multiple occasions. We refined our larval selection procedures in 2016 by learning to distinguish *Catostomus* larvae from *Gila* larvae, and submitted 120 specimens from both Cottonwood and Potter creeks to collaborators at UNM for genetic analysis. Additionally, randomly selected, putatively pure Bluehead and Flannelmouth sucker adults (n = 30 each species) were fin-clipped to obtain genetic samples representing the spawning fish allowed access to Cottonwood Creek. No non-native genetics were detected in the adult fish; one was identified as a Bluehead x Flannelmouth hybrid. Of the 240 2016 larval samples, 204 (108 larvae from Potter Creek and 96 larvae from Cottonwood Creek) resulted in useable genetic data. Potter Creek remained heavily represented by pure native suckers, and of the hybrids, all but one were hybrids between the native species (Figure 2.9). No pure White Suckers were present. Despite the heavy dominance of native suckers in the 2016 spawning run in Cottonwood Creek (Figure 2.5), the larval genetic results revealed a preponderance (n = 66, 69% of total) of White Sucker and White Sucker hybrid larvae in the stream following the spawn. Explanations for this phenomenon are elusive, as the larvae were collected in many different localities over several dates in the lower portion of the stream to avoid the possibility of sampling sibling groups. Due to this incongruence, in 2018 we had a private lab (Pisces Molecular, LLC, Boulder, CO) run microsatellite species assignments from a selection of larvae collected at the same times in 2016 as those run previously at UNM. We obtained species assignments for 64 larvae, and of those 49 (77%) had White Sucker genetics present, confirming the high incidence of non-native genetics (Figure 2.10). This indicates that we either missed many more non-native suckers both entering and exiting Cottonwood Creek than we suspected, or they disproportionately used lower reaches, or that non-native suckers produced vastly more offspring per individual than the natives.

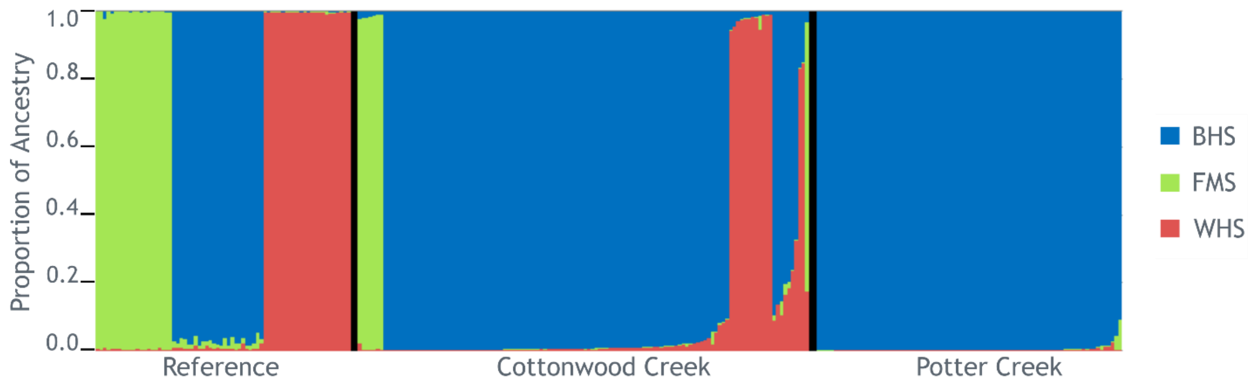

Figure 2.8. Structure analysis of species admixture for larval samples collected from Potter (n = 93) and Cottonwood (n = 124) creeks in 2015, and reference samples for three species of sucker tested for in the analysis. Colors represent each species' genetic contribution (based on six microsatellite markers) in a fish specimen, and each column of the chart displays the results for a single fish. BHS = Bluehead Sucker *C. discobolus*, FMS = Flannelmouth Sucker *C. latipinnis*, and WHS = White Sucker *C. commersonii*.

Figure 2.9. Structure analysis of species admixture for larval samples collected from Potter (n = 108) and Cottonwood (n = 96) creeks in 2016, and reference samples for three species of sucker tested for in the analysis. Colors represent each species' genetic contribution (based on six microsatellite markers) in a fish specimen, and each column of the chart displays the results for a single fish. BHS = Bluehead Sucker *C. discobolus*, FMS = Flannelmouth Sucker *C. latipinnis*, and WHS = White Sucker *C. commersonii*.

2017 - Matching 2016 methods, we collected tissue samples from randomly selected adult fish ascending Cottonwood Creek that we deemed to be pure native suckers based on morphology (n = 30 for each species). As in 2016, no non-native genetics were detected, and one adult was identified as a Bluehead x Flannelmouth hybrid. We collected larvae from Cottonwood and Potter creeks and submitted 120 putative Catostomus larvae from each creek to colleagues at UNM. Larvae for genetic analysis were collected from Cottonwood Creek on May 22 (n = 3), May 26 (n = 13), June 2 (n = 70), and June 6 (n = 34). Those representing Potter Creek were collected on May 26 (n = 2), May 30 (n = 4), and June 7 (n = 114). Microsatellite analyses resulted in 111 usable samples from each creek. In Potter Creek, all but one fish (a Bluehead X White hybrid) were pure natives or native hybrids (51 Flannelmouth, 45 Bluehead, and 14 Flannelmouth X Bluehead

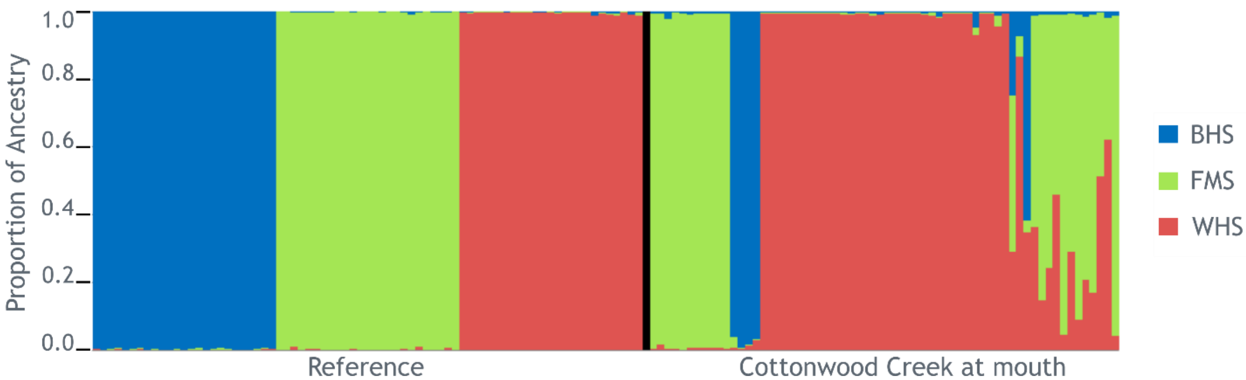

Figure 2.10. Structure analysis of species admixture for larval samples collected from Cottonwood Creek (n = 64) in 2016 at similar times and locations as those represented in Figure 2.9. Samples shown here were run at a separate facility (Pisces Aquatics) to confirm the high rate of occurrence of White Sucker genetics. Colors represent each species' genetic contribution (based on six microsatellite markers) in a fish specimen, and each column of the chart displays the results for a single fish. BHS = Bluehead Sucker *C. discobolus*, FMS = Flannelmouth Sucker *C. latipinnis*, and WHS = White Sucker *C. commersonii*.

Figure 2.11. Structure analysis of admixture for larval samples collected from Potter (n = 111) and Cottonwood (n = 111) creeks in 2017, and reference samples for three species of sucker tested for in the analysis. Colors represent each species' genetic contribution (based on six microsatellite markers) in a fish specimen, and each column of the chart displays the results for a single fish. BHS = Bluehead Sucker *C. discobolus*, FMS = Flannelmouth Sucker *C. latipinnis*, and WHS = White Sucker *C. commersonii*.

hybrids; Figure 2.11). Unlike in 2016, Cottonwood Creek larval genetics results did more closely reflect spawning sucker species numbers observed at the weir. Over 97% of the samples were identified as pure native suckers (n = 14 Flannelmouth Sucker; n = 89 Bluehead Sucker) or native sucker hybrids (n = 5). The only non-native genetics were represented by three Flannelmouth X White Sucker hybrids.

Overall, we were more successful at maintaining the integrity of the weir in 2017 than in 2016, and were thus likely able to better limit the number of non-native suckers passing the weir; however, there were still many occasions in 2017 when pickets were at least partially removed. The high proportion of non-native larvae produced in 2016 and the low proportion in 2017 are vexing results. It is possible that White Sucker in the basin have a higher level of fitness resulting from a difference in fecundity, spawning behavior (e.g. do White Sucker males spawn more times or with more females than native males?), larval viability or survival. This idea may be supported by the fact that White Suckers and hybrids have become so numerous throughout the Gunnison River. If White Sucker do indeed have much higher reproductive capacity, then the relatively small proportion of adults using Cottonwood Creek and circumventing the weir may have been responsible for the high proportion of non-native genetics in the sampled larvae. Perhaps in 2017, the observed decrease in non-native adult immigrants (Figure 2.5) and the improved continuity of weir operation was enough to nullify this effect.

2.3.3 Short term PIT tag retention

A paper fully describing the study of short-term PIT tag retention in Bluehead and Flannelmouth Suckers conducted in 2016 was published (Hooley-Underwood et al. 2017; http://www.tandfonline.com/doi/full/10.1080/02755947.2017.1303008). To summarize the 2016 results, retention rates for all sucker species (including non-natives and hybrids) were between 99.3% and 100%. This represented two tags lost out of 883 recaptured fish. We saw no effect of sex on retention rate (one male and one female lost tags). These high rates of retention were achieved over an average of 36 days at large, and through a spawning event, suggesting strongly that suckers are not prone to expelling tags during spawning activities even when they are implanted intraperitoneally posterior to the pelvic girdle.

In 2017, tag retention was slightly lower. We did not tag White or hybrid suckers in 2017, and culled all that we captured at the weir, including previously tagged fish, so we only present retention rates for native suckers

Table 2.3. Short-term PIT-tag retention estimates for fish PIT-tagged and batch-marked (top caudal punch) in 2017. Recaptured fish with both a PIT tag and batch mark were considered to have retained their PIT-tag, while fish with a batch mark only were not. Sex was determined by the presence of flowing eggs (female) or milt (male), or the presence of tubercles (suspected male) or lack thereof (suspected female).

		Marked	**Recaptured**		
		PIT tag and Top Caudal Punch	PIT Tag and Top Caudal Punch	Top Caudal Punch Only	**Retention**
Bluehead Sucker	Male	577	211	0	1.000
	Female	42	15	1	0.938
	Suspected Male	28	195	1	0.995
	Suspected Female	613	517	8	0.985
	Total	1260	938	10	0.989
Flannelmouth Sucker	Male	173	93	0	1.000
	Female	26	7	0	1.000
	Suspected Male	14	45	0	1.000
	Suspected Female	117	112	3	0.974
	Total	330	257	3	0.988
All Fish		1590	1195	13	0.989

(Table 2.3). Overall, we tagged 1,590 fish and recaptured 1,208 of those. Of the recaptured fish, 13 had lost their PIT-tag, resulting in an overall retention rate of 98.9%. Retention rates between the two species were nearly identical, but 12 of the 13 losses occurred in fish that were confirmed or suspected females. In 2017, we had a larger crew with at least five novice taggers compared to a smaller, more highly trained crew in 2016. Moreover, those taggers that were initially inexperienced implanted a higher proportion of tags than in 2016. Although the learning process is relatively short and the implantation method simple, it is possible that the higher tag loss rates could be attributed partially to less experienced taggers. We did not have the data sufficiently partitioned to test such a hypothesis.

Overall, retention rates were very high and similar to rates observed in limited previous retention work with these species (Compton et al. 2008), favoring acceptance of the survival analysis assumption that marks are not lost to a degree that would materially affect survival analyses.

2.3.4 Longitudinal larval genetic sampling

In 2017, we collected larvae from three locations in Cottonwood Creek (Figure 2.12). We received microsatellite-based species assignments for 34 larvae collected at the weir site (2.9 miles from the Gunnison River), 36 larvae collected 10.9 miles from the Gunnison, and 26 larvae collected 15.8 miles from the Gunnison. At all three sites, Bluehead Suckers were most common whereas pure or hybrid White Suckers were absent (Figure 2.13). Interestingly, among the three sites, Flannelmouth Sucker larvae were most common at 10.9 miles from the Gunnison River, but this could have been a result of relatively small sample sizes. Genetic results for this longitudinal sampling were corroborated by those obtained at UNM for the non-native exclusion study in that non-native genetics were minimally represented in larvae collected at the weir (Figure 2.11).

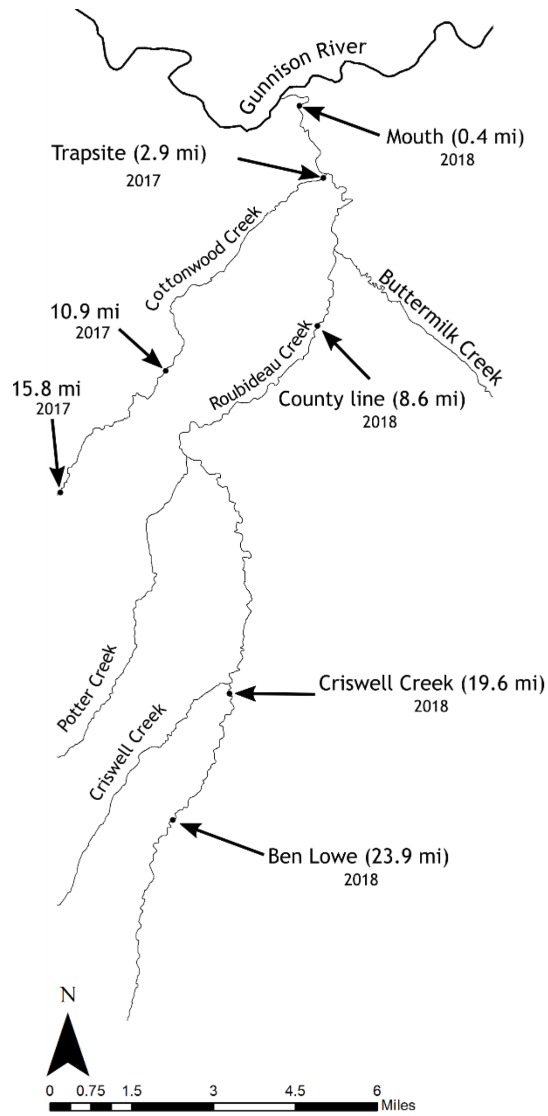

Figure 2.12. Larval catostomid collection locations (indicated by black circles and arrows) in the Roubideau Creek drainage for the longitudinal larval genetics studies conducted in 2017 (Cottonwood Creek only) and 2018 (Roubideau Creek only). Distances represent total stream-miles from the Gunnison River.

In 2018, we collected larvae from four locations in Roubideau Creek (Figure 2.12). We obtained microsatellite-based species assignments for 32 larvae collected at each of four sites. Near the mouth (0.3 mile from the Gunnison River), 30 larvae were assigned as White Sucker and two were Flannelmouth x White sucker hybrids (Figure 2.14). At the County Line site (8.6 miles from the mouth), 69% were natives (16 Bluehead Sucker, four

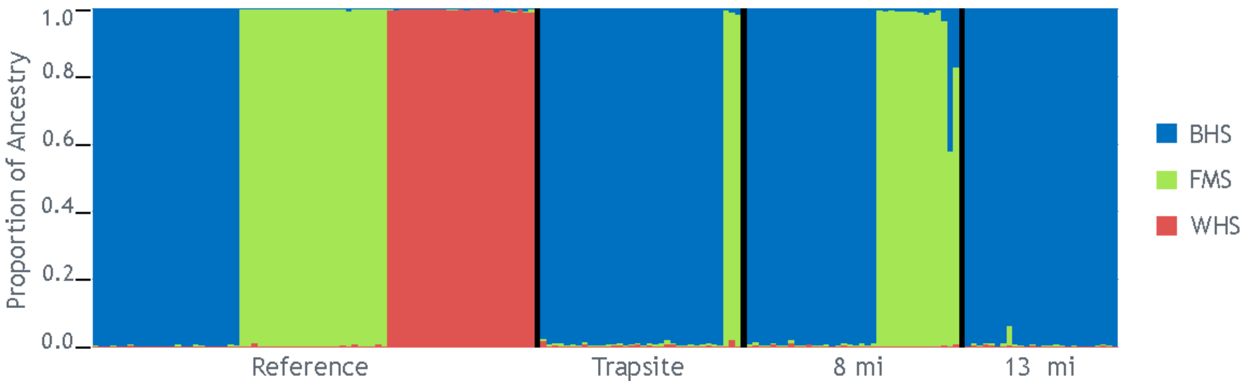

Figure 2.13. Longitudinal larval catostomid genetic sampling results for the 2017 study. Displayed is the structure analysis of admixture for larval samples collected from three different sites (displayed from downstream to upstream – left to right) on Cottonwood Creek in 2017, and reference samples for the three species of sucker tested for in the analysis. Colors represent each species' genetic contribution (based on six microsatellite markers) in a fish specimen, and each column of the chart displays the results for a single fish. BHS = Bluehead Sucker *C. discobolus*, FMS = Flannelmouth Sucker *C. latipinnis*, and WHS = White Sucker *C. commersonii*.

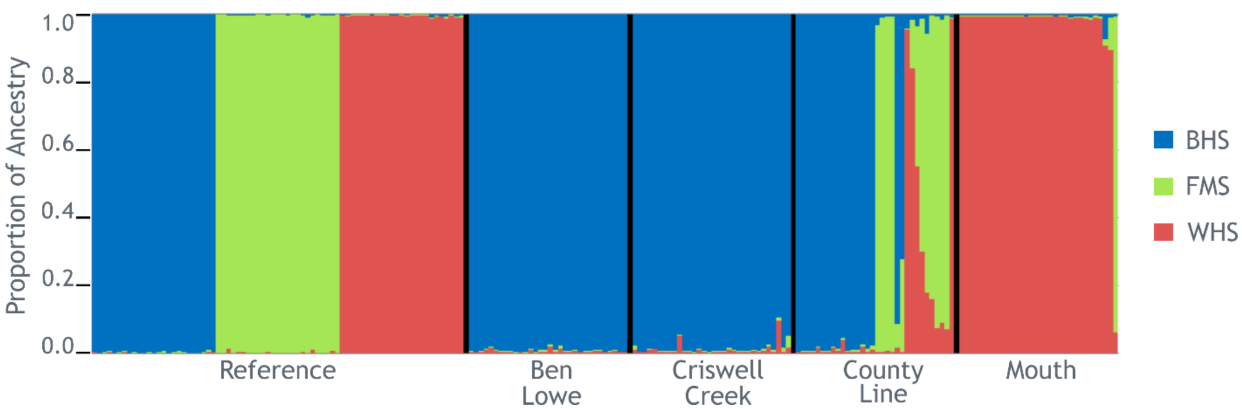

Figure 2.14. Longitudinal larval catostomid genetic sampling results for the 2018 study. Displayed is the structure analysis of species admixture for larval samples collected from four different sites (displayed from upstream to downstream – left to right) on Roubideau Creek in 2018. Colors represent each species' genetic contribution (based on six microsatellite markers) in a fish specimen, and each column of the chart displays the results for a single fish. BHS = Bluehead Sucker *C. discobolus*, FMS = Flannelmouth Sucker *C. latipinnis*, and WHS = White Sucker *C. commersonii*.

Flannelmouth Sucker, and two native hybrids), and 31% had non-native genetics. At the two higher sites (Criswell Creek and Ben Lowe Trail, 19.6 and 23.9 miles from mouth respectively), larvae were all Bluehead Sucker except for one Bluehead x Flannelmouth sucker hybrid and two Bluehead x White sucker hybrids collected at the Criswell Creek site. However, the ancestries of these hybrid larvae were largely attributed to Bluehead Sucker, indicating that the non-native parent in both cases were likely back-crossed hybrids rather than pure individuals.

Though we only have two years of specific longitudinal genetic sampling data from two different sets of sites (2018 was an anomalously dry year, precluding sampling in Cottonwood Creek), it does appear likely that native suckers, particularly Bluehead Suckers, are willing to travel farther upstream than non-native suckers as hypothesized. All four years of sampling at Potter Creek associated with the non-native exclusion study lend additional credence to this hypothesis as we collected very few adult or larval suckers with non-native genetics there. Future repeated sampling at these locations, under different hydrologic conditions, is needed to verify this apparent spatial stratification. If this phenomenon does occur reliably under differing hydrologic conditions, it may benefit the species in the long term, resulting in natural insulation from hybridization in non-perennial tributary systems. However, it also highlights the danger that structures like diversions and hanging culverts present to the species by limiting the potential for spatial stratification.

2.3.5 Spawning tributary fidelity

Roubideau Creek fidelity - We observed high rates of tributary fidelity in the Roubideau Creek spawning population of native suckers. For PIT-tagged fish detected crossing the Roubideau Creek PIA during the spawning period (mid-March through June) in any given year, we found that 69 to 78% of those fish were detected again the following year during the spawning period (Table 2.4). There was not a notable difference between Bluehead and Flannelmouth return rates. Comparing 1-year return rates with survival estimates for native suckers (about 0.8, KGT unpublished data), it seems possible that most surviving suckers return to Roubideau Creek in subsequent years. Returns of native suckers across multiple years decreased by roughly 13-23% per year, depending on species and year. Again, this level of decrease is not dissimilar to annual mortality rates.

In 2016 and 2017, return rates of non-native suckers detected in the previous years (2015 and 2016 respectively - years in which we tagged and released non-native suckers) were also relatively high (Table 2.4). The return rate in 2017 of 2016-detected non-native suckers was similar to the rates for native suckers, but the rate was low (53%) for non-native sucker originally detected in 2015 when our sample size was small. Non-native sucker return rates understandably dropped precipitously in 2018 after we ceased tagging new non-native suckers in 2017, and henceforth culled all non-native individuals that we encountered including those having PIT tags.

We also estimated fidelity rates of returning Roundtail Chub. Overall we PIT-tagged far fewer Roundtail Chub than suckers, but we still noted fairly high return rates to Roubideau Creek (Table 2.4). Rates ranged from 75 to 81% returns of PIT tagged Roundtail Chub from one year to the next.

Roubideau Creek spawning fidelity for all three-species as well as for non-native suckers was high during the course of this study. The hydrograph varied widely ranging from near-record low snowpack and flow to far above average. Despite this variability, we saw high return rates to Roubideau in all years for all species (excluding non-natives after culling efforts began). This elevated degree of fidelity inspires confidence in the idea that non-native exclusion could offer a long-term solution to the hybridization issue in the Gunnison River basin, and perhaps in other river systems. Under an exclusion approach, the proportion of native to non-native suckers should remain high as native suckers will return year after year. Furthermore, efforts could potentially be

Table 2.4. Spawning fidelity rates of PIT-tagged native Bluehead (BHS) and Flannelmouth (FMS) suckers, Roundtail Chub (RTC), and all nonnative suckers and hybrid suckers in combination (nonnative) for fish detected crossing the Roubideau Creek passive interrogation array. The “Total” columns indicate the number of unique PIT-tagged fish detected within the spawning season (April-June), and the “Redetections by year” columns display the number and percentage of those unique tagged fish that were redetected during the spawning seasons of the following years.

2015 unique fish detections							2016 unique fish detections					2017 unique fish detections		
	2016		2017		2018			2017		2018			2018	
Total	n	%	n	%	N	%	Total	n	%	n	%	Total	n	%
Bluehead Sucker														
1371	1014	74.0	729	53.2	543	39.6	2656	2067	77.8	1453	54.7	3537	2432	68.8
Flannelmouth Sucker														
385	280	72.7	223	57.9	165	42.9	598	464	77.6	352	58.9	859	636	74.0
Roundtail Chub														
155	116	74.8	91	58.7	72	46.5	177	136	76.8	110	62.1	225	183	81.3
Non-native sucker														
34	18	52.9	12	35.3	4	11.8	117	84	71.8	24	20.5	155	43	27.7

relaxed after several seasons of intense exclusion operations, as non-natives attempting to access the controlled tributary system would be expected to become increasingly scarce.

Tributary fidelity within the Roubideau basin - Our SPR antenna data also suggest that native suckers display spawning fidelity for specific tributary streams within the Roubideau Creek drainage when conditions allow. Overall detections of non-native suckers and Roundtail Chub were low, so we do not make specific tributary fidelity inferences for those species.

In 2016, SPRs were in place near the mouths of Cottonwood and Buttermilk creeks. Out of 536 individual fish detected on the Cottonwood Creek SPR, ≥ 62% of the detected

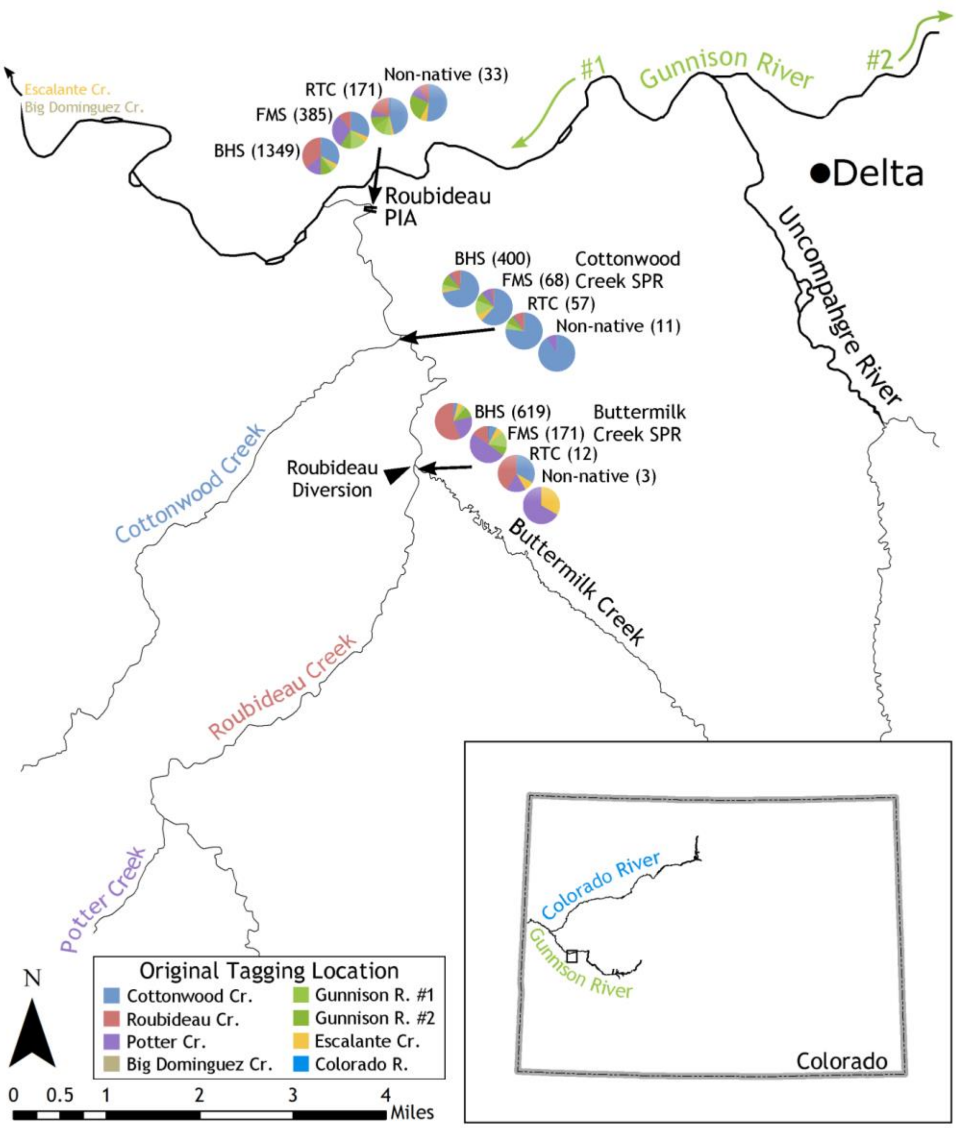

Figure 2.15. Original tagging locations of fish detected in 2016 at the Roubideau Creek passive interrogation array (PIA) and at two submersible PIT readers (SPR) as a proportion of all redetections (pie charts). Detection numbers (in parentheses) are limited to one occurrence of each individual tag. Data reflect tags implanted prior to 2016.

fish of each species were originally tagged in Cottonwood Creek (Figure 2.15). Very small fractions of these fish were originally tagged in other known spawning tributaries, and it should be noted that: 1) many fish tagged in Roubideau Creek were tagged near either the PIA below Cottonwood Creek and thus may have been destined for or returning from Cottonwood Creek, or at the 2015 weir on Roubideau Creek and thus may have been bound for Potter, Roubideau, or more distant spawning locations; 2) that most fish tagged in the Gunnison River were tagged outside of the spawning season, so we can infer little about their spawning tributary fidelity. The 805 individual fish detected in Buttermilk Creek in 2016 were mainly a mixture of fish tagged in Roubideau and Potter creeks. The

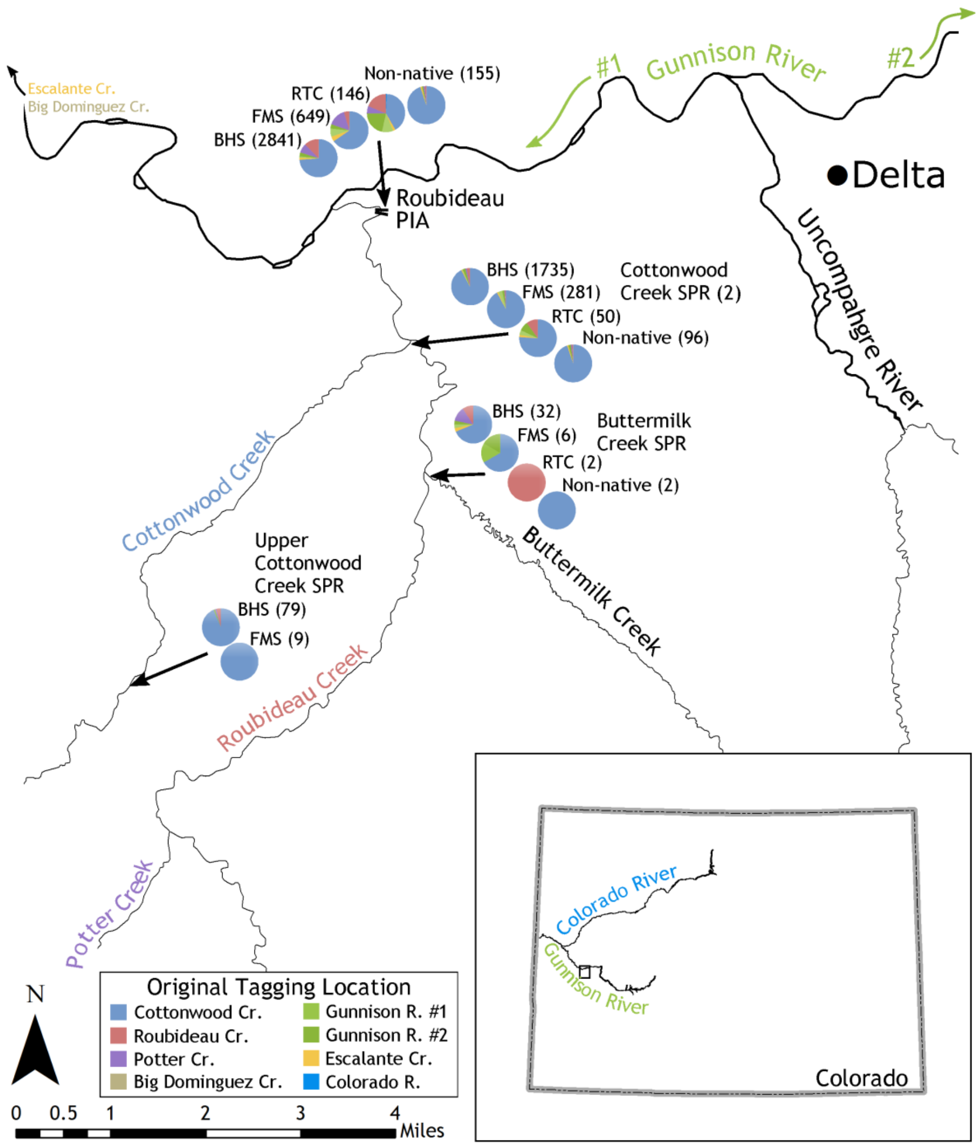

Figure 2.16. Original tagging locations of fish detected in 2017 at the Roubideau Creek passive interrogation array (PIA) and at two submersible PIT readers (SPR) as a proportion of all redetections (pie charts). Detection numbers (in parentheses) are limited to one occurrence of each individual tag. Data reflect tags implanted prior to 2017.

diversion in Roubideau Creek is suspected to have blocked the migration of many of these fish, which instead used Buttermilk Creek as the nearest alternative tributary.

In 2017, two SPRs were in place near the mouth of Cottonwood Creek, one was in place in Cottonwood Creek 8 miles upstream from its mouth, and one was in place near the mouth of Buttermilk Creek. The two Cottonwood Creek SPRs near the mouth detected a total of 2,162 individual PIT-tagged fish, the vast majority of which were originally tagged in Cottonwood Creek (mostly during weir operations in 2016; Figure 2.16). By comparison, we reported actual annual return rates to Cottonwood Creek between 61 and 71% in 2016 and 2017

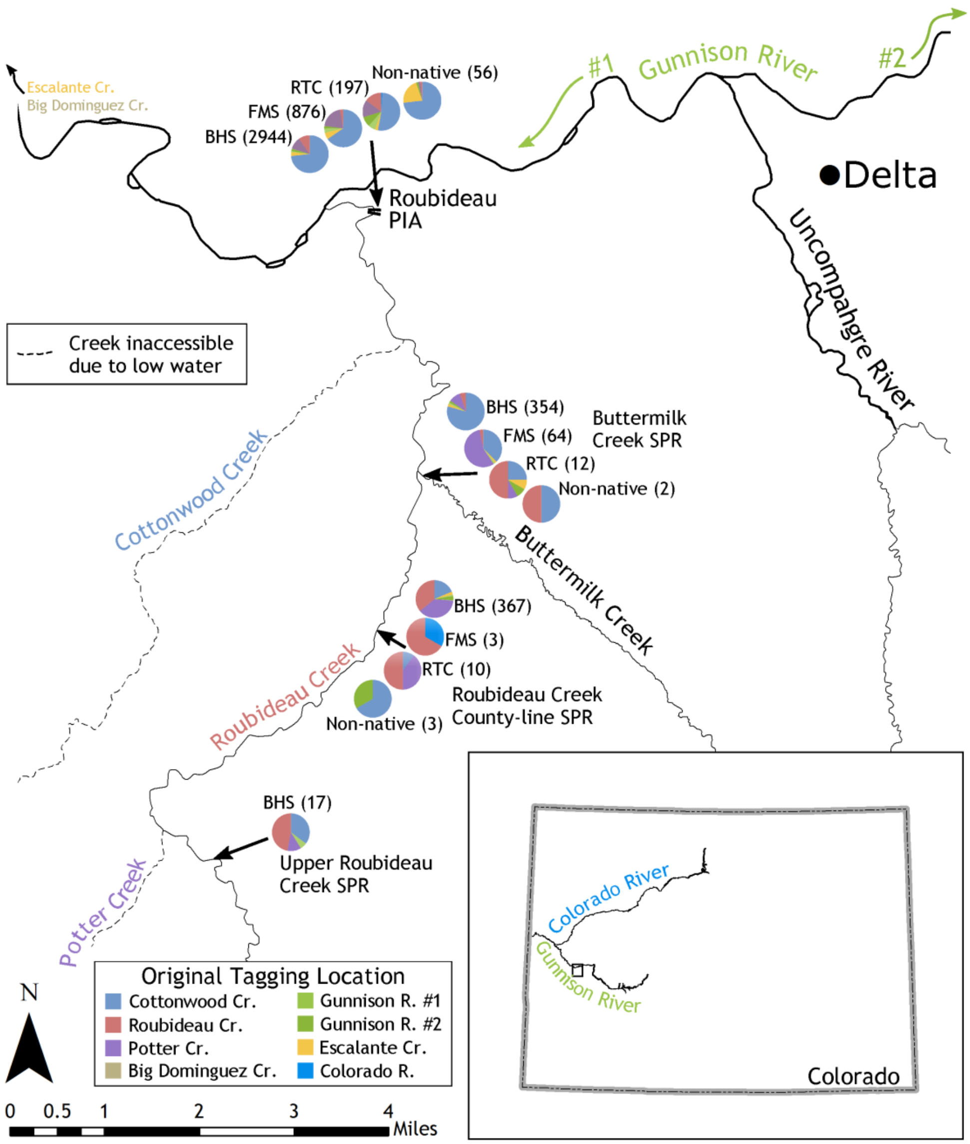

Figure 2.17. Original tagging locations of fish detected in 2018 at the Roubideau Creek passive interrogation array (PIA) and at two submersible PIT readers (SPR) as a proportion of all redetections (pie charts). Detection numbers (in parentheses) are limited to one occurrence of each individual tag. Data reflect tags implanted prior to 2018.

in a publication on fish usage of Cottonwood Creek (Hooley-Underwood et al. 2019). On the upstream antenna in Cottonwood Creek, far fewer fish were detected (n = 88) but nearly all were originally tagged in Cottonwood Creek. Detections on this antenna corroborate longitudinal larval genetic results, in that all detected fish moving this far upstream were native suckers and were mostly Bluehead Suckers. Far fewer individuals (n = 42) were detected on the Buttermilk Creek SPR in 2017 than in 2016 indicating that in the absence of the diversion in Roubideau Creek (removed prior to the 2017 spawning season) tagged fish largely elected to go elsewhere. The majority of Bluehead and Flannelmouth suckers that were detected in Buttermilk Creek were originally tagged in Cottonwood Creek.

In 2018, due to the exceptionally low snowpack and resulting low (Potter Creek) or absent (Cottonwood Creek) flows, SPRs were placed only in Roubideau and Buttermilk Creeks. Despite the low flow conditions, similar numbers of fish were detected entering Roubideau Creek via the PIA as in the previous year. However, only a relatively small number of these fish were detected elsewhere in the system (Figure 2.17). The most detections (n = 432) occurred in Buttermilk Creek, where 79% of Bluehead Suckers were originally tagged in Cottonwood Creek. These same fish comprised 69% of all suckers detected in Buttermilk Creek. Only 64 Flannelmouth Suckers were detected here, 60 of which were originally tagged in Potter Creek or Cottonwood Creek, both inaccessible to large spawning fish in 2018. At the Roubideau Creek County Line SPR (8.6 miles upstream), 383 fish were detected. Again, the majority were Bluehead Suckers, but most were originally tagged in Roubideau and Potter creeks. Only three Flannelmouth Suckers were detected at that location. Farther upstream in Roubideau Creek, above the confluence of Potter and Roubideau creeks, just 17 Bluehead Suckers were detected. Because numerous fish were detected on the Roubideau Creek PIA, but low numbers were detected elsewhere in the basin, we infer that the majority of tagged fish, when faced with such extreme low flow conditions, remained in Roubideau Creek between the PIA and the County Line SPR site. Especially evident were the lack of detections of Cottonwood Creek-tagged fish in the system. Data from the PIA suggests that few fish exited the system before the week of April 20, so these fish likely spawned in this section of Roubideau Creek. While returns of tagged fish to Roubideau Creek itself remained high, it appears the drought conditions heavily impacted patterns of specific tributary fidelity. For this reason, it may be desirable to focus future non-native exclusion efforts on larger tributary networks as opposed to individual spawning streams.

In all years of this fidelity study, we did detect low numbers of fish in tributaries different than those in which they were originally tagged. Likewise, we did detect fish in all three years of study that were tagged in entirely different tributary systems (e.g. Escalante Creek) or in a different river (i.e. the Colorado River). These few wandering fish may be important for maintaining gene-flow between tributary spawning populations.

2.4 Conclusions and Recommendations

Effectiveness of weir projects - Having completed fish weir operations over three spawning seasons, it is apparent that the primary challenge encountered in such operations is maintaining the integrity of the picket weir and traps during spates of high runoff and the accompanying debris. We were never able to fully control a spawning run. Despite the difficulties encountered, we were able to intercept large numbers of migrating suckers, which allowed us to decrease the overall number of non-native suckers in the spawning mix as well as collect detailed data on native sucker spawning ecology. We did see, as evidenced by larval genetics, that larval species composition reflected that of the adult population in both streams with the exception of Cottonwood Creek in 2016. While the 2016 results are troubling, overall it does appear that we can affect the species composition of suckers produced in Cottonwood Creek by denying non-native suckers access to the stream. Additionally, we observed very high rates of tributary fidelity to Roubideau Creek, and to tributaries within the Roubideau drainage. This is encouraging in that weir operations could be viable long-term tools for protecting native sucker population components from hybridization.

The picket weir is an effective way to intercept large numbers of non-native and hybrid suckers in order to remove them from the population. However, the design used in this study proved to demand a great deal of manpower simply for physical maintenance. A likely better alternative would be a resistance board weir (Stewart 2003, Favrot and Kwak 2016), a design which permits debris loads to temporarily submerge the floating downstream end of the PVC weir pickets to allow debris to pass over, after which the weir regains buoyancy. Such weirs were originally designed to intercept Alaskan salmon runs and thus could be operable in streams far larger than Cottonwood Creek. Areas near the mouth of Roubideau Creek could accommodate this design, and if placed in Roubideau Creek there is much more certainty about the timing of installation, given the narrow window of earliest dates over which we've observed PIT-tagged fish crossing the Roubideau PIA.

Another major observation from this study that supports the idea of a Roubideau Creek resistance-board weir stems from the drought conditions observed in 2018. While fish returned to Roubideau Creek in large numbers in 2018, they were unable to spawn in Cottonwood or Potter Creeks, and SPR data indicated that spawning may have been concentrated in the lower reaches of Roubideau Creek. Not only would the Cottonwood weir, had it been in place, never have seen water let alone fish, hybridization rates may have been greatly amplified due to the decreased potential for spatial stratification between native and non-native suckers. For this reason, it is especially important to move the weir to the mouth of Roubideau Creek so that progress can be steadily maintained despite the highly variable climatic conditions in the Southwest.

Native fish ecology - These native suckers are very opportunistic in taking advantage of available spawning habitat. This was demonstrated by the rapid entry of Bluehead Suckers into Cottonwood Creek in 2015 when heavy rains initiated stream flow at the mouth, and apparently by the paucity of Flannelmouth Suckers in that same event. The latter presumably had accomplished spawning in the mainstem of Roubideau Creek or Buttermilk Creek, another tributary accessible below the diversion on Roubideau Creek. Then, in 2016 and 2017, with ample streamflow, thousands of Bluehead Suckers and hundreds of Flannelmouth Suckers used Cottonwood Creek. Renewed access to points upstream of the Roubideau irrigation diversion didn't appear to reduce the numbers of spawning adult suckers seeking to use spawning habitat in Cottonwood Creek.

We stress that these large spawning runs in Cottonwood Creek are in a stream that does not flow at the mouth during most of the year, a circumstance also observed by Compton et al. (2008) in a southern Wyoming drainage for all of the three-species. Streams such as these would be likely to receive little attention or consideration under ordinary circumstances from fish managers, yet they may be heavily used for certain aspects of native fish life history. As such, it is important to view such streams through a new lens, recognizing the possibility that even snowmelt-driven intermittent streams could be very important to the conservation of the three-species fishes.

Specific recommendations – Below we offer a list of specific management actions that our findings suggest may improve the situation of the three-species in the Gunnison River Basin, and potentially range-wide.

1) Install and operate a resistance board weir near the mouth of Roubideau Creek. If this style of weir is more manageable under different flows and when faced with high debris loads, it may provide a better tool to more completely control spawning access to the Roubideau Creek drainage tributaries. This is especially true in drought years when fish may not be able to access smaller streams such as Cottonwood Creek.

2) Identify other tributaries to three-species inhabited rivers that may be suitable for weir operations. Suitable tributaries should be used regularly for spawning by substantial numbers of native suckers, be largely uninhabited by adult suckers outside of the spawning season, and be accessible enough to allow for construction of weirs, and round-the-clock operation during spawning seasons. Ideally, a set of candidate streams should be identified in each of the major Western Slope river basins in Colorado.

3) Identify barriers on potential spawning streams that may be preventing spatial stratification of native and non-native suckers as seen with the Roubideau Creek diversion. If possible, removal of such barriers may aid in lowering hybridization rates. We do however note that in rare cases, barriers may be important for conserving genetically pure sucker populations. For example, a genetically pure population of both Bluehead and Flannelmouth suckers exists in Escalante Creek (a Gunnison River tributary downstream of Roubideau Creek) above a large rock and concrete diversion that seems to be a complete fish barrier. Despite no connection to the Gunnison River, these fish reproduce and persist in this small stream, and so far, White or Longnose sucker have not invaded. While a few hybridized suckers have been sampled within this stream above the barrier, it is likely that such fish were the progeny of a few invaders during a year in which the diversion was washed out and subsequently rebuilt – a circumstance revealed to us by the ranch manager. In this instance, the barrier is preventing further hybridization within this population. Before any barrier is removed, the upstream population should be thoroughly sampled to ensure that a genetically pure, isolated population is not present.

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Appendix A: Sampling sites and occasions.

A randomly selected survey site on the Little Snake River in Moffatt County, Colorado.

Appendix Table A.1. Summary of the three-species, White Sucker, and select sucker hybrids detected at sites sampled from 2012 through 2017. Sites were spatially balanced from 2012 – 2014, but selected with investigator input from 2015 - 2017. SITE codes describe site type: “I” = intermittent, “P” = perennial, and “H” = historic. A “+” indicates that species or hybrid was detected at the site and a “-” indicates it was not. Area is the CPW Field Operations area.

SITE	RTC	FMS	BHS	FXB	WHS	WXF	WXB	Area	Date	Stream
I002	-	-	+	-	-	-	-	7	4/18/12	Kannah Creek
I005	-	+	-	-	-	-	-	6	5/7/12	Douglas Creek
I007	-	-	-	-	-	-	-	7	5/31/12	Dry Hollow Creek
I011	-	-	-	-	-	-	-	6	5/8/12	Cottonwood Creek
P001	-	-	-	-	+	-	-	15	9/26/12	Piedra River #1
P002	-	-	-	-	-	-	-	18	4/17/12	Spring Creek E Fork
P004	-	-	+	-	-	-	-	15	7/23/12	Cherry Creek
P005	-	-	-	-	-	-	-	6	5/9/12	Slater Creek #2
P006	-	-	-	-	-	-	-	18	5/10/12	La Fair Creek
P009	-	-	+	-	+	-	-	8	6/20/12	Roaring Fork #1
P010	-	-	-	-	-	-	-	18	6/15/12	Escalante Creek
P012	-	-	-	-	-	-	-	6	6/25/12	Spring Creek W Fork
P014	-	-	-	-	-	-	-	18	6/18/12	Big Bear Creek
P015	-	-	-	-	+	+	-	10	6/27/12	Trout Creek #1
P018	-	-	-	-	-	-	-	10	6/27/12	Mill Creek
P020	-	-	-	-	+	-	-	10	9/13/12	Elk River #1
P022	-	+	+	-	+	+	+	16	7/17/12	Muddy Creek
P025	-	-	-	-	-	-	-	6	6/28/12	Vermillion Creek
P026	-	-	-	-	-	-	-	16	8/3/12	Coal Creek
P029	+	+	+	-	+	+	+	6	9/7/12	Little Snake River #1
P032	-	-	-	-	+	-	-	8	9/19/12	Eagle River #1
P033	-	-	-	-	-	-	-	15	7/24/12	Spring Creek
P034	-	-	-	-	-	-	-	8	9/20/12	Crystal River #2
P037	-	-	-	-	-	-	-	15	7/26/12	M. Fork Piedra R.
P038	-	-	-	-	-	-	-	7	8/1/12	Gill Creek
P045	-	-	-	-	-	-	-	16	9/4/2	Alfalfa Run
P046	-	-	-	-	-	-	-	18	9/28/12	Burro Creek
P047	-	-	-	-	-	-	-	6	10/3/12	Beaver Creek Big
P048	-	+	-	-	+	+	-	6	9/6/12	Milk Creek
I020	-	-	-	-	-	-	-	6	5/21/13	Sand Wash
I030	-	-	-	-	-	-	-	7	5/30/13	Bull Creek
I031	-	-	-	-	-	-	-	6	5/20/13	Douglas Creek
I038	-	-	-	-	-	-	-	6	6/18/13	Fourmile Creek
I052	-	-	-	-	-	-	-	6	6/17/13	Little Beaver Creek
I057	-	-	-	-	-	-	-	6	6/20/13	Deep Channel Creek
P051	-	-	-	-	+	-	-	16	7/2/13	Leroux Creek

Appendix Table A.1. Continued.

SITE	RTC	FMS	BHS	FXB	WHS	WXF	WXB	Area	Date	Stream
P053	-	+	+	-	+	+	-	6	6/17/13	Milk Creek
P054	-	+	+	+	+	-	-	15	7/30/13	Rio Blanco #1
P056	-	-	-	-	+	-	-	10	6/19/13	Trout Creek #1
P062	-	-	-	-	-	-	-	15	5/14/13	McElmo Creek
P063	+	+	+	-	+	-	-	6	7/24/13	Little Snake R #1
P064	-	-	-	-	-	-	-	6	6/4/13	Steward Gulch Mid Fk
P068	-	-	-	-	+	-	-	6	5/22/13	Fortification Cr
P069	-	-	+	-	-	-	-	18	7/12/13	West Creek
P070	-	-	-	-	-	-	-	18	5/28/13	Loutsenhizer Arroyo
P072	-	-	-	-	+	-	-	6	6/18/13	Elkhead Creek #3
P074	-	-	-	-	-	-	-	6	6/4/13	Fawn Creek
P076	-	-	-	-	-	-	-	9	6/19/13	Un-named
P078	-	-	-	-	-	-	-	8	7/26/13	Eagle River #2
P079	-	-	-	-	-	-	-	6	5/23/13	Piceance Creek
P080	-	-	-	-	-	-	-	18	5/16/13	Cottonwood Creek
P081	+	+	+	-	-	-	-	18	6/5/13	Escalante Cr
P083	-	-	-	-	+	-	-	15	7/11/13	Stollsteimer Creek
P084	-	-	-	-	-	-	-	6	7/25/13	Deer Creek
P088	-	-	-	-	-	-	-	15	10/28/13	Mancos River #2
P089	+	+	+	-	-	-	-	6	7/24/13	Little Snake R #1
P093	-	-	+	-	-	-	-	7	6/3/13	Divide Creek West
P096	-	-	-	-	-	-	-	18	8/28/13	Peach Valley
P099	-	-	-	-	-	-	-	7	9/3/13	Salt Creek East
P101	-	-	+	-	+	-	+	15	7/31/13	Piedra River #1
P106	-	-	+	-	+	-	-	15	8/1/13	Spring Creek
P109	-	-	+	-	-	-	-	15	7/9/13	Dolores River West Fk
P112	-	-	-	-	-	-	-	15	10/28/13	Mancos River #2
P117	-	-	-	-	+	-	-	18	7/2/13	Wise Creek
P124	-	+	-	-	-	-	-	6	7/23/13	Piceance Creek
P150	-	-	-	-	-	-	-	15	8/1/13	Turkey Creek
P159	-	-	-	-	-	-	-	10	8/13/13	Foidel Creek
P160	-	-	-	-	-	-	-	10	8/14/13	Willow Cr #2
P161	-	-	-	-	-	-	-	7	9/6/13	Salt Creek
P163	-	-	-	-	-	-	-	18	8/29/13	Dry Creek
P166	-	-	-	-	+	-	+	10	8/13/13	Fish Creek #1 (Milner)
H001	-	-	+	-	-	-	-	15	6/20/14	Yellowjacket Canyon
H002	-	-	+	-	-	-	-	15	7/22/14	Rio Blanco #1
H003	-	-	-	+	-	-	-	7	5/8/14	East Creek
H004	-	-	-	-	-	-	-	7	5/22/14	Dry Owens Creek
H005	-	-	-	-	-	-	-	15	8/5/14	Dolores River #4
H006	-	-	-	+	-	-	-	10	6/24/14	Elkhead Creek #1
H009	+	+	+	+	+	-	-	7	11/12/14	Badger Wash

Appendix Table A.1. Continued.

SITE	RTC	FMS	BHS	FXB	WHS	WXF	WXB	Area	Date	Stream
H010	-	-	-	-	-	-	-	6	5/23/14	Piceance Creek
H012	-	-	-	-	+	-	-	18	5/9/14	Montrose Arroyo
H013	+	-	-	-	-	-	-	15	10/22/14	Mancos River #2
H014	-	-	-	-	-	-	-	6	7/15/14	Milk Creek
H015	-	-	+	-	-	-	-	18	7/8/14	Cimarron R, Little
H016	-	-	+	-	-	-	-	15	6/3/14	Mancos River #3
H017	-	-	-	-	-	-	-	7	7/16/14	Divide Creek, East
H018	-	-	+	-	-	-	-	18	5/14/14	Tabeguache Creek
H019	-	-	-	-	-	-	-	6	7/29/14	Miller Creek
H020	-	-	-	+	-	-	-	7	11/21/14	Mack Wash
H023	-	-	-	-	-	-	-	7	5/15/14	Hightower Creek
H026	-	-	+	-	+	-	-	7	7/7/14	Buzzard Creek #1
H027	+	+	+	+	-	-	+	18	6/30/14	San Miguel R #1
H028	-	-	+	-	-	-	-	18	5/30/14	Naturita Creek
H029	-	-	+	-	-	-	-	8	7/22/14	Dry Fork Cabin Creek
H031	-	-	+	-	-	-	-	7	9/8/14	Roan Creek
H032	-	-	+	-	-	-	-	7	7/9/14	Buzzard Creek #2
H035	-	-	-	-	-	-	-	10	9/25/14	Elk River #1
H036	-	-	-	-	+	-	+	15	7/23/14	Rock Creek
H037	-	-	-	-	-	-	-	15	6/18/14	Lightner Creek #1
H038	-	-	-	-	+	+	+	6	9/24/14	Williams Fk Y
H039	-	-	-	-	+	-	-	15	7/23/14	Piedra River #1
H041	-	-	-	-	-	-	-	6	6/25/14	Milk Creek
H043	-	-	+	-	-	-	-	18	6/11/14	Potter Creek
H044	+	+	+	+	+	-	-	7	9/8/14	Roan Creek
H045	+	+	-	-	+	+	+	7	11/13/14	Persigo Wash
H047	+	+	+	-	-	-	-	7	11/13/14	Salt Creek
H048	-	+	+	-	-	-	-	18	8/4/14	San Miguel R #1
H050	-	-	-	-	-	-	-	9	9/10/14	Rock Creek
H051	-	-	-	-	-	-	-	18	7/10/14	Cow Creek
H056	+	+	+	+	+	+	+	6	9/22/14	Little Snake R #1
H057	+	+	+	+	+	+	-	7	11/12/14	Salt Wash, Big
H058	-	-	-	-	-	-	-	6	7/14/14	Piceance Creek
H059	-	-	+	-	-	-	-	15	8/6/14	Yellowjacket Canyon
H060	+	-	-	-	+	-	+	7	7/25/14	Rifle Creek
H062	-	-	+	-	-	-	-	15	10/1/14	Long Hollow Creek
H063	-	-	+	-	+	-	+	6	9/26/14	Milk Creek
H064	+	-	-	-	-	-	-	15	10/22/14	Mancos River #2
H066	-	-	+	-	-	-	-	18	7/31/14	Tabeguache Creek
H067	-	-	-	-	-	-	-	6	7/29/14	Vermillion Creek
H068	-	-	-	-	+	-	-	7	7/28/14	Garfield Creek
H069	-	-	+	+	+	-	+	18	8/21/14	Cimarron River

Appendix Table A.1. Continued.

SITE	RTC	FMS	BHS	FXB	WHS	WXF	WXB	Area	Date	Stream
H070	+	+	+	-	-	-	-	18	8/18/14	Escalante Creek
H071	-	-	-	-	-	-	-	18	10/23/14	Dallas Creek
H073	+	+	+	-	+	+	+	18	7/18/14	Dry Creek
H074	-	-	+	-	-	-	-	7	8/19/14	Grove Creek
H075	-	-	-	-	-	-	-	15	8/5/14	Cherry Creek
H076	+	+	+	-	+	+	-	7	9/9/14	Plateau Creek #1
H079	-	-	-	-	-	-	-	15	9/30/14	Junction Cr #1
H002	-	-	+	-	-	-	-	15	9/30/15	Rio Blanco #1
H016	-	-	+	-	-	-	-	15	8/25/15	Mancos River #3
H018	-	-	+	-	-	-	-	18	4/22/15	Tabeguache Cr
H018	-	+	+	-	-	-	-	18	7/23/15	Tabeguache Cr
H018	-	-	+	-	-	-	-	18	9/11/15	Tabeguache Cr
H032	-	+	+	-	-	-	-	7	7/28/15	Buzzard Creek #2
H041	+	+	+	-	+	-	-	6	10/7/15	Milk Creek
H043	-	-	+	-	-	-	-	18	7/29/15	Potter Creek
H056	+	+	+	+	+	+	+	6	8/20/15	Little Snake R #1
H058	-	-	+	-	-	-	-	6	8/19/15	Piceance Creek
H073	-	-	-	-	+	-	-	18	9/28/15	Dry Creek
H081	-	+	+	-	-	-	+	18	8/17/15	Naturita Creek
H112	+	-	+	-	+	+	-	18	4/28/15	Dominguez Creek, Big
H112	+	-	-	-	-	-	-	18	8/24/15	Dominguez Creek, Big
H114	-	-	+	-	-	-	-	7	9/29/15	Owens Creek
H126	-	+	-	-	-	-	-	6	10/26/15	Douglas Creek
H142	+	+	+	-	-	-	-	18	4/15/15	Tabeguache Cr
H142	+	+	+	-	-	-	-	18	4/22/15	Tabeguache Cr
H142	+	+	+	-	-	-	-	18	6/3/15	Tabeguache Cr
H142	-	+	-	-	-	-	-	18	9/11/15	Tabeguache Cr
H209	-	-	+	-	+	-	+	6	9/23/15	Williams Fk Yampa
H278	-	+	+	-	-	-	-	18	4/14/15	Potter Creek
H278	+	+	-	-	-	-	-	18	4/21/15	Potter Creek
H278	-	-	+	-	-	-	-	18	4/30/15	Potter Creek
H278	+	+	+	-	-	-	-	18	5/14/15	Potter Creek
H278	+	+	+	+	-	-	-	18	6/2/15	Potter Creek
H278	+	-	+	-	+	-	-	18	6/17/15	Potter Creek
H303	-	+	+	-	+	-	-	6	10/7/15	Milk Creek
H311	-	+	+	-	-	-	-	6	8/19/15	Piceance Creek
H341	+	+	+	+	-	-	-	18	8/6/15	Escalante Creek
H701	+	+	+	+	+	+	+	18	8/27/15	Roubideau Cr
H702	+	+	+	+	+	+	+	18	5/6/15	Escalante Creek
H702	+	+	+	+	+	+	+	18	5/20/15	Escalante Creek
H703	+	+	+	-	-	-	-	18	8/31/15	Escalante Creek
H705	+	-	+	-	+	-	+	18	5/12/15	Cottonwood Creek

Appendix Table A.1. Continued.

SITE	RTC	FMS	BHS	FXB	WHS	WXF	WXB	Area	Date	Stream
H705	+	-	+	-	-	-	-	18	5/22/15	Cottonwood Creek
H705	+	+	+	-	-	-	-	18	6/18/15	Cottonwood Creek
H706	+	+	+	-	-	-	-	6	9/2/15	Little Snake R. #1
H707	-	-	+	-	-	-	-	18	4/22/15	Tabeguache Cr
H707	-	-	-	-	-	-	-	18	6/3/15	Tabeguache Cr
H001	+	+	-	-	-	-	-	15	9/29/16	Yellowjacket Canyon
H004	-	-	+	-	+	-	-	7	6/28/16	Owens Creek, Dry
H016	-	-	+	-	-	-	-	15	6/29/16	Mancos River
H018	-	+	+	-	-	-	-	18	6/2/16	Tabeguache Creek
H018	-	+	+	-	-	-	-	18	8/2/16	Tabeguache Creek
H018	-	+	+	-	-	-	-	18	9/21/16	Tabeguache Creek
H036	+	+	+	-	-	-	-	15	11/7/16	Rock Creek
H053	+	-	+	-	-	-	-	15	9/27/16	Yellowjacket Canyon
H056	+	+	+	-	+	-	-	6	9/8/16	Little Snake River
H058	-	-	+	-	-	-	-	6	6/22/16	Piceance Creek
H058	-	+	+	-	-	-	-	6	9/7/16	Piceance Creek
H068	-	-	+	-	+	-	-	7	9/6/16	Garfield Creek
H073	-	+	+	-	+	-	-	18	7/27/16	Dry Creek
H076	+	+	+	-	+	+	+	7	9/14/16	Plateau Creek
H080	+	+	-	-	-	-	-	15	9/26/16	Yellowjacket Canyon
H081	-	+	+	-	-	-	+	15	8/3/16	Naturita Creek
H082	-	-	+	-	-	-	-	15	10/13/16	Divide Creek,West
H085	+	+	+	-	-	-	-	15	9/28/16	Yellowjacket Canyon
H093	+	-	+	-	-	-	-	15	6/29/16	Weber Canyon Creek
H093	+	-	+	-	-	-	-	15	7/19/16	Weber Canyon Creek
H112	-	-	-	-	-	-	-	18	4/7/16	Big Dominguez Creek
H114	-	-	-	-	-	-	-	7	6/28/16	Owens Creek
H125	-	-	+	-	-	-	-	7	10/12/16	Divide Creek, West
H187	+	+	+	-	-	-	-	15	9/28/16	Yellowjacket Canyon
H188	-	+	+	-	+	+	+	7	9/14/16	Plateau Creek
H258	-	-	-	-	+	-	-	7	9/6/16	Garfield Creek
H262	+	-	-	-	-	-	-	18	6/1/16	Roubideau Creek
H278	+	+	+	-	-	-	-	18	5/3/16	Potter Creek
H278	-	+	+	-	-	-	-	18	5/11/16	Potter Creek
H278	+	+	+	-	-	-	-	18	5/17/16	Potter Creek
H278	+	+	+	+	-	-	-	18	5/25/16	Potter Creek
H278	-	-	-	-	-	-	+	18	6/1/16	Potter Creek
H278	+	+	+	+	-	-	-	18	9/29/16	Potter Creek
H311	-	+	-	-	-	-	-	6	6/23/16	Piceance Creek
H341	+	+	+	+	-	-	-	18	8/30/16	Escalante Creek
H354	+	+	+	+	-	+	+	7	10/13/16	Divide Creek, West
H702	-	+	+	+	+	+	+	18	5/5/16	Escalante Creek

Appendix Table A.1. Continued.

SITE	RTC	FMS	BHS	FXB	WHS	WXF	WXB	Area	Date	Stream
H703	+	+	+	-	-	-	-	18	7/28/16	Escalante Creek
P080	-	-	-	-	-	-	-	18	5/10/16	Cottonwood Creek
H004	-	-	-	-	-	-	-	7	6/15/17	Owens Creek, Dry
H018	+	+	+	-	-	-	-	18	5/30/17	Tabeguache Cr
H018	-	-	-	-	-	-	-	18	7/17/17	Tabeguache Cr
H029	-	-	-	-	-	-	-	8	7/12/17	Dry Fork Cabin Cr
H032	-	+	+	-	-	-	-	7	7/5/17	Buzzard Creek
H058	-	+	-	-	-	-	-	6	5/23/17	Piceance Creek
H058	-	+	+	-	-	-	-	6	10/31/17	Piceance Creek
H061	+	+	+	+	+	+	+	18	6/27/17	Gunnison R. North Fk
H076	+	+	+	-	-	-	-	7	6/20/17	Plateau Creek
H076	-	+	+	-	-	-	-	7	7/10/17	Plateau Creek
H081	-	-	+	-	-	-	-	18	5/25/17	Naturita Creek
H093	+	-	+	-	-	-	-	15	6/5/17	Weber Canyon Cr
H093	-	-	+	-	-	-	-	15	6/13/17	Weber Canyon Cr
H093	-	-	+	-	-	-	-	15	6/22/17	Weber Canyon Cr
H093	+	-	+	-	-	-	-	15	6/29/17	Weber Canyon Cr
H093	-	-	+	-	-	-	-	15	8/9/17	Weber Canyon Cr
H093	-	-	+	-	-	-	-	15	9/19/17	Weber Canyon Cr
H114	-	-	+	-	-	-	-	7	6/15/17	Owens Creek
H143	+	+	+	+	+	+	+	18	6/27/17	Gunnison R. North Fk
H144	-	-	+	-	-	-	-	7	7/27/17	Roan Creek
H171	-	-	-	-	-	-	-	18	10/13/17	Roc Creek
H188	-	+	-	-	-	-	-	7	6/20/17	Plateau Creek
H255	-	-	-	-	-	-	-	6	10/30/17	Yellow Creek
H268	-	-	+	-	-	-	-	7	4/26/17	Kannah Creek
H278	-	+	-	-	-	-	-	18	3/21/17	Potter Creek
H278	-	-	+	-	-	-	-	18	3/28/17	Potter Creek
H278	-	+	-	-	-	-	-	18	4/4/17	Potter Creek
H278	-	+	+	-	-	-	-	18	4/11/17	Potter Creek
H278	-	+	+	-	-	-	-	18	4/18/17	Potter Creek
H278	-	+	+	-	-	-	-	18	4/24/17	Potter Creek
H278	-	+	+	-	-	-	-	18	5/1/17	Potter Creek
H278	+	+	+	+	-	-	-	18	5/8/17	Potter Creek
H278	-	+	+	-	-	-	+	18	5/10/17	Potter Creek
H278	+	+	+	+	+	+	+	18	5/16/17	Potter Creek
H278	+	+	+	+	-	-	+	18	5/22/17	Potter Creek
H278	+	-	+	-	-	-	+	18	5/31/17	Potter Creek
H278	+	-	+	-	-	-	-	18	6/7/17	Potter Creek
H278	+	+	+	-	-	-	-	18	9/26/17	Potter Creek
H297	+	+	-	-	-	-	-	15	6/21/17	McElmo Creek
H311	-	+	+	-	-	-	-	6	8/30/17	Piceance Creek

Appendix Table A.1. Concluded.

SITE	RTC	FMS	BHS	FXB	WHS	WXF	WXB	Area	Date	Stream
H311	-	+	+	-	-	-	-	6	10/30/17	Piceance Creek
H330	-	-	+	-	-	-	-	18	7/6/17	Buzzard Creek
H341	+	+	+	-	-	-	-	18	6/8/17	Escalante Creek
H341	+	+	+	-	-	-	-	18	10/16/17	Escalante Creek
H342	+	+	+	+	+	+	+	18	6/27/17	Gunnison R. North Fk
H703	+	+	+	-	-	-	-	18	5/24/17	Escalante Creek
H703	+	+	+	-	-	-	-	18	6/8/17	Escalante Creek
H703	+	+	+	-	-	+	-	18	9/20/17	Escalante Creek
P254	-	-	-	-	+	+	-	18	7/26/17	Vermillion Creek

Appendix Table A.2. Sampling conducted under the three-species research program from 2011 – 2017; these sites include some for which Research personnel were assisting Area or Conservation biologists. Site Type column is filled only for sites that were part of dual frame sampling scheme, where "Int" = intermittent stream random site, "Per" = perennial stream random site, and "His" = historically sampled site that was randomly selected. In the species columns, "N" indicates the species was not captured and "Y" indicates the species was captured. Method column entries "2-pass" and "3-pass" refer to removal sampling; "MCR" refers to mark-capture-recapture sampling.

Stream	HUC 12 Unit	Date	Site Type	Method	Sample Gear	FMS	BHS	RTC
			2011					
			Colorado River Basin					
Badger Wash	140100051705	6/1/2011		2-Pass	Backpack	Y	Y	N
West Salt Creek	140100051705	6/1/2011		2-Pass	Backpack	Y	Y	N
West Salt Creek	140100051705	6/1/2011		1-Pass	Backpack	Y	N	N
			Dolores River Basin					
Blue Creek	140300040403	9/21/2011		1-Pass	Backpack	N	N	N
Coyote Wash	140300040804	4/21/2011		Spot Check	Dip nets, Seine	N	N	N
Disappointment Creek	140300020513	9/20/2011		1-Pass	Backpack	N	N	N
Disappointment Creek	140300020510	9/20/2011		1-Pass	Backpack	N	N	N
North Fork Mesa Creek	140300040101	9/21/2011		1-Pass	Backpack	N	N	N
Tabeguache Creek	140300030605	9/21/2011		1-Pass	Backpack	Y	Y	Y
Tabeguache Creek	140300030605	9/21/2011		1-Pass	Backpack	N	Y	Y
Tabeguache Creek	140300030605	9/21/2011		1-Pass	Backpack	N	Y	Y
West Creek	140300040304	9/22/2011		1-Pass	Backpack	N	N	N
			Green River Basin					
		None						
			Gunnison River Basin					
Dry Creek	140200060502	9/16/2011		Spot shock	Backpack	N	N	Y
Dry Fork Escalante Creek	140200050305	9/15/2011		Net Set	Net	Y	Y	N
East Creek	140200050604	5/31/2011		1-Pass	Backpack	N	N	N
Escalante Creek	140200050306	9/15/2011		1-Pass	Backpack	N	N	Y
Escalante Creek	140200050306	9/15/2011		1-Pass	Backpack	Y	Y	Y
Escalante Creek	140200050306	9/15/2011		1-Pass	Backpack	N	N	N
Escalante Creek	140200050306	9/26/2011		1-Pass	Backpack	Y	Y	Y
Escalante Creek	140200050306	9/27/2011		2-Pass	Bank Shocker	Y	Y	Y

Appendix Table A.2. Continued.

Stream	HUC 12 Unit	Date	Site Type	Method	Sample Gear	FMS	BHS	RTC
Escalante Creek	140200050306	10/3/2011		1-Pass	Bank Shocker	Y	Y	Y
Escalante Creek	140200050306	10/3/2011		2-Pass	Bank Shocker	Y	Y	Y
Gunnison River	140200050505	8/25/2011		MCR	Raft Shocker	Y	Y	Y
Gunnison River	140200050114	8/26/2011		MCR	Raft Shocker	Y	Y	Y
Potter Creek	140200050202	9/14/2011		1-Pass	Backpack	Y	Y	N
Potter Creek	140200050202	9/14/2011		1-Pass	Backpack	Y	Y	N
West Muddy Creek	140200040102	7/26/2011		1-Pass	Backpack	N	Y	N
West Muddy Creek	140200040102	7/26/2011		1-Pass	Backpack	N	Y	N
West Muddy Creek	140200040102	7/26/2011		1-Pass	Backpack	N	Y	N
			San Juan River Basin					
Mancos River	140801070311	11/1/2011		1-Pass	Bank Shocker	Y	Y	N
Mancos River	140801070209	11/2/2011		1-Pass	Bank Shocker	N	Y	Y
Mancos River	140801070201	11/2/2011		1-Pass	Bank Shocker	Y	N	Y
Mancos River	140801070201	11/3/2011		1-Pass	Barge Shocker	Y	Y	Y
McElmo Creek	140802020302	4/12/2011		2-Pass	Barge Shocker	Y	N	Y
McElmo Creek	140802020104	4/12/2011		1-Pass	Barge Shocker	N	Y	N
Moccasin Canyon	140802020208	4/14/2011		1-Pass	Backpack	Y	Y	N
Yellowjacket Canyon	140802020208	4/14/2011		1-Pass	Backpack	Y	Y	N
Yellowjacket Canyon	140802020210	4/15/2011		1-Pass	Backpack	Y	Y	Y
			White River Basin					
Coal Creek	140500050307	5/3/2011		1-Pass	Backpack	Y	N	N
Coal Creek	140500050307	5/3/2011		1-Pass	Backpack	N	N	N
Coal Creek	140500050307	5/26/2011		1-Pass	Bank Shocker, net	Y	Y	N
Coal Creek	140500050307	5/27/2011		1-Pass	Bank shocker, net	Y	Y	N
Coal Creek	140500050307	7/7/2011		Net Set	Trap net	N	N	N
Coal Creek	140500050307	7/7/2011		Net Set	Trap net	Y	Y	N
Coal Creek	140500050307	7/7/2011		Net Set	Trap net	N	N	N
Coal Creek	140500050307	7/8/2011		Net Set	Trap net	Y	Y	N
Coal Creek	140500050307	7/8/2011		Net Set	Trap net	Y	Y	N
Coal Creek	140500050307	7/8/2011		Net Set	Trap net	Y	Y	N
Coal Creek	140500050307	7/13/2011		Net Set	Trap net	Y	Y	N
Coal Creek	140500050307	7/13/2011		Net Set	Trap net	N	N	N
Coal Creek	140500050307	7/13/2011		Net Set	Trap net	N	N	N

Appendix Table A.2. Continued.

Stream	HUC 12 Unit	Date	Site Type	Method	Sample Gear	FMS	BHS	RTC
Coal Creek	140500050307	7/13/2011		Net Set	Trap net	N	N	N
Coal Creek	140500050307	7/14/2011		Net Set	Trap net	N	N	N
Coal Creek	140500050307	7/14/2011		Net Set	Trap Net	N	Y	N
Coal Creek	140500050307	7/14/2011		Net Set	Trap net	Y	N	N
Coal Creek	140500050307	7/15/2011		Net Set	Trap net	Y	N	N
Coal Creek	140500050307	7/15/2011		Net Set	Trap net	N	N	N
Coal Creek	140500050307	7/15/2011		Net Set	Trap net	Y	Y	N
Coal Creek	140500050307	7/19/2011		Net Set	Trap net	N	N	N
Coal Creek	140500050307	7/19/2011		Net Set	Trap net	Y	N	N
Coal Creek	140500050307	7/19/2011		Net Set	Trap net	N	N	N
Coal Creek	140500050307	7/20/2011		Net Set	Trap net	Y	N	N
Coal Creek	140500050307	7/20/2011		Net Set	Trap net	N	Y	N
Coal Creek	140500050307	7/21/2011		Net Set	Trap net	N	Y	N
Coal Creek	140500050307	7/21/2011		Net Set	Trap net	N	N	N
Coal Creek	140500050307	8/2/2011		1-Pass	Bank Shocker	Y	N	N
Coal Creek	140500050307	8/2/2011		1-Pass	Bank Shocker	N	N	N
Coal Creek	140500050307	8/2/2011		1-Pass	Bank Shocker	N	N	N
Crooked Wash	140500050506	5/6/2011		1-Pass	Backpack	Y	N	N
Crooked Wash	140500050506	5/6/2011		1-Pass	Backpack	Y	N	N
Curtis Creek	140500050308	6/24/2011		1-Pass	Backpack	N	N	N
Flag Creek	140500050401	4/13/2011		1-Pass	Backpack	Y	N	N
Flag Creek	140500050401	4/13/2011		1-Pass	Backpack	N	N	N
Flag Creek	140500050401	5/4/2011		1-Pass	Backpack	Y	N	N
Flag Creek	140500050401	5/4/2011		1-Pass	Backpack	N	N	N
Flag Creek	140500050401	5/4/2011		1-Pass	Backpack	N	N	N
Flag Creek	140500050401	5/4/2011		1-Pass	Backpack	N	N	N
Flag Creek	140500050401	5/5/2011		1-Pass	Backpack	N	N	N
Miller Creek	140500050304	5/2/2011		1-Pass	Backpack	N	N	N
Piceance Creek	140500060211	4/14/2011		1-Pass	Backpack	Y	N	N
Piceance Creek	140500060211	4/15/2011		1-Pass	Backpack	Y	N	N
Piceance Creek	140500060211	4/15/2011		1-Pass	Backpack	N	N	N
Piceance Creek	140500060211	6/8/2011		1-Pass	Backpack	Y	N	N
Piceance Creek	140500060211	6/8/2011		1-Pass	Backpack	Y	N	N
Piceance Creek	140500060211	6/8/2011		1-Pass	Backpack	N	N	N
Piceance Creek	140500060211	6/23/2011		1-Pass	Backpack	N	N	N

Appendix Table A.2. Continued.

Stream	HUC 12 Unit	Date	Site Type	Method	Sample Gear	FMS	BHS	RTC
Piceance Creek	140500060211	6/23/2011		1-Pass	Backpack	Y	N	N
West Douglas Creek	140500070205	5/19/2011		1-Pass	Backpack	N	N	N
White River	140500070406	7/12/2011		1-Pass	Boat Shocker	Y	Y	N
White River	140500070406	8/3/2011		3-Pass	Boat Shocker	Y	Y	Y
Yellow Creek	140500070401	5/5/2011		1-Pass	Backpack	Y	N	Y
						Y		N
Yellow Creek	140500070406	5/5/2011		1-Pass	Backpack		N	
			Yampa River Basin					
		None						
			2012					
			Colorado River Basin					
Crystal River	140100040705	9/20/2012	Per	2-Pass	Bank Shocker	N	N	N
Dry Hollow Creek	140100050403	5/31/2012	Int	2-Pass	Backpack	N	N	N
Eagle River	140100030606	9/19/2012	Per	2-Pass	Boat Shocker	N	N	N
Roaring Fork River	140100041003	6/20/2012	Per	1-Pass	Boat Shocker	N	Y	N
			Dolores River Basin					
Big Bear Creek	140300030107	6/18/2012	Per	2-Pass	Backpack	N	N	N
Cabin Canyon	140300020603	4/25/2012	Int	Visual		N	N	N
Dolores River	140300020605	8/28/2012		1-Pass	Seine	N	Y	Y
Dolores River	140300020605	8/29/2012		1-Pass	Seine	N	N	Y
Dolores River	140300021002	8/30/2012		1-Pass	Seine	Y	N	Y
San Miguel River	140300030707	5/24/2012		1-Pass	Boat Shocker	Y	Y	Y
			Green River Basin					
Vermillion Creek	140401090213	6/28/2012	Per	2-Pass	Backpack	N	N	N
			Gunnison River Basin					
Alfalfa Run	140200050105	9/4/2012	Per	1-Pass	Backpack	N	N	N
Burro Creek	140200060102	9/28/2012	Per	2-Pass	Backpack	N	N	N
Coal Creek	140200040306	8/3/2012	Per	2-Pass	Bank Shocker	N	N	N
East Fork Spring Creek	140200060601	4/17/2012	Per	2-Pass	Backpack/Seine	N	N	N
Escalante Creek	140200050306	5/4/2012		1-Pass	Bank Shocker	Y	Y	Y
Escalante Creek	140200050306	5/23/2012		1-Pass	Backpack	Y	Y	Y

Appendix Table A.2. Continued.

Stream	HUC 12 Unit	Date	Site Type	Method	Sample Gear	FMS	BHS	RTC
Escalante Creek	140200050306	6/15/2012	Per	2-Pass	Backpack	N	N	N
Escalante Creek	140200050306	7/12/2012		1-Pass	Seine	N	N	Y
Escalante Creek	140200050306	7/12/2012		1-Pass	Seine	Y	N	Y
Escalante Creek	140200050306	9/24/2012		2-Pass	Bank Shocker	Y	Y	Y
Escalante Creek	140200050306	9/24/2012		2-Pass	Bank Shocker	Y	Y	Y
Gill Creek	140200050702	8/1/2012	Per	2-Pass	Backpack	N	N	N
Kannah Creek	140200050705	4/18/2012	Int	2-Pass	Backpack/Seine	N	Y	N
La Fair Creek	140200050401	5/10/2012	Per	2-Pass	Backpack	N	N	N
Leroux Creek	140200040506	10/4/2012		2-Pass	Backpack	N	N	N
Muddy Creek	140200040401	7/17/2012	Per	2-Pass	Backpack	Y	Y	N
Potter Creek	140200050202	7/12/2012		1-Pass	Seine	Y	N	N
Roubideau Creek	140200050205	7/12/2012		1-Pass	Seine	Y	Y	Y
Roubideau Creek	140200050205	7/12/2012		1-Pass	Seine	Y	N	Y
Roubideau Creek	140200050205	7/12/2012		1-Pass	Seine	Y	N	Y
			San Juan River Basin					
Cherry Creek	140801050107	7/23/2012	Per	2-Pass	Backpack/Seine	N	Y	N
Mancos River	140801070201	9/25/2012		2-Pass	Bank Shocker	N	N	N
Mancos River	140801070201	9/25/2012		1-Pass	Bank Shocker	N	N	Y
Mancos River	140801070201	9/25/2012		1-Pass	Bank Shocker	N	N	N
Mancos River	140801070108	9/25/2012		1-Pass	Bank Shocker	N	N	Y
McElmo Creek	140802020303	4/23/2012		1-Pass	Backpack	Y	Y	Y
McElmo Creek	140802020305	4/23/2012		2-Pass	Barge Shocker	Y	Y	Y
McElmo Creek	140802020303	4/25/2012		1-Pass	Barge Shocker	Y	N	Y
M. Fork Piedra River	140801020102	7/26/2012	Per	2-Pass	Backpack	N	N	N
Piedra River	140801020501	9/26/2012	Per	2-Pass	Bank Shocker	N	N	N
Spring Creek	140801010605	7/24/2012	Per	2-Pass	Backpack	N	N	N
Yellowjacket Canyon	140802020208	4/24/2012		1-Pass	Backpack	N	Y	N
			White River Basin					
Big Beaver Creek	140500050301	10/3/2012	Per	2-Pass	Backpack	N	N	N
Coal Creek	140500050307	5/8/2012		1-Pass	Bank Shocker	N	Y	N
Douglas Creek	140500070504	5/7/2012	Int	2-Pass	Backpack/Seine	Y	N	N
Piceance Creek	140500060211	5/17/2012	His	1-Pass	Backpack	N	N	N
Piceance Creek	140500060211	5/17/2012		1-Pass	Backpack/Seine	N	N	N

Appendix Table A.2. Continued.

Stream	HUC 12 Unit	Date	Site Type	Method	Sample Gear	FMS	BHS	RTC
Piceance Creek	140500060211	6/26/2012	His	2-Pass	Backpack	Y	N	N
Piceance Creek	140500060210	6/26/2012		2-Pass	Backpack/Seine	Y	Y	N
Spring Creek	140500070402	6/25/2012	Per	2-Pass	Backpack/Seine	N	N	N
White River	140500050403	6/5/2012		MCR	Raft Shocker	Y	Y	N
White River	140500070406	6/7/2012		MCR	Raft Shocker	Y	Y	Y
White River	140500070406	6/13/2012		MCR	Raft Shocker	Y	Y	Y
			Yampa River Basin					
Cottonwood Creek	140500010704	5/8/2012	Int	2-Pass	Backpack	N	N	N
Elk River	140500010305	9/13/2012	Per	2-Pass	Bank Shocker	N	N	N
Little Snake River	140500030905	9/7/2012	Per	2-Pass	Backpack/Seine	Y	Y	Y
Milk Creek	140500020106	9/6/2012	Per	2-Pass	Backpack/Seine	Y	N	N
Mill Creek	140500010604	6/27/2012	Per	2-Pass	Backpack	N	N	N
Slater Creek	140500030301	5/9/2012	Per	2-Pass	Backpack	N	N	N
Stinking Gulch	140500020106	9/6/2012		2-Pass	Backpack	Y	N	Y
Stinking Gulch	140500020106	9/6/2012		Net	Seine	Y	N	Y
Trout Creek	140500010506	6/27/2012	Per	2-Pass	Backpack/Seine	N	N	N
			2013					
			Colorado River Basin					
Bull Creek	140100051305	5/30/2013	Int	2-Pass	Backpack	N	N	N
Eagle River	140100030306	7/26/2013	Per	2-Pass	Bank Shocker	N	N	N
East Salt Creek	140100051807	9/3/2013	Per	1-Pass	Backpack	N	N	N
Plateau Creek	140100051310	9/17/2013		2-Pass	Bank Shocker	Y	Y	Y
Plateau Creek	140100051310	9/17/2013		2-Pass	Bank Shocker	Y	Y	Y
Salt Creek	140100051203	9/6/2013	Per	2-Pass	Backpack	N	N	N
Un-Named Creek	140100010701	6/19/2013	Per	2-Pass	Backpack	N	N	N
West Divide Creek	140100050307	6/3/2013	Per	2-Pass	Bank Shocker	N	Y	N
			Dolores River Basin					
Dolores River	140300021005	8/6/2013		Net	Seine, Trammel	N	N	Y
Dolores River	140300021002	8/21/2013		Net	Seine	Y	N	Y
Tabeguache Creek	140300030605	5/29/2013		1-Pass	Bank Shocker	N	Y	Y
Tabeguache Creek	140300030605	5/29/2013		1-Pass	Bank Shocker	N	Y	Y
West Creek	140300040306	7/12/2013	Per	2-Pass	Backpack	N	Y	N

Appendix Table A.2. Continued.

Stream	HUC 12 Unit	Date	Site Type	Method	Sample Gear	FMS	BHS	RTC
West Fork Dolores River	140300020104	7/9/2013	Per	2-Pass	Backpack	N	Y	N
			Green River Basin					
		None						
			Gunnison River Basin					
Cottonwood Creek	140200050204	5/16/2013	Per	2-Pass	Backpack	N	N	N
Dry Creek	140200060504	5/15/2013		2-Pass	Bank Shocker	Y	N	Y
Dry Creek	140200060502	8/29/2013		1-Pass	Backpack	N	N	Y
Dry Creek	140200060502	8/29/2013	Per	2-Pass	Backpack	N	N	N
Escalante Creek	140200050306	5/6/2013		1-Pass	Bank Shocker	Y	Y	Y
Escalante Creek	140200050306	6/5/2013	Per	2-Pass	Bank Shocker	Y	Y	Y
Gunnison River	140200050103	9/26/2013		1-Pass	Raft Shocker	Y	Y	Y
Leroux Creek	140200040505	7/2/2013	Per	2-Pass	Backpack	N	N	N
Loutzenhiser Arroyo	140200060605	5/28/2013	Per	2-Pass	Backpack	N	N	N
Peach Valley Creek	140200050104	8/28/2013	Per	1-Pass	Backpack	N	N	N
Potter Creek	140200050202	5/7/2013		2-Pass	Bank Shocker	Y	Y	Y
Roubideau Creek	140200050203	5/7/2013		2-Pass	Bank Shocker	Y	Y	Y
Uncompahgre River	140200060407	11/1/2013		2-Pass	Bank Shocker	N	N	N
Uncompahgre River	140200060407	11/1/2013		2-Pass	Bank Shocker	N	N	N
Uncompahgre River	140200060407	11/1/2013		2-Pass	Bank Shocker	N	N	N
Uncompahgre River	140200060407	11/1/2013		2-Pass	Bank Shocker	N	N	N
Wise Creek	140200050205	7/2/2013	Per	2-Pass	Backpack	N	N	N
			San Juan River Basin					
Mancos River	140801070301	10/28/2013	Per	2-Pass	Backpack	N	N	N
Mancos River	140801070301	10/28/2013	Per	2-Pass	Backpack	N	N	N
Mancos River	140801070201	10/29/2013		1-Pass	Bank Shocker	N	N	N
McElmo Creek	140802020102	5/14/2013	Per	1-Pass	Backpack	N	N	N
Piedra River	140801020503	7/31/2013	Per	2-Pass	Bank Shocker	N	Y	N
Rio Blanco River	140801010702	7/30/2013	Per	2-Pass	Bank Shocker	Y	Y	N
Spring Creek	140801010605	8/1/2013	Per	2-Pass	Backpack	N	Y	N
Stollsteimer Creek	140801020404	7/11/2013	Per	2-Pass	Backpack	N	N	N
Turkey Creek	140801010401	8/1/2013	Per	2-Pass	Backpack	N	N	N

Appendix Table A.2. Continued.

Stream	HUC 12 Unit	Date	Site Type	Method	Sample Gear	FMS	BHS	RTC
			White River Basin					
Deep Channel Creek	140500050505	6/20/2013	Int	2-Pass	Backpack	N	N	N
Douglas Creek	140500070301	5/20/2013	Int	2-Pass	Backpack	N	N	N
Fawn Creek	140500060203	6/4/2013	Per	2-Pass	Backpack	N	N	N
Middle Fork Steward Gulch	140500060106	6/4/2013	Per	2-Pass	Backpack	N	N	N
Piceance Creek	140500060210	5/23/2013	Per	2-Pass	Backpack	N	N	N
Piceance Creek	140500060206	7/23/2013	Per	2-Pass	Backpack	Y	Y	N
White River	140500070406	5/4/2013		MCR	Raft Shocker	Y	Y	Y
White River	140500070406	6/23/2013		MCR	Raft Shocker	Y	Y	Y
White River	140500050403	6/24/2013		MCR	Raft Shocker	Y	Y	N
			Yampa River Basin					
Deer Creek	140500011003	7/25/2013	Per	2-Pass	Backpack	N	N	N
Elkhead Creek	140500010601	6/18/2013	Per	2-Pass	Backpack	N	N	N
Fish Creek	140500010504	8/13/2013	Per	2-Pass	Backpack	N	N	N
Foidel Creek	140500010502	8/13/2013	Per	2-Pass	Backpack	N	N	N
Fortification Creek	140500010709	5/22/2013	Per	2-Pass	Bank Shocker	N	N	N
Fourmile Creek	140500030504	6/18/2013	Int	2-Pass	Backpack	N	N	N
Little Beaver Creek	140500020102	6/17/2013	Int	2-Pass	Backpack	N	N	N
Little Snake River	140500030909	7/24/2013	Per	2-Pass	Backpack	Y	Y	Y
Little Snake River	140500031102	7/24/2013	Per	2-Pass	Backpack	Y	Y	Y
Milk Creek	140500020102	6/17/2013	Per	2-Pass	Backpack	Y	Y	N
Sand Wash	140500031006	5/21/2013	Int	2-Pass	Backpack	N	N	N
Trout Creek	140500010506	6/19/2013	Per	2-Pass	Bank Shocker	N	N	N
Willow Creek	140500010206	8/14/2013	Per	2-Pass	Backpack	N	N	N
			2014					
			Colorado River Basin					
Badger Wash	140100051705	11/12/2014	His	2-Pass	Bank Shocker	Y	Y	Y
Big Salt Wash	140100051613	11/12/2014	His	2-Pass	Bank Shocker	Y	Y	Y
Buzzard Creek	140100051108	7/7/2014	His	2-Pass	Backpack	N	Y	N
Buzzard Creek	140100051103	7/9/2014	His	2-Pass	Backpack	N	Y	N
Dry Fork Cabin Creek	140100011102	7/22/2014	His	2-Pass	Backpack	N	Y	N
Dry Owens Creek	140100051101	5/22/2014	His	2-Pass	Backpack	N	N	N
East Divide Creek	140100050305	7/16/2014	His	2-Pass	Backpack	N	N	N

Appendix Table A.2. Continued.

Stream	HUC 12 Unit	Date	Site Type	Method	Sample Gear	FMS	BHS	RTC
Garfield Creek	140100050602	7/28/2014	His	2-Pass	Backpack	N	N	N
Grove Creek	140100051301	8/19/2014	His	2-Pass	Backpack	N	Y	N
Hightower Creek	140100051103	5/15/2014	His	2-Pass	Backpack	N	N	N
Mack Wash	140100051807	11/21/2014	His	2-Pass	Bank Shocker	N	N	N
Mack Wash	140100051807	11/21/2014		1-Pass	Bank Shocker	Y	Y	N
Persigo Wash	140100051604	11/13/2014	His	2-Pass	Bank Shocker	Y	N	Y
Plateau Creek	140100051310	9/9/2014	His	2-Pass	Bank Shocker	Y	Y	Y
Rifle Creek	140100050505	7/25/2014	His	2-Pass	Backpack	N	N	Y
Rifle Creek	140100050505	11/10/2014	His	1-Pass	Bank Shocker	Y	Y	Y
Roan Creek	140100050909	9/8/2014	His	2-Pass	Backpack	N	Y	N
Roan Creek	140100051006	9/8/2014	His	2-Pass	Bank Shocker	Y	Y	Y
Rock Creek	140100011006	9/10/2014	His	2-Pass	Backpack	N	N	N
Salt Creek	140100051807	11/13/2014	His	1-Pass	Bank Shocker	Y	Y	Y
			Dolores River Basin					
Disappointment Creek	140300020513	4/28/2014		1-Pass	Backpack/Seine	Y	N	Y
Dolores River	140300020706	3/28/2014		2 Nets	Trammel nets	Y	N	Y
Dolores River	140300020302	8/5/2014	His	2-Pass	Bank Shocker	N	N	N
Dolores River	140300020605	8/28/2014		1-Pass	Seine	Y	N	Y
Mesa Creek	140300040102	4/22/2014		1-Pass	Backpack	N	N	N
Naturita Creek	140300030407	5/30/2014	His	2-Pass	Backpack	N	Y	N
N. Fork Mesa Creek	140300040101	4/22/2014		1-Pass	Backpack	N	N	N
San Miguel River	140300030707	6/30/2014	His	2-Pass	Boat Shocker	Y	Y	Y
San Miguel River	140300030703	8/4/2014	His	2-Pass	Bank Shocker	Y	Y	N
Tabeguache Creek	140300030605	3/29/2014		1-Pass	Bank Shocker	Y	N	Y
Tabeguache Creek	140300030605	3/29/2014		1-Pass	Bank Shocker	N	N	Y
Tabeguache Creek	140300030605	3/29/2014		1-Pass	Bank Shocker	Y	Y	Y
Tabeguache Creek	140300030605	5/14/2014	His	2-Pass	Bank Shocker	N	Y	N
Tabeguache Creek	140300030605	5/14/2014		1-Pass	Backpack	Y	Y	N
Tabeguache Creek	140300030605	5/14/2014		1-Pass	Backpack	Y	N	Y
Tabeguache Creek	140300030603	7/31/2014	His	2-Pass	Backpack	N	Y	N
			Green River Basin					
Vermillion Creek	140401090213	7/29/2014	His	2-Pass	Backpack	N	N	N

Appendix Table A.2. Continued.

Stream	HUC 12 Unit	Date	Site Type	Method	Sample Gear	FMS	BHS	RTC
		Gunnison River Basin						
Cimarron River	140200020906	8/21/2014	His	2-Pass	Bank shocker	N	Y	N
Cottonwood Creek	140200050204	5/5/2014		2-Pass	Bank shocker	Y	Y	Y
Cottonwood Creek	140200050204	5/6/2014		1-Pass	Backpack	Y	Y	N
Cottonwood Creek	140200050204	5/6/2014		1-Pass	Backpack	Y	Y	Y
Cottonwood Creek	140200050204	5/6/2014		1-Pass	Backpack	Y	Y	Y
Cottonwood Creek	140200050204	5/6/2014		1-Pass	Backpack	Y	Y	Y
Cottonwood Creek	140200050204	5/19/2014		1-Pass	Bank shocker	N	Y	Y
Cow Creek	140200060102	7/10/2014	His	2-Pass	Backpack	N	N	N
Cow Creek	140200060102	9/3/2014	His	2-Pass	Backpack	N	N	N
Dallas Creek	140200060208	10/23/2014	His	2-Pass	Bank Shocker	N	N	N
Dry Creek	140200060505	7/18/2014	His	2-Pass	Backpack	Y	Y	Y
East Creek	140200050604	5/8/2014	His	2-Pass	Backpack	N	N	N
Escalante Creek	140200050306	1/24/2014		1-Pass	Backpack	Y	Y	Y
Escalante Creek	140200050306	1/24/2014		1-Pass	Backpack	Y	Y	Y
Escalante Creek	140200050306	4/10/2014		1-Pass	Backpack/Seine	Y	Y	Y
Escalante Creek	140200050306	4/10/2014		1-Pass	Backpack/Seine	Y	Y	Y
Escalante Creek	140200050306	5/1/2014		2-Pass	Bank Shocker	Y	Y	Y
Escalante Creek	140200050306	5/1/2014		1-Pass	Bank Shocker	Y	Y	Y
Escalante Creek	140200050306	5/7/2014		2-Pass	Backpack	Y	Y	Y
Escalante Creek	140200050306	8/18/2014	His	2-Pass	Backpack	Y	Y	Y
Kannah Creek	140200050705	8/19/2014	Int	2-Pass	Backpack	N	N	N
Little Cimarron River	140200020904	7/8/2014	His	2-Pass	Bank Shocker	N	Y	N
Little Cimarron River	140200020904	10/28/2014	His	2-Pass	Backpack	N	N	N
Montrose Arroyo	140200060405	5/9/2014	His	2-Pass	Backpack	N	N	N
Potter Creek	140200050202	4/9/2014		1-Pass	Backpack	N	N	N
Potter Creek	140200050202	5/2/2014		1-Pass	Bank Shocker	Y	Y	Y
Potter Creek	140200050202	5/12/2014		1-Pass	Backpack	Y	Y	Y
Potter Creek	140200050202	5/19/2014		1-Pass	Backpack	Y	Y	Y
Potter Creek	140200050202	6/11/2014	His	2-Pass	Backpack	N	Y	N
Roubideau Creek	140200050205	4/9/2014		1-Pass	Backpack	Y	Y	Y
Roubideau Creek	140200050205	4/9/2014		1-Pass	Backpack	Y	Y	Y
Roubideau Creek	140200050203	4/9/2014		1-Pass	Backpack	Y	N	N
Roubideau Creek	140200050205	5/2/2014		1-Pass	Bank Shocker	Y	Y	Y
Roubideau Creek	140200050203	5/2/2014		1-Pass	Bank Shocker	Y	Y	Y

Appendix Table A.2. Continued.

Stream	HUC 12 Unit	Date	Site Type	Method	Sample Gear	FMS	BHS	RTC
Roubideau Creek	140200050203	6/12/2014		1-Pass	Backpack	N	Y	Y
Roubideau Creek	140200050205	7/3/2014		2-Pass	Bank Shocker	Y	Y	Y
Roubideau Creek	140200050205	7/17/2014		2-Pass	Backpack	Y	Y	Y
Roubideau Creek	140200050205	9/4/2014		2-Pass	Bank Shocker	Y	Y	Y
			San Juan River Basin					
Cherry Creek	140801050106	8/5/2014	His	2-Pass	Backpack	N	N	N
E. Fork Cherry Creek	140801050106	8/5/2014		2-Pass	Backpack	N	Y	N
Junction Creek	140801040601	9/30/2014	His	2-Pass	Backpack	N	N	N
Lightner Creek	140801040602	6/18/2014	His	2-Pass	Backpack	N	N	N
Long Hollow Creek	140801050108	10/1/2014	His	2-Pass	Backpack	N	Y	N
Mancos River #2	140801070201	10/22/2014	His	2-Pass	Bank Shocker	N	N	Y
Mancos River #2	140801070202	10/22/2014	His	2-Pass	Bank Shocker	N	N	Y
Mancos River #3	140801070104	6/3/2014	His	2-Pass	Backpack	N	Y	N
Piedra River #1	140801020502	7/23/2014	His	2-Pass	Backpack	N	N	N
Rio Blanco #1	140801010304	7/22/2014	His	2-Pass	Backpack	N	Y	N
Rock Creek	140801011502	7/23/2014	His	2-Pass	Backpack	N	N	N
Yellowjacket Canyon	140802020208	6/20/2014	His	2-Pass	Backpack	N	Y	N
Yellowjacket Canyon	140802020208	8/6/2014	His	2-Pass	Backpack	N	Y	N
			White River Basin					
Crooked Wash	140500050506	4/16/2014		1-Pass	Backpack	N	N	N
Miller Creek	140500050304	7/29/2014	His	2-Pass	Backpack	N	N	N
Piceance Creek	140500060210	5/23/2014	His	2-Pass	Backpack	N	N	N
Piceance Creek	140500060211	7/14/2014	His	2-Pass	Backpack	N	N	N
			Yampa River Basin					
Elk River	140500010305	9/25/2014	His	2-Pass	Bank shocker	N	N	N
Elkhead Creek	140500010607	6/24/2014	His	2-Pass	Backpack	N	N	N
Little Snake River	140500030905	9/22/2014	His	2-Pass	Bank shocker	Y	Y	Y
Milk Creek	140500020106	7/15/2014	His	2-Pass	Backpack	N	N	N
Milk Creek	140500020106	6/25/2014	His	2-Pass	Backpack	N	N	N
Milk Creek	140500020102	9/26/2014	His	2-Pass	Backpack	N	Y	N
Williams Fork Yampa River	140500011005	9/23/2014		2-Pass	Bank shocker	N	N	N
Williams Fork Yampa River	140500011005	9/23/2014		2-Pass	Bank shocker	Y	Y	N

Appendix Table A.2. Continued.

Stream	HUC 12 Unit	Date	Site Type	Method	Sample Gear	FMS	BHS	RTC
Williams Fork Yampa River	140500010906	9/24/2014		2-Pass	Bank shocker	N	N	N
Williams Fork Yampa River	140500011002	9/24/2014	His	2-Pass	Bank shocker	Y	Y	N
			2015					
			Colorado River Basin					
Buzzard Creek	140100051103	7/28/2015	His	2-Pass	Backpack	Y	Y	N
Owens Creek	140100051101	9/28/2015	His	2-Pass	Backpack	N	Y	N
			Dolores River Basin					
Dolores River	140300040503	3/19/2015		1-Pass	Bank Shocker	Y	Y	N
Dolores River	140300040503	3/19/2015		1-Pass	Bank Shocker	Y	Y	N
Naturita Creek	140300030407	8/17/2015	His	2-Pass	Backpack	Y	Y	N
San Miguel River	140300030707	4/15/2015		1-Pass	Bank Shocker	Y	Y	N
San Miguel River	140300030707	4/15/2015		1-Pass	Bank Shocker	Y	Y	N
Tabeguache Creek	140300030605	4/15/2015	His	1-Pass	Backpack	N	Y	Y
Tabeguache Creek	140300030605	4/22/2015	His	1-Pass	Backpack	Y	Y	Y
Tabeguache Creek	140300030605	4/22/2015	His	1-Pass	Backpack	N	Y	N
Tabeguache Creek	140300030605	4/22/2015	His	1-Pass	Backpack	N	Y	N
Tabeguache Creek	140300030605	4/22/2015		1-Pass	Backpack	N	N	N
Tabeguache Creek	140300030605	6/3/2015	His	2-Pass	Backpack	Y	Y	Y
Tabeguache Creek	140300030605	6/3/2015	His	2-Pass	Backpack	N	N	N
Tabeguache Creek	140300030605	7/23/2015	His	2-Pass	Backpack	Y	Y	N
Tabeguache Creek	140300030605	9/11/2015	His	2-Pass	Backpack	N	Y	N
Tabeguache Creek	140300030605	9/11/2015	His	2-Pass	Backpack	Y	N	N
			Green River Basin					
		None						
			Gunnison River Basin					
Big Dominguez Creek	140200050404	4/28/2015	His	1-Pass	Backpack	N	Y	Y
Big Dominguez Creek	140200050404	8/24/2015	His	2-Pass	Backpack	N	N	Y
Cottonwood Creek	140200050204	5/12/2015	His	1-Pass	Backpack	N	Y	Y
Cottonwood Creek	140200050204	5/22/2015	His	2-Pass	Backpack	N	Y	Y
Cottonwood Creek	140200050204	6/18/2015	His	2-Pass	Backpack	Y	Y	Y

Appendix Table A.2. Continued.

Stream	HUC 12 Unit	Date	Site Type	Method	Sample Gear	FMS	BHS	RTC
Dry Creek	140200060505	9/28/2015	His	1-Pass	Backpack	N	N	N
Dry Fork Escalante Creek	140200050305	4/29/2015		1-Pass	Backpack	N	Y	N
Dry Fork Escalante Creek	140200050305	4/29/2015		1-Pass	Backpack	N	N	N
East Creek	140200050604	8/24/2015	His					
Escalante Creek	140200050306	8/6/2015	His	2-Pass	Backpack	Y	Y	Y
Escalante Creek	140200050306	8/31/2015	His	2-Pass	Backpack	Y	Y	Y
Escalante Creek	140200050306	5/6/2015	His	1-Pass	Backpack	Y	Y	Y
Escalante Creek	140200050306	5/20/2015	His	1-Pass	Backpack	Y	Y	Y
Gunnison River	140200050501	7/27/2015		1-Pass	Raft Shocker	Y	Y	Y
Potter Creek	140200050202	4/14/2015	His	1-Pass	Backpack	Y	Y	N
Potter Creek	140200050202	4/21/2015	His	1-Pass	Backpack	Y	N	Y
Potter Creek	140200050202	4/30/2015	His	1-Pass	Backpack	N	Y	N
Potter Creek	140200050202	5/14/2015	His	2-Pass	Backpack	Y	Y	Y
Potter Creek	140200050202	6/2/2015	His	1-Pass	Backpack	Y	Y	Y
Potter Creek	140200050202	6/17/2015	His	2-Pass	Backpack	N	Y	Y
Potter Creek	140200050202	4/24/2015		1-Pass	Backpack	N	N	N
Potter Creek	140200050202	4/24/2015		1-Pass	Backpack	N	N	N
Potter Creek	140200050202	5/13/2015		1-Pass	Backpack	Y	Y	Y
Potter Creek	140200050202	7/29/2015	His	2-Pass	Backpack	N	Y	N
Roubideau Creek	140200050203	4/14/2015		1-Pass	Backpack/Seine	Y	Y	Y
Roubideau Creek	140200050205	4/14/2015		1-Pass	Backpack/Seine	Y	Y	Y
Roubideau Creek	140200050205	4/14/2015		1-Pass	Backpack	Y	N	Y
Roubideau Creek	140200050203	4/22/2015		1-Pass	Backpack	Y	Y	N
Roubideau Creek	140200050203	4/23/2015		1-Pass	Backpack	N	N	N
Roubideau Creek	140200050203	4/23/2015		1-Pass	Backpack	N	Y	Y
Roubideau Creek	140200050203	5/14/2015		1-Pass	Backpack	Y	Y	N
Roubideau Creek	140200050203	7/7/2015		2-Pass	Backpack	Y	N	N
Roubideau Creek	140200050205	7/7/2015		2-Pass	Backpack	Y	N	Y
Roubideau Creek	140200050205	8/27/2015	His	2-Pass	Bank Shocker	Y	Y	Y
		San Juan River Basin						
Mancos River #3	140801070104	8/25/2015	His	2-Pass	Backpack	N	Y	N
Rio Blanco #1	140801010304	9/30/2015	His	2-Pass	Backpack	N	Y	N

Appendix Table A.2. Continued.

Stream	HUC 12 Unit	Date	Site Type	Method	Sample Gear	FMS	BHS	RTC
			White River Basin					
Douglas Creek	140500070504	10/26/2015	His	2-Pass	Bank Shocker	Y	N	N
Piceance Creek	140500060211	8/19/2015	His	2-Pass	Backpack	Y	Y	N
			Yampa River Basin					
Little Snake River	140500030905	8/20/2015	His	2-Pass	Bank Shocker	Y	Y	Y
Little Snake River	140500030901	9/1/2015		1-Pass	Bank Shocker	Y	Y	Y
Little Snake River	140500031103	9/1/2015		1-Pass	Backpack	Y	Y	Y
Little Snake River	140500030909	9/2/2015	His	1-Pass	Backpack	Y	Y	Y
Milk Creek	140500020106	10/7/2015	His	2-Pass	Backpack	Y	Y	Y
Milk Creek	140500020106	10/7/2015	His	2-Pass	Bank Shocker	Y	Y	N
Williams Fork Yampa River	140500011002	9/22/2015	His	2-Pass	Bank Shocker	Y	Y	N
Williams Fork Yampa River	140500011005	9/23/2015		2-Pass	Bank Shocker	Y	Y	N
Williams Fork Yampa River	140500011005	9/23/2015		2-Pass	Bank Shocker	N	Y	Y
Williams Fork Yampa River	140500011005	9/23/2015		2-Pass	Bank Shocker	N	Y	N
			2016					
			Colorado River Basin					
Dry Owens Creek	140100051101	6/28/2016	His	2-Pass	Backpack	N	N	N
Garfield Creek	140100050602	9/6/2016	His	2-Pass	Backpack	N	N	N
Garfield Creek	140100050602	9/6/2016	His	2-Pass	Backpack	N	N	N
Owens Creek	140100051101	6/28/2016	His	2-Pass	Backpack	N	N	N
Plateau Creek	140100051310	9/14/2016	His	Net	Seine	Y	N	N
Plateau Creek	140100051310	9/14/2016	His	1-Pass	Backpack	Y	Y	N
Plateau Creek	140100051310	9/14/2016	His	Net	Seine	Y	N	N
Plateau Creek	140100051310	9/14/2016	His	1-Pass	Backpack	Y	Y	N
West Divide Creek	140100050302	10/12/2016	His	2-Pass	Backpack	N	Y	N
West Divide Creek	140100050307	10/13/2016	His	2-Pass	Backpack	N	Y	N
West Divide Creek	140100050307	10/13/2016	His	2-Pass	Backpack	Y	Y	Y
			Dolores River Basin					
Dolores River	140300020605	8/9/2016		Net	Seine	N	N	Y
Dolores River	140300020605	8/9/2016		Net	Trammel	N	N	Y
Dolores River	140300020605	8/9/2016		Net	Seine	N	N	Y
Dolores River	140300020605	8/10/2016		Net	Seine	N	Y	Y

Appendix Table A.2. Continued.

Stream	HUC 12 Unit	Date	Site Type	Method	Sample Gear	FMS	BHS	RTC
Dolores River	140300020605	8/10/2016		Net	Seine	N	N	Y
Dolores River	140300020605	8/10/2016		Net	Seine	Y	Y	Y
Dolores River	140300020605	8/10/2016		Net	Seine	N	N	Y
Dolores River	140300020605	8/10/2016		Net	Seine	N	N	Y
Dolores River	140300021002	8/11/2016		Net	Seine	N	N	N
Dolores River	140300021002	8/11/2016		Net	Trammel	N	N	Y
Dolores River	140300021002	8/11/2016		Net	Seine	N	N	N
Dolores River	140300021002	8/11/2016		Net	Trammel	N	N	N
La Sal Creek	140300020903	9/27/2016		2-Pass	Backpack	N	Y	N
La Sal Creek	140300020904	9/27/2016		2-Pass	Backpack	N	Y	N
La Sal Creek	140300020904	9/28/2016		2-Pass	Backpack	N	Y	Y
Naturita Creek	140300030407	8/3/2016	His	2-Pass	Backpack	Y	Y	N
Roc Creek	140300040203	10/4/2016	His	2-Pass	Backpack	N	Y	N
Tabeguache Creek	140300030605	6/2/2016	His	2-Pass	Bank Shocker	Y	Y	N
Tabeguache Creek	140300030605	6/2/2016		2-Pass	Bank Shocker	Y	Y	Y
Tabeguache Creek	140300030605	8/2/2016	His	2-Pass	Backpack	Y	Y	N
Tabeguache Creek	140300030605	9/21/2016	His	2-Pass	Backpack	Y	Y	Y
Tabeguache Creek	140300030603	9/13/2016		Net	Seine	Y	Y	Y
Tabeguache Creek	140300030603	9/13/2016		Net	Seine	Y	Y	Y
			Green River Basin					
		None						
			Gunnison River Basin					
Anthracite Creek	140200040307	9/1/2016		3-Pass	Backpack	N	N	N
Big Dominguez Creek	140200050404	4/7/2016	His	1-Pass	Backpack	N	N	N
Cottonwood Creek	140200050204	4/15/2016		1-Pass	Backpack	Y	Y	N
Cottonwood Creek	140200050204	5/9/2016		1-Pass	Backpack+Seine	Y	Y	N
Cottonwood Creek	140200050204	5/10/16	Per	2-Pass	Backpack	N	N	N
Cottonwood Creek	140200050204	5/19/2016		1-Pass	Bank Shocker	Y	Y	Y
Cottonwood Creek	140200050204	5/19/2016		1-Pass	Backpack	Y	Y	Y
Dry Creek	140200060505	7/27/2016	His	2-Pass	Backpack	Y	Y	Y
Escalante Creek	140200050306	5/5/2016	His	1-Pass	Bank Shocker	Y	Y	N
Escalante Creek	140200050306	7/28/2016	His	2-Pass	Backpack	Y	Y	Y
Escalante Creek	140200050306	8/30/2016	His	2-Pass	Backpack	Y	Y	Y

Appendix Table A.2. Continued.

Stream	HUC 12 Unit	Date	Site Type	Method	Sample Gear	FMS	BHS	RTC
Escalante Creek	140200050306	9/12/2016		Net	Seine	Y	Y	Y
Escalante Creek	140200050306	9/12/2016		Net	Seine	Y	Y	Y
Escalante Creek	140200050306	9/12/2016		Net	Seine	Y	Y	Y
North Fork Gunnison	140200040403	9/1/2016		3-Pass	Bank Shocker	N	Y	N
North Fork Gunnison	140200040403	9/1/2016		3-Pass	Backpack	N	N	N
Potter Creek	140200050202	4/20/2016	His	1-Pass	Bank Shocker	Y	N	N
Potter Creek	140200050202	5/3/2016	His	1-Pass	Bank Shocker	Y	Y	Y
Potter Creek	140200050202	5/11/2016	His	1-Pass	Backpack	Y	Y	N
Potter Creek	140200050202	5/17/2016	His	1-Pass	Backpack	Y	Y	Y
Potter Creek	140200050202	5/25/2016	His	1-Pass	Backpack	Y	Y	Y
Potter Creek	140200050202	6/1/2016		1-Pass	Backpack	N	N	N
Potter Creek	140200050202	9/29/2016	His	2-Pass	Backpack	N	Y	Y
Roubideau Creek	140200050205	5/3/2016		1-Pass	Bank Shocker	Y	Y	Y
Roubideau Creek	140200050205	8/30/2016		2-Pass	Bank Shocker	Y	Y	Y
Roubideau Creek	140200050203	6/1/2016		1-Pass	Backpack	N	N	Y
			San Juan River Basin					
Mancos River	140801070104	6/29/2016	His	2-Pass	Backpack	N	Y	N
Rock Creek	140801011502	11/7/2016	His	2-Pass	Backpack	N	Y	N
Weber Canyon Creek	140801070107	6/29/2016	His	2-Pass	Backpack	N	Y	Y
Weber Canyon Creek	140801070107	7/19/2016	His	2-Pass	Backpack	N	Y	Y
Weber Canyon Creek	140801070107	7/20/2016		1-Pass	Backpack	N	N	N
Weber Canyon Creek	140801070107	7/20/2016		Net	Seine	N	Y	N
			White River Basin					
Piceance Creek	140500060211	6/22/2016	His	2-Pass	Backpack	Y	Y	N
Piceance Creek	140500060211	6/23/2016	His	2-Pass	Backpack	Y	N	N
Piceance Creek	140500060211	9/7/2016	His	2-Pass	Backpack	Y	Y	N
			Yampa River Basin					
Little Snake River	140500030905	9/8/16	His	2-Pass	Bank Shocker	Y	Y	Y
Little Snake River	140500030909	9/8/16	His	2-Pass	Backpack	Y	Y	Y

Appendix Table A.2. Continued.

Stream	HUC 12 Unit	Date	Site Type	Method	Sample Gear	FMS	BHS	RTC
			2017					
			Colorado River Basin					
Buzzard Creek	140100051103	7/5/2017	His	2-Pass	Backpack	Y	Y	N
Buzzard Creek	140100051103	7/6/2017	His	2-Pass	Backpack	N	Y	N
Dry Owens Creek	140100051101	6/15/2017	His	2-Pass	Backpack	N	N	N
Dry Fork Cabin Creek	140100011102	7/12/2017	His	1-Pass	Backpack	N	N	N
Little Dolores River	140300010307	7/20/2017		Net	Visual/Dipnet	N	N	N
Little Dolores River	140300010307	7/20/2017		Net	Visual/Dipnet	N	N	N
Owens Creek	140100051101	6/15/2017	His	2-Pass	Backpack	N	Y	N
Plateau Creek	140100051310	6/20/2017	His	2-Pass	Backpack	Y	Y	Y
Plateau Creek	140100051310	6/20/2017	His	1-Pass	Backpack	Y	N	N
Plateau Creek	140100051310	7/10/2017	His	2-Pass	Bank Shocker	Y	Y	N
Red Dirt Creek	140100011504	7/12/2017		Net	Visual/Dipnet	N	N	N
Roan Creek	140100050909	7/27/2017	His	2-Pass	Backpack	N	Y	N
			Dolores River Basin					
Horsefly Creek	140300030203	7/18/2017		2-Pass	Backpack	N	N	N
La Sal Creek	140300020904	8/16/2017		2-Pass	Backpack	N	Y	N
Naturita Creek	140300030407	5/25/2017	His	2-Pass	Backpack	N	Y	N
Roc Creek	140300040203	4/25/2017	His	1-Pass	Backpack	N	N	N
Tabeguache Creek	140300030603	4/6/2017		1-Pass	Backpack	N	N	N
Tabeguache Creek	140300030603	4/12/2017		1-Pass	Backpack	Y	Y	N
Tabeguache Creek	140300030603	4/25/2017		1-Pass	Backpack	N	N	N
Tabeguache Creek	140300030605	5/2/2017		1-Pass	Backpack	Y	N	N
Tabeguache Creek	140300030603	5/2/2017		1-Pass	Backpack	N	N	Y
Tabeguache Creek	140300030605	5/30/2017	His	2-Pass	Bank Shocker	Y	Y	Y
Tabeguache Creek	140300030605	7/7/2017	His	2-Pass	Backpack	N	N	N
			Green River Basin					
Vermillion Creek	140401090213	7/26/2017	Per	1-Pass	Seine	N	N	N
Vermillion Creek	140401090213	7/26/2017		1-Pass	Backpack	N	N	N
			Gunnison River Basin					
Escalante Creek	140200050306	5/3/2017	His	2-Pass	Bank Shocker	Y	Y	Y
Escalante Creek	140200050306	5/24/2017	His	1-Pass	Backpack	Y	Y	Y

Appendix Table A.2. Continued.

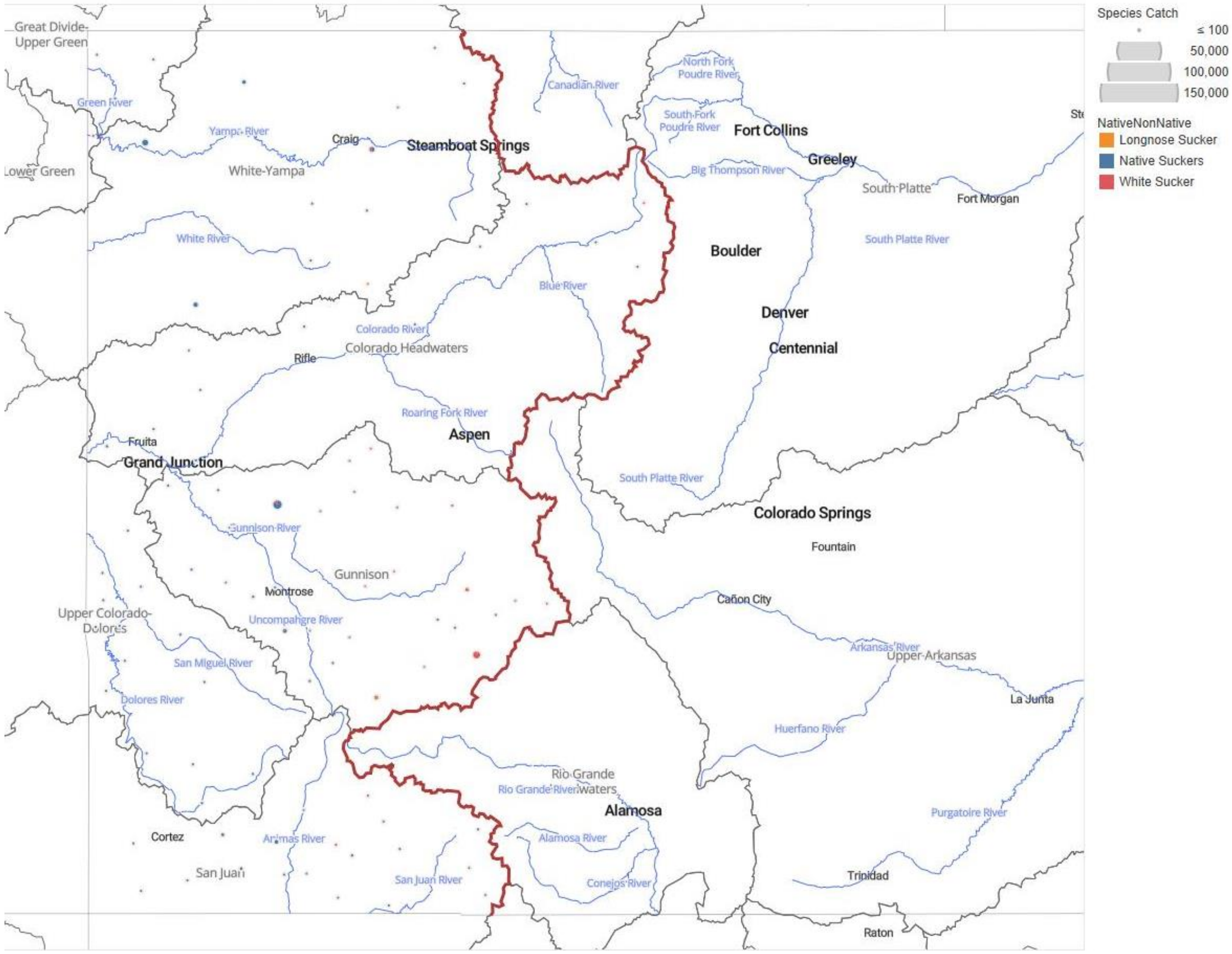
Stream	HUC 12 Unit	Date	Site Type	Method	Sample Gear	FMS	BHS	RTC
Escalante Creek	140200050306	6/8/2017	His	2-Pass	Backpack	Y	Y	Y
Escalante Creek	140200050306	6/8/2017	His	2-Pass	Backpack	Y	Y	Y
Escalante Creek	140200050306	9/20/2017	His	2-Pass	Backpack	Y	Y	Y
Escalante Creek	140200050306	10/16/2017	His	2-Pass	Backpack	Y	Y	Y
Gunnison River	140200050501	7/31/2017	His	2-Pass	Raft Shocker	Y	Y	Y
Kannah Creek	140200050705	4/26/2017	His	2-Pass	Backpack	N	Y	N
Monitor Creek	140200050202	4/19/2017		1-Pass	Backpack	Y	Y	N
Monitor Creek	140200050202	5/22/2017		1-Pass	Backpack	N	N	N
N. Fork Gunnison R.	140200040508	6/27/2017	His	2-Pass	Raft Shocker	Y	Y	Y
N. Fork Gunnison R.	140200040508	6/27/2017	His	2-Pass	Raft Shocker	Y	Y	Y
N. Fork Gunnison R.	140200040508	6/27/2017	His	2-Pass	Raft Shocker	Y	Y	Y
Potter Creek	140200050202	3/21/2017	His	1-Pass	Backpack	Y	N	N
Potter Creek	140200050202	3/28/2017	His	1-Pass	Backpack	N	Y	N
Potter Creek	140200050202	4/4/2017	His	2-Pass	Bank Shocker	Y	N	N
Potter Creek	140200050202	4/11/2017	His	2-Pass	Bank Shocker	Y	Y	N
Potter Creek	140200050202	4/18/2017	His	1-Pass	Bank Shocker	Y	Y	N
Potter Creek	140200050202	4/24/2017	His	1-Pass	Bank Shocker	Y	Y	N
Potter Creek	140200050202	5/1/2017	His	1-Pass	Bank Shocker	Y	Y	N
Potter Creek	140200050202	5/8/2017	His	2-Pass	Bank Shocker	Y	Y	Y
Potter Creek	140200050202	5/10/2017	His	1-Pass	Backpack	Y	Y	N
Potter Creek	140200050202	5/16/2017	His	1-Pass	Bank Shocker	Y	Y	Y
Potter Creek	140200050202	5/22/2017	His	2-Pass	Backpack	Y	Y	N
Potter Creek	140200050202	5/31/2017	His	2-Pass	Backpack	N	Y	Y
Potter Creek	140200050202	6/7/2017	His	2-Pass	Backpack	N	Y	Y
Potter Creek	140200050202	9/26/2017	His	2-Pass	Backpack	Y	Y	Y
Roubideau Creek	140200050205	6/6/2017		2-Pass	Bank Shocker	Y	Y	Y
Roubideau Creek	140200050205	7/20/2017	His	2-Pass	Bank Shocker	Y	Y	Y
McElmo Creek	140802020305	6/21/2017	His	2-Pass	Backpack	Y	N	Y
		Yampa River Basin						
Weber Canyon Creek	140801070107	6/5/2017	His	2-Pass	Backpack	N	Y	Y
Weber Canyon Creek	140801070107	6/13/2017	His	2-Pass	Backpack	N	Y	N
Weber Canyon Creek	140801070107	6/13/2017		1-Pass	Backpack	N	N	N
Weber Canyon Creek	140801070107	6/22/2017	His	1-Pass	Backpack	N	Y	Y
Weber Canyon Creek	140801070107	6/22/2017		1-Pass	Backpack	N	Y	Y

Appendix Table A.2. Concluded.

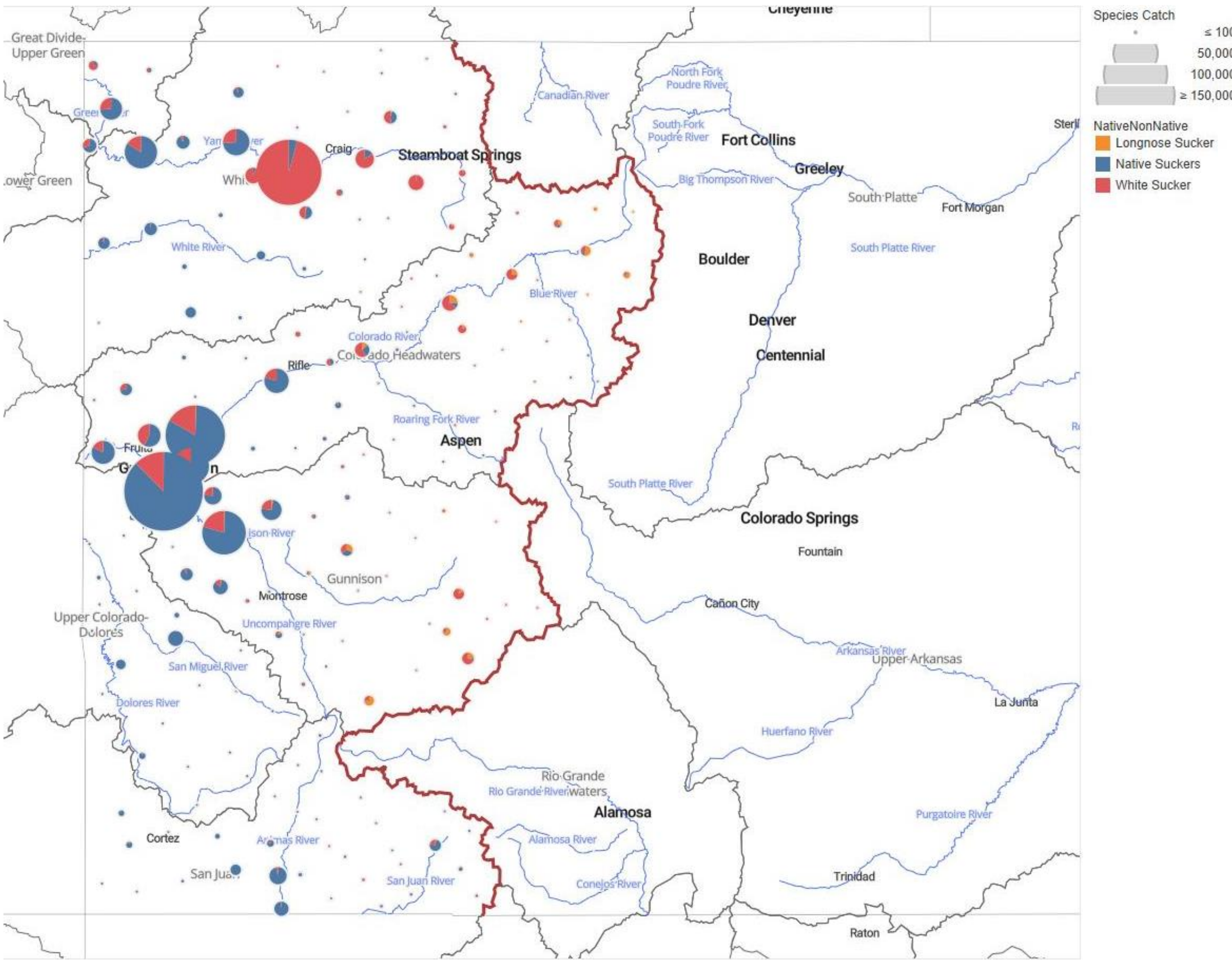
Stream	HUC 12 Unit	Date	Site Type	Method	Sample Gear	FMS	BHS	RTC
Weber Canyon Creek	140801070107	6/29/2017	His	2-Pass	Backpack	N	Y	Y
Weber Canyon Creek	140801070107	6/29/2017		1-Pass	Backpack	N	N	N
Weber Canyon Creek	140801070107	8/9/2017	His	2-Pass	Backpack	N	Y	N
Weber Canyon Creek	140801070107	8/9/2017		1-Pass	Backpack	N	Y	N
Weber Canyon Creek	140801070107	9/19/2017	His	1-Pass	Backpack	N	Y	N
Weber Canyon Creek	140801070107	9/19/2017		1-Pass	Backpack	N	Y	N
			White River Basin					
Piceance Creek	140500060211	5/23/2017	His	2-Pass	Backpack	Y	N	N
Piceance Creek	140500060211	10/31/2017	His	2-Pass	Backpack	Y	Y	N
Piceance Creek	140500060211	5/23/2017	His	2-Pass	Backpack	Y	N	N
Piceance Creek	140500060211	10/30/2017	His	2-Pass	Backpack	Y	Y	N
Yellow Creek	140500060308	10/30/2017	His	2-Pass	Backpack	N	N	N
Yellow Creek	140500060308	7/25/2017		1-Pass	Backpack	N	N	N
			Yampa River Basin					
		None						

Appendix B: **Expansion of Non-Native Suckers on the Western Slope**

Top: White Sucker (Kevin Thompson)
Bottom: Longnose Sucker (Jenn Logan)



Appendix Figure B.1. The proportion of Bluehead and Flannelmouth suckers (Native) and non-native Longnose and White suckers in fish surveys conducted in western slope waters of Colorado from 1941 to 1979. Hybrids of either non-native sucker with native suckers are grouped with the appropriate non-native category.



Appendix Figure B.2. The proportion of Bluehead and Flannelmouth suckers (Native) and non-native Longnose and White suckers in fish surveys conducted in western slope waters of Colorado from 1941 to 2018. Hybrids of either non-native sucker with native suckers are grouped with the appropriate non-native category.

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