Colorado River Aquatic Resource Investigations

Federal Aid Project F-237-R23

Dan A. Kowalski

Aquatic Research Scientist

Job Progress Report

Colorado Parks & Wildlife

Aquatic Research Section

Fort Collins, Colorado

July 2016

STATE OF COLORADO

John W. Hickenlooper, Governor

COLORADO DEPARTMENT OF NATURAL RESOURCES

Bob Randall, Executive Director

COLORADO PARKS & WILDLIFE

Bob Broscheid, Director

WILDLIFE COMMISSION

AQUATIC RESEARCH STAFF

George J. Schisler, Aquatic Research Leader
Kelly Carlson, Aquatic Research Program Assistant
Peter Cadmus, Aquatic Research Scientist/Toxicologist, Water Pollution Studies
Eric R. Fetherman, Aquatic Research Scientist, Salmonid Disease Studies
Ryan Fitzpatrick, Aquatic Research Scientist, Eastern Plains Native Fishes
Eric E. Richer, Aquatic Research Scientist/Hydrologist, Stream Habitat Restoration
Matthew C. Kondratieff, Aquatic Research Scientist, Stream Habitat Restoration
Dan Kowalski, Aquatic Research Scientist, Stream & River Ecology
Adam Hansen, Aquatic Research Scientist, Coldwater Lakes and Reservoirs
Kevin B. Rogers, Aquatic Research Scientist, Colorado Cutthroat Studies
Kevin G. Thompson, Aquatic Research Scientist, 3-Species and Boreal Toad Studies
Andrew J. Treble, Aquatic Research Scientist, Aquatic Data Management and Analysis
Brad Neuschwanger, Hatchery Manager, Fish Research Hatchery
Tracy Davis, Hatchery Technician, Fish Research Hatchery
Christopher Praamsma, Hatchery Technician, Fish Research Hatchery

Jim Guthrie, Federal Aid Coordinator
Kay Knudsen, Librarian

Prepared by: ______________________________
Dan Kowalski, Aquatic Research Scientist

Approved by: ______________________________
George J. Schisler, Aquatic Wildlife Research Chief

Date: August 17, 2016

The results of the research investigations contained in this report represent work of the authors and may or may not have been implemented as Colorado Parks & Wildlife policy by the Director or the Wildlife Commission.

Table of Contents

State: Colorado Project Number: F-237-R21

Project Title: Coldwater Stream Ecology Investigations

Period Covered: July 1, 2015 through June 30, 2016

Purpose: Improve aquatic habitat conditions and angling recreation in Colorado.

Project Objective: Investigate biological and ecological factors impacting sport fish populations in coldwater streams and rivers in Colorado.

Job No. 1. Salmonfly Habitat and Ecology Studies

Job Objective: Investigate the habitat use, hatching ecology and limiting factors of the Salmonfly *Pteronarcys californica* in Colorado Rivers.

Need

The salmonfly (*Pteronarcys californica*) is a large aquatic invertebrate that can reach high densities in some Colorado Rivers. They play an important ecological role as grazers in stream systems and have been documented to be extremely important to stream dwelling trout as a food resource. Nehring (1987) reported in a diet study of trout in the Colorado River that *P. californica* was the most common food item, comprising 64-75% of the mean stomach content over the four year study. Because of their high biomass and hatching behavior, they also play an important role in supplementing terrestrial food webs and riparian communities with stream derived nutrients (Baxter et al. 2005, Walters et al. 2014). While ecologically important and found in high abundance at some sites, the salmonfly has relatively specific environmental requirements and is considered intolerant of disturbance in bioassessment protocols (Barbour et al. 1999, Fore et al. 1996, Erickson 1983).

One characteristic of salmonflies that makes them sensitive to habitat alterations their lifespan; it is one of the longest lived aquatic insects in the Neararctic (DeWalt and Stewart 1995). It has been reported to have a three to five year life cycle but two studies indicate it is likely to have a three or four year life cycle in Colorado (DeWalt and Stewart 1995, Nehring 1987). These two studies also identify *P. californica* as one of the most synchronously emerging of all species of stoneflies with emergence at any one site lasting from 5-13 days. The synchronous emergence and hatching behavior allow it to be sampled in unique ways compared to other aquatic invertebrates. Salmonflies hatch at night by crawling from the water onto riparian vegetation and other vertical structures such as rocks, cliff faces and bridge abutments where they emerge from the nymphal exuvia which is left attached to the structure. If sites are visited soon after emergence then the density of stoneflies emerging at a site can be estimated by completing multiple pass removal surveys of the exuvia. Nehring (2011) found a 0.95 correlation coefficient between post emergence exuvia density estimates and more traditional pre-emergent quantitative benthic sampling at 23 sites.

Previous work completed under Project F-237 identified that the range and density of *P. californica* have declined in the Colorado River and that these declines may be associated with flow alterations (Nehring 2011). Once common in the upper Colorado River, the abundance of salmonflies has declined; especially below Windy Gap Reservoir where flow alterations associated with trans-mountain water diversions are the largest. The objective of this project is to document the distribution, density and habitat use of *P. californica* in several rivers and measure environmental variables that may be limiting factors of this species in Colorado rivers. By comparing the habitat characteristics of similar sites with differing densities of stoneflies, the optimal habitat characteristics and limiting factors will be identified. Knowledge of the preferred habitat characteristics will assist in ecological restoration of sites where *P. californica* have been extirpated. Once limiting habitat features are identified, the effects of flow and sediment changes on those features will be investigated. This information will benefit management and river restoration activities as well as the evaluation of re-introduction sites for *P. californica* such as those currently being conducted on the Arkansas and upper Gunnison Rivers.

Objectives

1. Document the distribution and density of *P. californica* at 18 sites on the Gunnison, Colorado and Rio Grande rivers.
2. Measure physical habitat variables at all 18 sites.
3. Identify the important habitat characteristics that explain their distribution and density.

Approach

Action #1- Develop and test population estimation techniques for salmonflies.
- Level 1 Action Category: Data collection and analysis
- Level 2 Action Strategy: Techniques development
- Level 3 Action Activity: Fish and wildlife research, survey and management techniques

Previous work under Project F-237 established that traditional sampling methods (i.e. 0.086 m^2 Hess sampler) may be inadequate for accurately estimating density of salmonflies due to their patchy distribution and the large substrate they commonly occupy. Two alternative techniques that were proposed included extra large Surber type samplers and multiple pass removal estimates of the insect's exoskeleton (exuvia) post emergence. While the large Surber sampler did sample a large enough area to reduce the spatial variation of *P. californica* larvae between samples, it was time consuming to set up and use and difficult to deploy in heavy current. A 0.456 m^2 Hess sampler was constructed out of 1/8 inch plate steel, mimicking the design of standard Hess samplers but scaling up for the larger size. To test the new sampler, five replicate samples were taken from four sites on the Gunnison River and 5 sites on the Colorado River in 2016. The sites were a subset of the 18 riffle sites where exuvia density estimates have been conducted for the last 4 years. All *P.c.* larvae in each sample will be counted, sexed and measured. All field sampling is complete for Job #1 Action #1. Processing of the samples is ongoing and will be reported in 2016-2017 Federal Aid Report for Project F-237.

Table 1. Summary of salmonfly habitat sampling sites for Job#1. Six sites each on three rivers were sampled over four years for exuvia density and surveyed for physical habitat characteristics.

River	#	Site	Side	UTM NAD 83 (Zone 13)
Gunnison	1	Orchard Boat Ramp	River Left	247947, 4295297
Gunnison	2	Cottonwood Campground	River Left	252129, 4295940
Gunnison	3	Goldmine	River Left	253728, 4295747
Gunnison	4	Smith Fork	River Left	253338, 4291889
Gunnison	5	Ute Park	River Left	252376, 4284894
Gunnison	6	Chukar	River Left	253421, 4278775
Colorado	7	State Bridge	River Right	359889, 4414634
Colorado	8	Pumphouse BLM	River Left	370827, 4427300
Colorado	9	Powers BLM	River Right	394914, 4435762
Colorado	10	Byers Canyon	River Left	403335, 4434268
Colorado	11	Hwy 40 Bridge	River Right	408133, 4437708
Colorado	12	Hitching Post	River Left	414589, 4440304
Rio Grande	13	LaGarita	River Left	338264, 4182888
Rio Grande	14	Lower Wason 2	River Right	335653, 4186302
Rio Grande	15	Lower Wason 1	River Right	335353, 4187197
Rio Grande	16	Upper Wason 2	River Right	333668, 4187683
Rio Grande	17	Creede Hatchery	River Left	332145, 4187768
Rio Grande	18	Creede Boat Ramp	River Left	331362, 4187243

Action #2- Estimate the density of salmonflies at a variety of sites in the Colorado, Gunnison and Rio Grande Rivers.

- Level 1 Action Category: Data collection and analysis
- Level 2 Action Strategy: Research, survey or monitoring- fish and wildlife populations
- Level 3 Action Activity: Abundance determination

Sampling is now complete on all 18 sites on the three rivers. All sites have at least 3 years of data and a minimum of two years of data collected under favorable flow conditions that did not compromise the estimates. Locations and description of sites are presented in Table 1. Estimates were completed by searching 30 meter (98.6 ft) sections of stream bank for *P. californica* exuvia adjacent to riffle habitat. If possible, each site was visited 2-3 times to encompass the entire emergence. If a site was visited only once, estimates were done as soon as possible after the emergence was complete (emergence usually last from 7-13 days at our study sites). Stream flow changes and weather conditions also were taken into account when planning surveys to best estimate the total emergence at each site. Three to seven people intensively searched the riparian area from one to twenty meters from the water's edge. The search area varied by site and depended on the thickness and structure of riparian vegetation. The area was extended laterally from the water's edge until no exuvia were encountered, with the exuvia at most sites being encountered with the first 3 meters from the water. On a single sampling occasion, each area was searched two to four times with similar search areas, effort and personnel. Each exuvia on the first pass was examined to determine sex. A multiple pass removal model was used to estimate the total density of exuvia at each site (Zippin 1956). Methods were similar but not identical to previous work (Nehring

2011) and many of the sites on the Colorado and Fraser River were identical to previous work. More effort (higher number of people) was used compared to earlier studies resulting in higher capture probabilities that better met assumptions of the removal model and likely allowed unbiased estimates of exuvia with two depletion passes. Simple two pass population models were more than sufficient in the vast majority of cases, only at very high and very low densities was there any evidence of biased estimates due to changing capture probabilities with pass (Figure 1). The two pass depletion technique worked well for these estimates and many of the issues with depletion estimates encountered in fish population estimates were not a problem due to the immobile nature of the exuvia, high capture probability, and no size selective gear (Riley and Fausch 1992, Peterson et al. 2004, Saunders et al. 2011). All sampling is now complete for Job #1, Action #2, results will be presented in 2016-2017 Federal Aid Report.

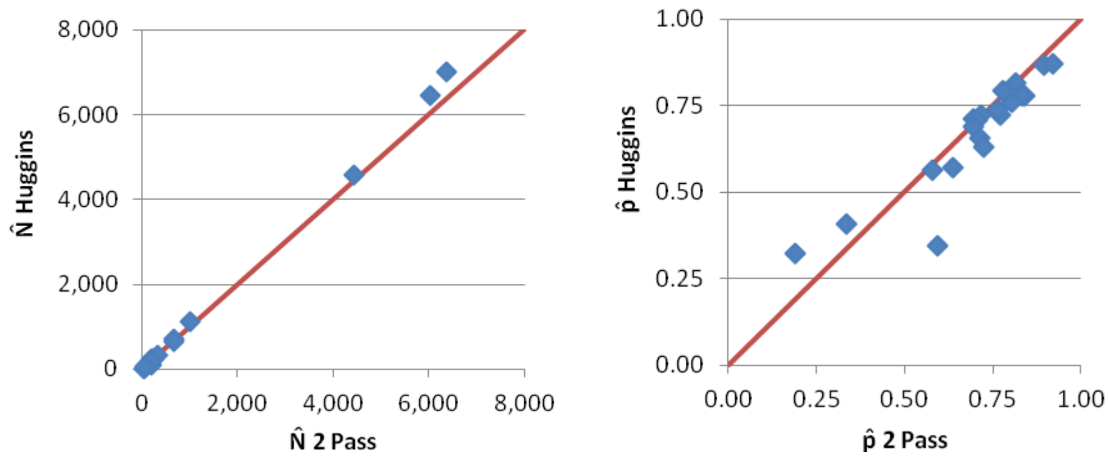

Figure 1. Population and capture probability estimates comparing a 3 pass Huggins Closed Capture model in Program Mark (with time effects that varied capture p^'s) to a simple two pass removal model of Zippin 1956. There was some variation in the estimated capture probability at very low densities (<80 exuvia per 30 m) and very high densities (> 6,000 exuvia per 30 m) indicating that the assumption of equal capture probabilities for all passes is violated with the simple 2 pass model. However, that bias was relatively small and population estimates of the two models were very close.

Action #3- Measure aquatic habitat variables at salmonfly population estimate sites.
- Level 1 Action Category: Data collection and analysis
- Level 2 Action Strategy, survey or monitoring- habitat
- Level 3 Action Activity: Monitoring

Physical habitat surveys have been complete at all 18 sites. These surveys included pebble counts to characterize dominant substrate size (Potyondy and Hardy 1994) and two methods to measure substrate embeddedness. Embeddedness was visually estimated following the methods of Bain and Stevenson (1999) and was measured following the Weighted Burns Quantitative Method (Burns 1985, Sennatt et al. 2006). Physical surveys of each site were completed with survey-grade GPS equipment and a HydroSurveyor acoustic Doppler current profiler system (ADCP). The GPS and ADCP surveys were analyzed by CPW aquatic researcher and hydrologist Eric Richer. Examples of the physical habitat survey maps and bathymetric maps produced with the GPS and ADCP surveys are presented in Figures 1 and 2. The data from the physical habitat surveys will be analyzed to compile a list of variables that are hypothesized to explain differences in stonefly habitat quality. A candidate set of models will be developed to identify which variables best explain differences in stonefly density with the information theoretic approach (Burnham and Anderson 2002). Density estimates and habitat surveys will be completed for a total of 18 sites on all three major rivers in Colorado with large populations of salmonflies. The modeling exercise will identify habitat variables that explain differences in stonefly density and could explain their decline or extirpation from sites. This information can then be used to guide habitat improvement projects in the Upper Colorado River basin as well as inform water development decisions on how to protect in stream aquatic habitat. All sampling is now complete for Job #1 Action #3; results will be presented in 2016-2017 Federal Aid Report.

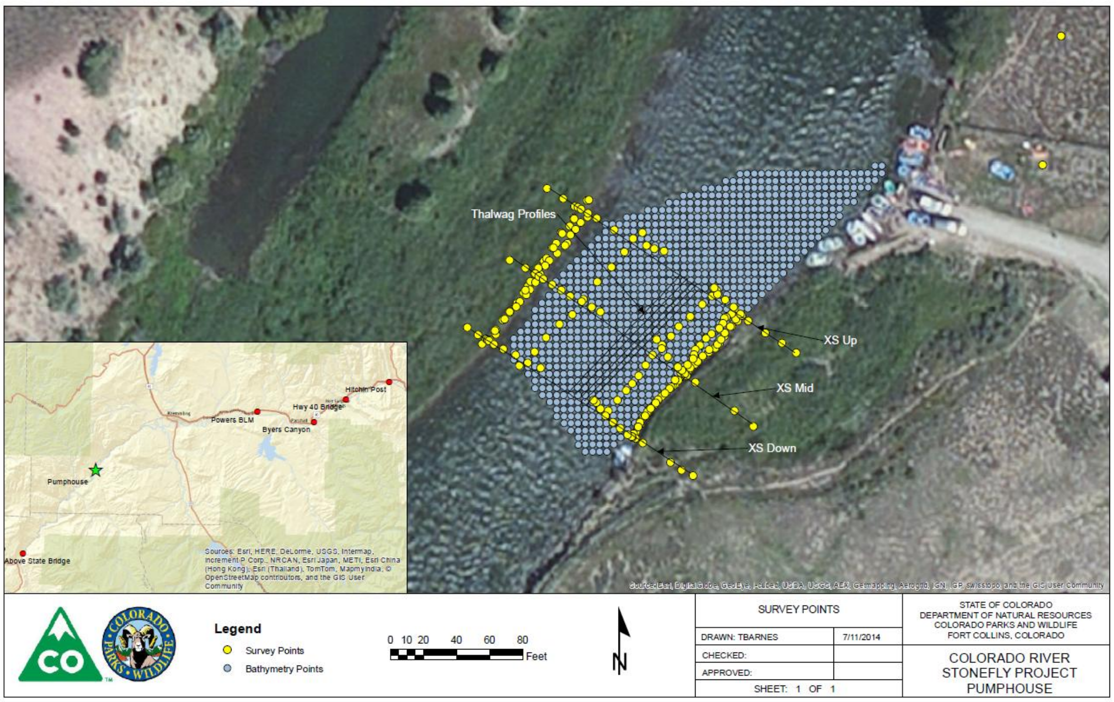

Figure 2. Survey points and bathymetry data collected with the survey-grade GPS equipment and Acoustic Doppler Current Profiler of the Pumphouse stonefly site.

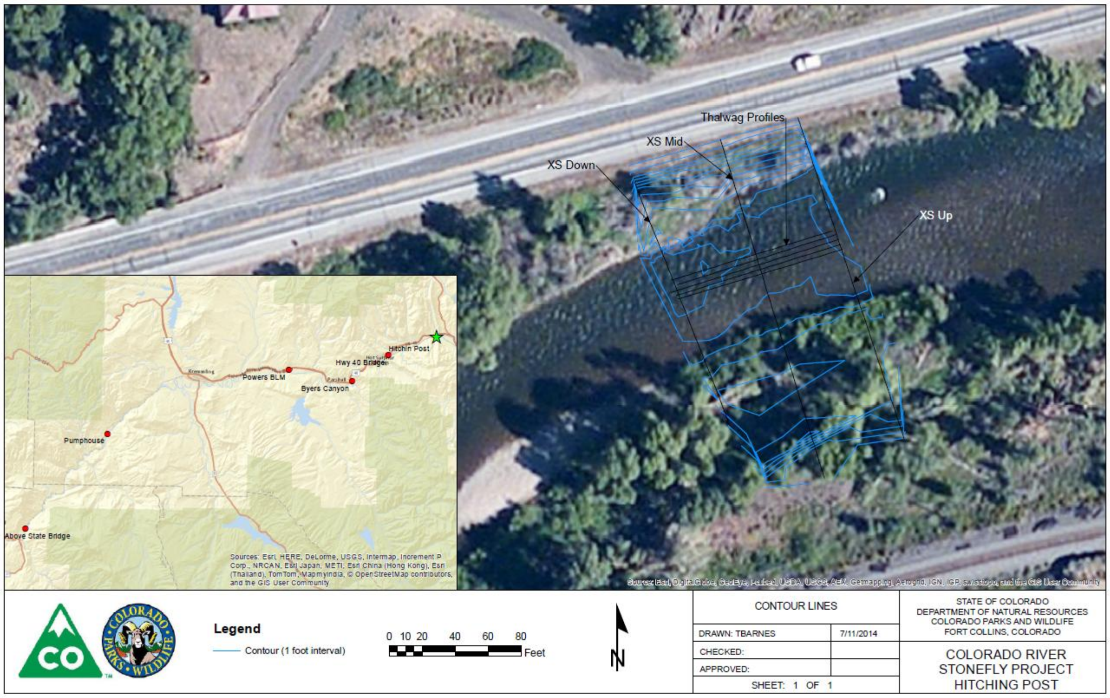

Figure 3. Bathymetric map produced by the GPS and ADCP survey used to estimate physical channel characteristics of stonefly study sites

References

Bain, M.B., and Stevenson, N.J., eds. 1999. Aquatic habitat assessment: common methods. American Fisheries Society, Bethesda, MD.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates and fish. Second edition. EPA 841– D–97–002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Baxter, C.V., K.D. Fausch, and W.C. Saunders. 2005. Tangled webs: reciprocal flows of Invertebrate prey link streams and riparian zones. Freshwater Biology. 50: 201-220.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach, 2nd edition. Springer-Verlag, New York.

Burns, D. C., and Edwards, R. E. 1985. Embeddedness of salmonid habitat of selected streams on the Payette National Forest. USDA Forest Service, Payette National Forest, McCall, ID.

Dewalt, R. E. and K.W. Stewart. 1995. Life-histories of stoneflies (Plecoptera) in the Rio Conejos of southern Colorado. Great Basin Naturalist. 55: 1-18.

Erickson, R.C. 1983. Benthic field studies for the Windy Gap study reach, Colorado River, Colorado, fall, 1980 to fall, 1981. Prepared for The Northern Colorado Water Conservancy District, Municipal Sub-District.

Fore, L.S., J.R. Karr, and R.W. Wisseman. 1996. Assessing invertebrate responses to human activities: Evaluating alternative approaches. Journal of the North American Benthological Society 15(2):212-231.

Nehring, R.B. 1987. Stream fisheries investigations. Colorado Division of Wildlife, Federal Aid in Sportfish Restoration, Project F-51-R, Progress Report, Fort Collins.

Nehring, R.B. 2011. Colorado River aquatic resources investigations. Colorado Division of Wildlife, Federal Aid in Sportfish Restoration, Project F-237R-18, Final Report, Fort Collins.

Peterson, J.T., R.F. Thurow, and J.W. Guzevich. 2004. An evaluation of multipass electrofishing for estimating the abundance of stream-dwelling salmonids. Transactions of the American Fisheries Society 133:462-475.

Potyondy, J.P. and T. Hardy. 1994. Use of pebble counts to evaluate fine sediment increase in stream channels. Water Resources Bulletin 30:509-520.

Riley, S.C., and K.D. Fausch. 1992. Underestimation of trout population size by maximum likelihood removal estimates in small streams. North American Journal of Fisheries Management 12:768–776.

Saunders, W.C., K.D. Fausch and G.C. White. 2011. Accurate estimation of salmonid abundance in small streams using nighttime removal electrofishing: an evaluation using marked fish. North American Journal of Fisheries Management, 31:403-415.

Sennatt, K.M., N.L. Salant, C.E. Renshaw, and F.J. Magilligan. 2006. Assessment of Methods for Measuring Embeddedness: Application to Sedimentation in Flow Regulated Streams. Journal of the American water Resources Association 42(6):1671-1682.

Walters, D.M., R.E. Zuellig, and D.A. Kowalski. 2014. Quantifying the emergence of giant stonefly *Pteronarcys californica* and its importance to terrestrial food webs in U.S. western rivers. Society for Freshwater Science. Portland, OR

Zippin, C. 1956. The removal method of population estimation. Journal of Wildlife Management 22:82-90.

Job No. 2. Impacts of Whitewater Park Development on Trout, Aquatic Invertebrates and Mottled Sculpin *Cottus bairdi*

Job Objective: Investigate the effects of whitewater parks on native invertebrates and mottled sculpin.

Need

Artificial whitewater parks (WWP) are increasingly common throughout Colorado and there are concerns about how they impact fish and aquatic invertebrates (Fox 2013, Kolden 2013). Many of the rivers around the state with whitewater parks are also some of the best wild trout fisheries. The construction of whitewater parks involves replacing natural riffles with concrete or grouted rock grade control structures to produce hydraulic waves for recreational boating. Natural riffles serve many important physical and ecological roles in rivers. Ecologically, riffles serve as the most productive areas of a stream for periphyton and invertebrate production that form the foundation of the aquatic food web. Physically, riffles serve as grade control structures for streams and their location and frequency are main drivers of stream geomorphology. Artificial pools created below WWP waves have been found to hold a lower biomass of trout than natural pools, and have more dynamic and higher magnitude flows and velocities (Kolden 2013). Whitewater parks have also been documented to cause a suppression of fish movement that is related to fish length (Fox 2013). Concerns have been raised that whitewater parks not only impact fish habitat and fish passage but could affect some aquatic invertebrates that are primary diet items for trout (Kondratieff 2012).

In addition to sportfish concerns, native non-game fish are also common at many sites of whitewater parks. Mottled sculpin are a bottom dwelling fish that occupy many coldwater streams and rivers of Colorado. Their unique habitat preferences and reliance on quality riffle and run habitat make them a good ecological indicator of stream health (Nehring 2011). Because the function of riffle and run habitat is generally impacted when stream flows are altered or instream habitat is manipulated, mottled sculpin may be impacted by habitat related changes before higher predators like trout. Sculpin could not only indicate ecological problems that will eventually affect sport fish like trout, but they serve as an important food source, especially for brown trout common in many Colorado rivers. The objective of this study is to investigate the effects of building whitewater parks on mottled sculpin, aquatic invertebrates, and trout by sampling before and after construction with control sites. Two whitewater parks were constructed in western Colorado in 2014, on the Uncompahgre River in Montrose and at the Pumphouse Recreation site on the Colorado River. Their construction provided an opportunity for the first comprehensive study of before/after impacts to fish and invertebrates. To meet the objectives of this project a before, after, control, impact (BACI) study design was used to evaluate changes in trout population, mottled sculpin density and aquatic invertebrates at these two sites.

Objectives

1. Investigate the effects of building whitewater parks on aquatic invertebrate density and diversity at two whitewater park sites on the Colorado and Uncompahgre Rivers before and after construction.
2. Investigate the effects of building whitewater parks on the Colorado and Uncompahgre Rivers on the density of trout and mottled sculpin before and after construction.

Approach

Action #1- Sample aquatic invertebrates to estimate the density and diversity above, at and below the sites of whitewater parks before and after construction.

- Level 1 Action Category: Data collection and analysis
- Level 2 Action Strategy: Research, survey or monitoring- fish and wildlife populations
- Level 3 Action Activity: Abundance determination

Uncompahgre River

On the Uncompahgre River aquatic invertebrate samples were taken at five sites, one below the planned WWP, three within the park, and one above. Of the three sites within the WWP, one was converted from a natural riffle to a run (WWP3) while the other two remained functioning (but smaller) riffles between drop structures. The WWP on the Uncompahgre River consist of six drop structures over about 0.2 miles of river. Replicate macroinvertebrate samples (n = 5) were collected at each site using a 0.086 m^2 Hess sampler with a 350 µm mesh net. Samples were collected in November of 2014 (before construction) and 2015. The replicate samples were collected from the same riffle with predominantly cobble substrate by disturbing the streambed to a depth of approximately 10 cm. Field samples were washed through a 350-µm sieve and organisms preserved in 80% ethanol. Velocity and depth were taken at each Hess sample site to ensure samples were taken from similar riffle habitat. Macroinvertebrate samples were sorted and sub-sampled in the laboratory using a standard USGS 300-count protocol, except that replicates were not composited and each one underwent the protocol (Moulton et al. 2000). All organisms, except for chironomids and non-insects, were identified to genus or species. Chironomids were identified to subfamily and non-insects (e.g., oligochaetes, amphipods) were identified to class. Each replicate sample was processed separately so an average of 1,670 individual specimens were identified at each riffle site. Many more individual specimens were identified from each site compared to standard methods to ensure rare organism were sampled and increase robustness of the comparisons between riffles sites in close proximity within the same stream (Vincent and Hawkins 1996). A summary of macroinvertebrate results is presented in Figures 4-6. Data analysis was still ongoing at the time of this report, but invertebrate density and diversity increased at most sites in 2015. High sampling variation led to relative large standard errors and limited the statistical significance of annual changes. Interestingly, WWP1 site, which is the best remaining riffle within the park, not only had the highest density in 2015 but had the largest increase from 2014-2015. The WWP3 site, which was a riffle pre-construction and a run post-construction, had the lowest density of EPT fauna (Ephemeroptera, Plecoptera, and Trichoptera). Sampling is planned to continue for one more year to evaluate longer term changes in the invertebrate community.

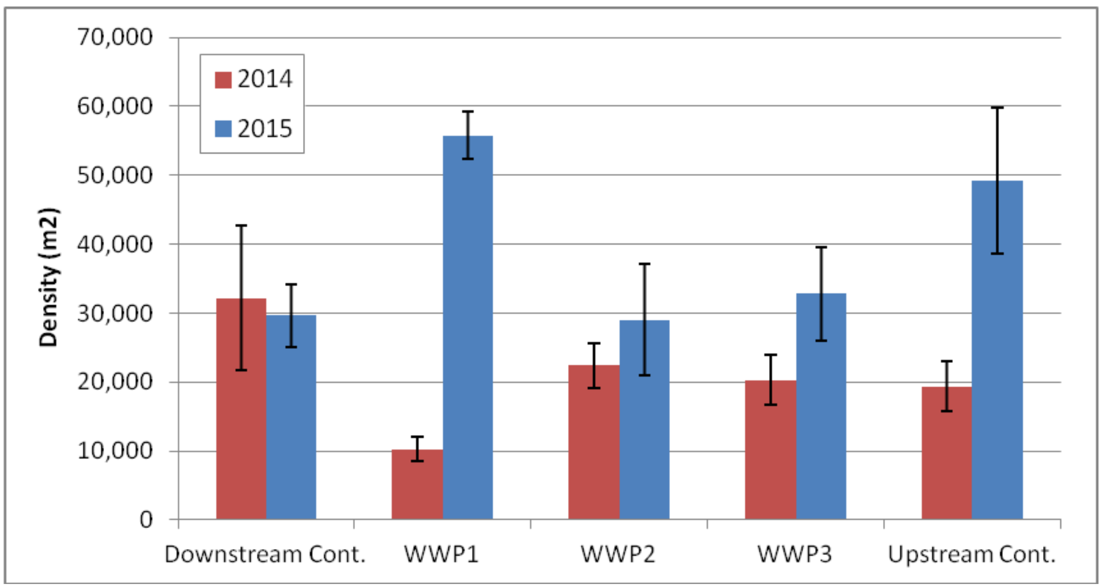

Figure 4. Density of all invertebrates with standard error bars on the Uncompahgre River 2014-2015.

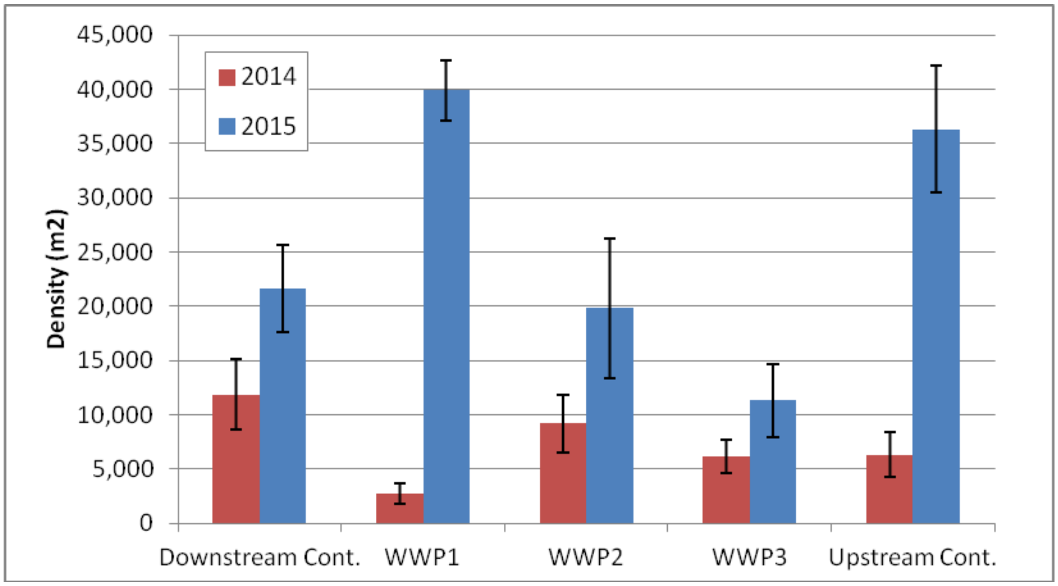

Figure 5. Density of EPT fauna with standard error bars on the Uncompahgre River 2014-2015.

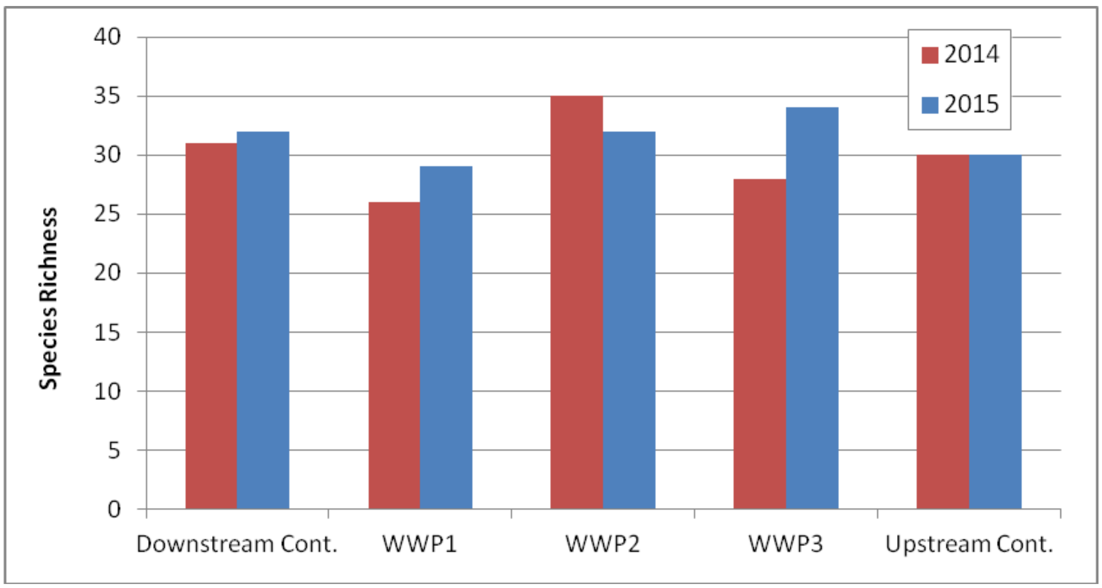

Figure 6. Total species richness on the Uncompahgre River 2014-2015.

To monitor mottled sculpin and brown trout, three electrofishing stations were established concurrent with the invertebrate sites, one below the WWP, one within (that encompassed two invertebrate sampling riffles) and one above. Sites 1 and 3 had habitat improvement projects completed in 2007 aimed at improving fish habitat. The electrofishing stations averaged 704.3 ft (512-849) long. Attempts were made to use block nets, but they could not be kept in place due to high discharge and velocity. Natural stream features like shallow riffles were used as endpoints to best insure closure. Three pass removal electrofishing was completed at each site with a Smith Root VVP15 truck mounted electrofisher and five anodes. All fish were weighed, measured and population estimates were made with the Huggins Closed Capture model in Program Mark (Huggins 1989, White and Burnham 1999). To reduce the bias associated with the size selectivity of electrofishing, capture probabilities were modeled with fish length as a covariate similar to the approach described in Saunders et al. 2011. Four models were built for each species estimating capture probabilities by length, time, time + length, as well as a constant capture probability for all fish and all three passes. The time models allowed for different capture probabilities for the 2nd and 3rd passes compared to the first to address a common source of bias in electrofishing removal models. Model selection was done with AICc and population and parameter estimates were made by model averaging across all four models with AICc weights (Burnham and Anderson 2002). Table 3 summarizes the fish data. Due to high discharge during the 2015 sampling, capture probabilities were generally low leading to low precision of the estimates. Site 1 is particularly high in gradient and water velocities making precise, unbiased estimates difficult. Brown trout numbers increased at all three sampling sites. At the WWP site, brown trout numbers increased post construction while mottled sculpin numbers declined; both effects were significant at the 95% level. All other estimates were statistically similar before and after construction. Sampling is planned to continue for one more year to evaluate longer term changes in the fish community.

Table 3. Fish Sampling Data from the Uncompahgre River 2014- 2015.

	2014 Brown Trout (95% C.I.)	2015 Brown Trout (95% C.I.)	2014 Mottled Sculpin (95% C.I.)	2015 Mottled Sculpin (95% C.I.)
Site 1 (Downstream Control)	49 (±28.9)	75.8 (±681)	85.8 (±143.4)	635.3 (±11,677.4)
Site 2 (Whitewater Park)	18.4 (±5.8)	44.8 (±22.2)	67.9 (±14.9)	16.4 (±9.6)
Site 3 (Upstream Control)	43.2 (±102.4)	68.4 (±16.3)	165 (±950.7)	81.6 (±68.5)

Colorado River

On the Colorado River aquatic invertebrate samples were taken at three sites, one below the WWP, one within and one above. The upper site is two riffles above the WWP site and the lower site is the next downstream riffle, all sites are with a 0.4 mile reach. The WWP on the Colorado River consists of a single large cross channel wave structure so fewer sites were necessary. Unlike the Uncompahgre where post construction riffles remained in the WWP, at Pumphouse the middle site was converted from a run to a drop structure with pools above and below. Replicate macroinvertebrate samples (n = 5) were collected at each site using a 0.086 m^2 Hess sampler with a 350 µm mesh net. The replicate samples were collected from the same riffle with predominantly cobble substrate by disturbing the streambed to a depth of approximately 10 cm. Field samples were washed through a 350-µm sieve and organisms preserved in 80% ethanol. Velocity and depth were taken at each Hess sample site to ensure samples were taken from similar riffle habitat. Macroinvertebrate samples were sorted and sub-sampled in the laboratory using a standard USGS 300-count protocol, except that replicates were not composited and each one underwent the protocol (Moulton et al. 2000). All organisms, except for chironomids and non-insects, were identified to genus or species. Chironomids were identified to subfamily and non-insects (e.g., oligochaetes, amphipods) were identified to class. Each replicate sample was processed separately so an average of 1,379 individual specimens were identified at each riffle site. A much higher number of individual specimens were identified from each site compared to standard methods, to ensure rare organism were sampled and increase robustness of the comparisons between riffles sites in close proximity in the same stream (Vinson and Hawkins 1996). A preliminary summary of macroinvertebrate results is presented in Table 5 and Figure 11. Data analysis was ongoing at the time of this report. Overall invertebrate density, EPT density, and species richness declined at the WWP site post construction. Similar declines were observed at the upstream control site while the downstream control site remained relatively similar across years.

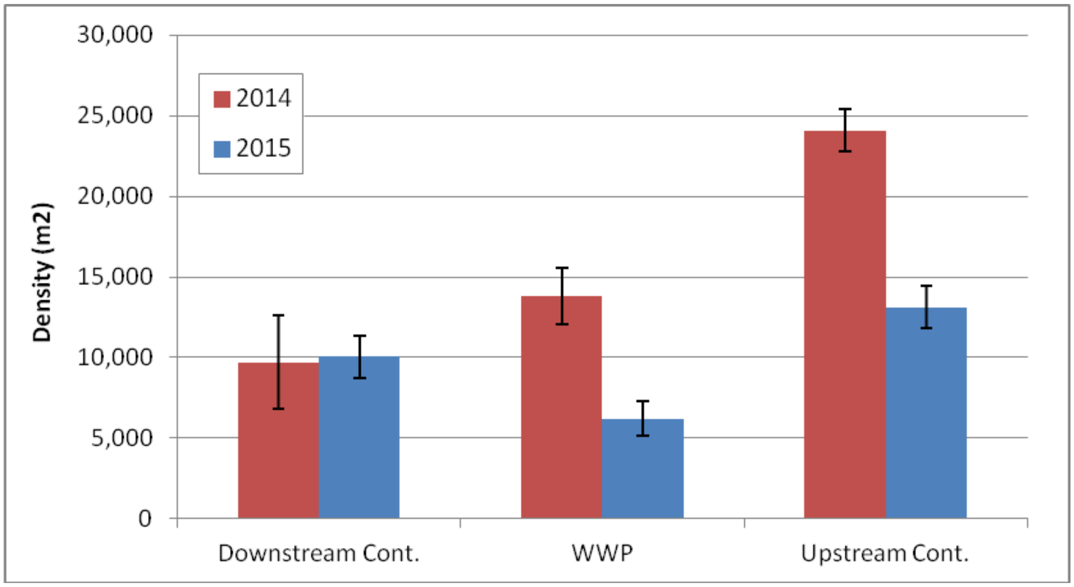

Figure 7. Density of all invertebrates with standard error bars at sites on the Colorado River 2014-2015 at Pumphouse.

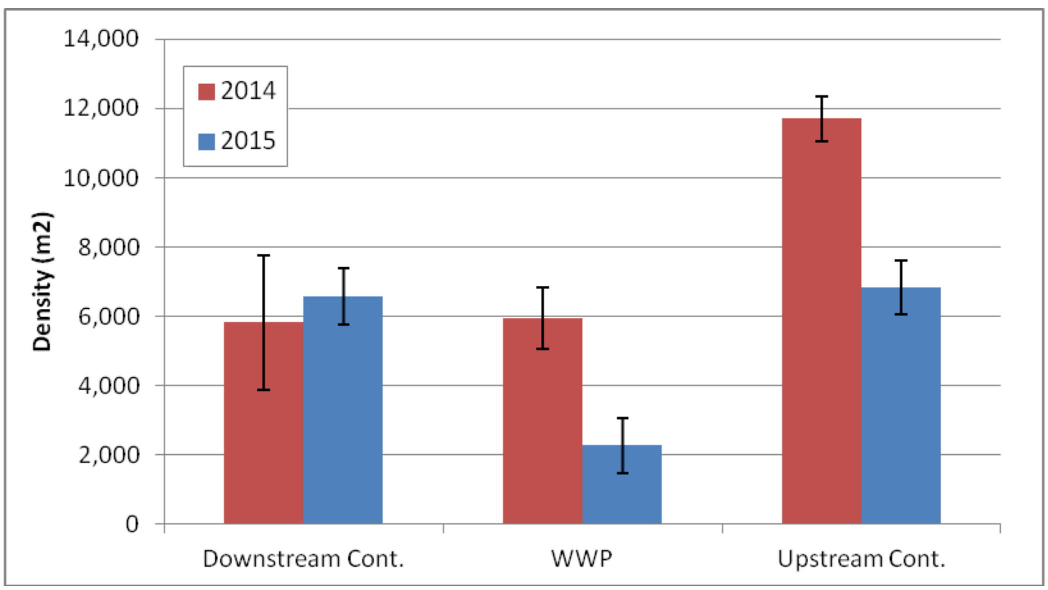

Figure 8. Density of EPT fauna with standard error bars at sites on the Colorado River 2014-2015 at Pumphouse.

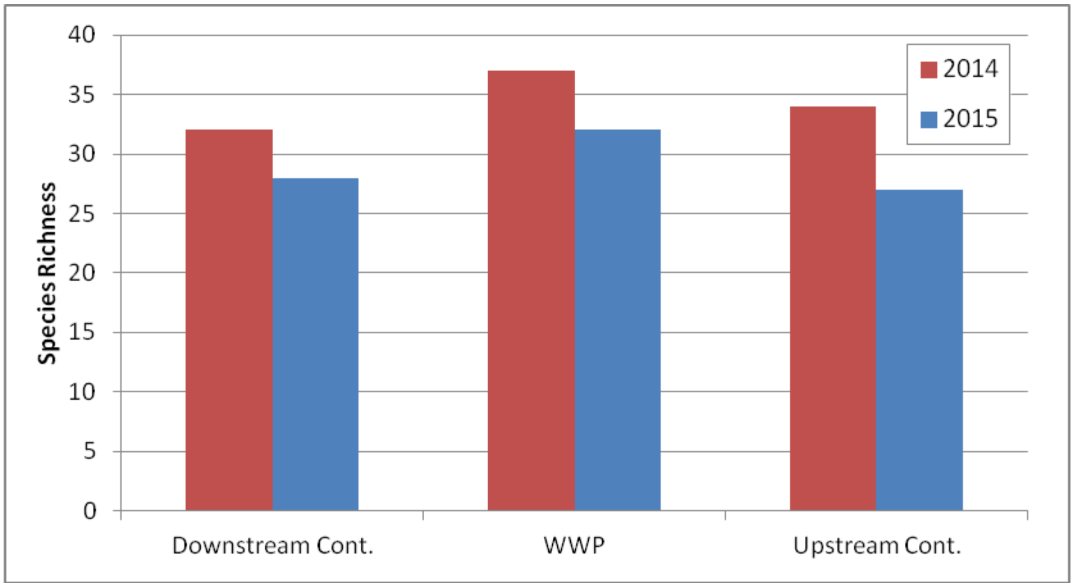

Figure 9. Total species richness at sites on the Colorado River 2014-2015 at Pumphouse.

To monitor trout and mountain whitefish populations around the WPP, mark recapture electrofishing was done with a 16 ft aluminum jet boat and a Smith Root 2.5GPP electrofisher. The sampling reach was 7,085 ft long and averaged 170.5 ft wide and was centered on the WWP structure. Fish population estimates were made with the Huggins Closed Capture Model in Program Mark (Huggins 1989, White and Burnham 1999). Four models were built by estimating capture probabilities by length, species, species + length, as well as a constant capture probability for all fish, identical to a Lincoln Petersen model (Seber 1982). Model selection was done with AICc and population and parameter estimates were made by model averaging across all four models with AICc weights (Burnham and Anderson 2002). In 2015 prior to WWP construction, there were an estimated 5,146±795 brown trout, 98±41 rainbow trout, and 1,077±409 mountain whitefish in the sampling reach. The study reach contained an estimated 3,908 trout per mile and exceeds the Gold Medal standard for biomass and quality fish. In 2016 there were an estimated 4,443±692 brown trout, 79±36 rainbow trout, and 958±363 mountain whitefish in the sampling reach. After construction, estimated brown trout population declined 14%, mountain whitefish declined 11%, and rainbow trout declined 19%. None of the declines were significant at the 95% level. Data analysis is ongoing and comparisons will be made within the study reach above and below the WWP structure. Sampling is planned to continue for one more year to evaluate longer term changes in the fish community.

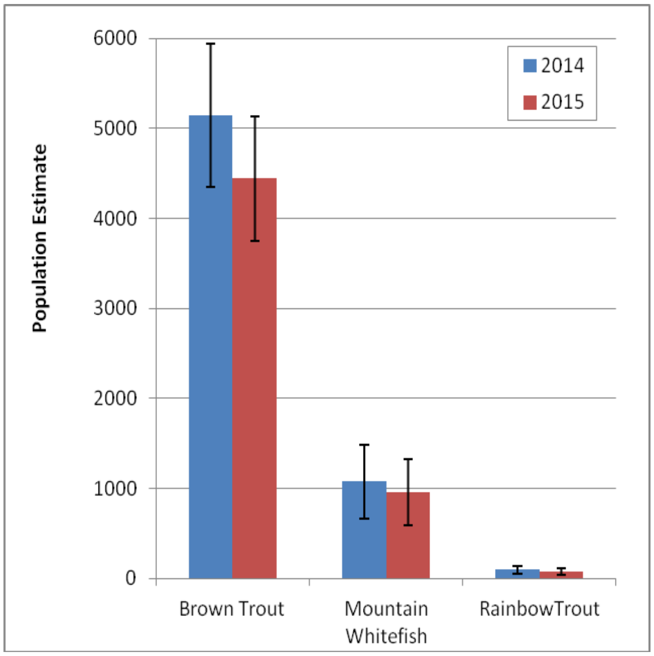

Figure 10. Fish population estimates before and after construction of the whitewater park structure on the Colorado River at Pumphouse.

Action #2- Develop and test population estimation techniques for mottled sculpin.
- Level 1 Action Category: Data collection and analysis
- Level 2 Action Strategy: Techniques development
- Level 3 Action Activity: Fish and wildlife research, survey and management techniques

Mottled sculpin are difficult to effectively sample for quantitative population or density estimates. Their small size, cryptic nature and lack of a swim bladder make them less than ideal subjects for common fisheries techniques like multiple pass removal electrofishing. Because of the size of rivers in which they inhabit, making total population estimates is unlikely or impossible as closure assumptions of most population estimation models are violated. To test sculpin density estimation techniques on large rivers, three electrofishing stations were established on the Colorado River at the Pumphouse recreation area. Because the river averages 170.5 ft wide at this site, it was impossible to electrofish for mottled sculpin across the whole channel and smaller plots along the bank in run habitat were chosen. Site 1 was near BLM Boat Launch #1 above the WWP, site #2 was centered on the WWP structure, and site 3 was near BLM Boat Launch #3, below the WWP. Three pass removal electrofishing was completed at each plot with three Smith Root LR24 backpack electrofishers. To evaluate the closure assumptions of the removal model and check estimated capture probabilities, mottled sculpin were captured before each site was sampled, marked with a caudal fin clip and then released inside each plot. The electrofishing sites averaged 302 feet long and 17.6 feet wide. All fish were measured to the nearest mm and population estimates were made with the Huggins Closed Capture model in Program Mark (Huggins 1989, White and Burnham 1999). To reduce the bias associated with the size selectivity of electrofishing, capture probabilities were modeled with length as a covariate similar to the approach described in Saunders et al. 2011. Four population estimation models were built modeling capture probabilities by fish length, time, time + length, as well as a constant capture probability for all fish and all three passes. The time models allowed for different capture probabilities for the 2nd and 3rd passes compared to the first to address a common source of bias in electrofishing removal models. Model selection was done with AICc and population and parameter estimates were made by model averaging across all four models with AICc weights (Burnham and Anderson 2002).

Mottled sculpin density estimates are presented in Table 4. Capture probabilities were average (0.42-0.54) and declined with subsequent passes (Figure 12). Measured capture probabilities were lower than the model averages estimates (Figure 13) indicating there was a violation of the closure assumption and/or individual heterogeneity in capture probabilities. These issues are well known with removal models with electrofishing but can be overcome in some instances (i.e. with salmonids) with high capture probabilities, modeling capture probabilities over time and by using length as a covariate to model capture probabilities (Riley and Fausch 1992, Saunders et al. 2011, Petersen et. al 2004). Because mottled sculpin are small, cryptic, lack a swim bladder and because we could not ensure closure, our density estimates are likely biased low. However, it does appear that the biases are relatively small and all in the same direction (low) so comparisons of relative density between these sites (all collected with same methods and equipment) should be valid. Petersen et al. (2004) states that, "at relatively high first-pass efficiencies (>35%) and low reduction in efficiency per pass (<1.10), the removal estimates were nearly unbiased." Riley and Fausch (1992) found that the negative bias for estimates decreased as initial capture probability increased and for three-pass estimates confidence interval coverage was actually better at low population sizes because of the larger standard deviations associated with small samples. More work is necessary to determine appropriate methods for robust population estimates for mottled sculpin in large rivers.

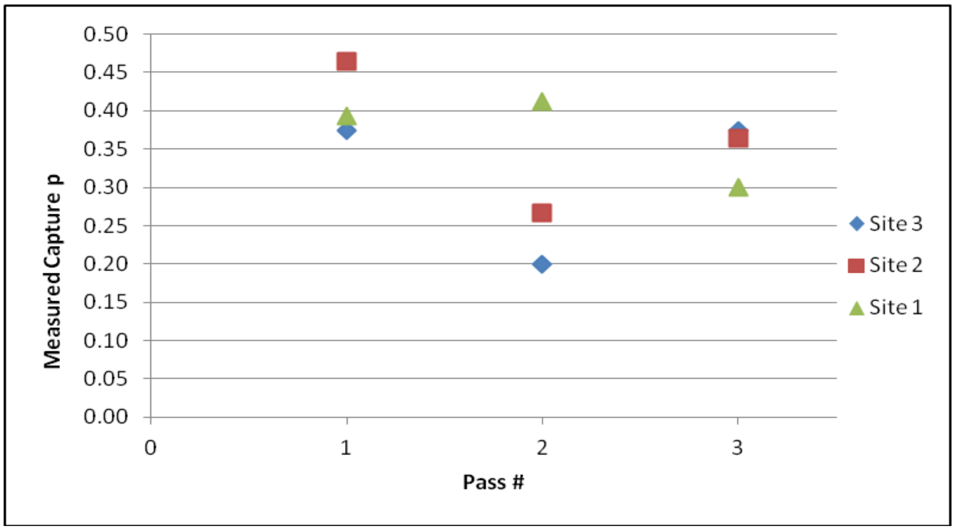

Figure 11. “Measured” capture probability across passes for mottled sculpin sites on the Colorado River. Measured capture probability was calculated by comparing the number of marked fish captured in a pass to the number available.

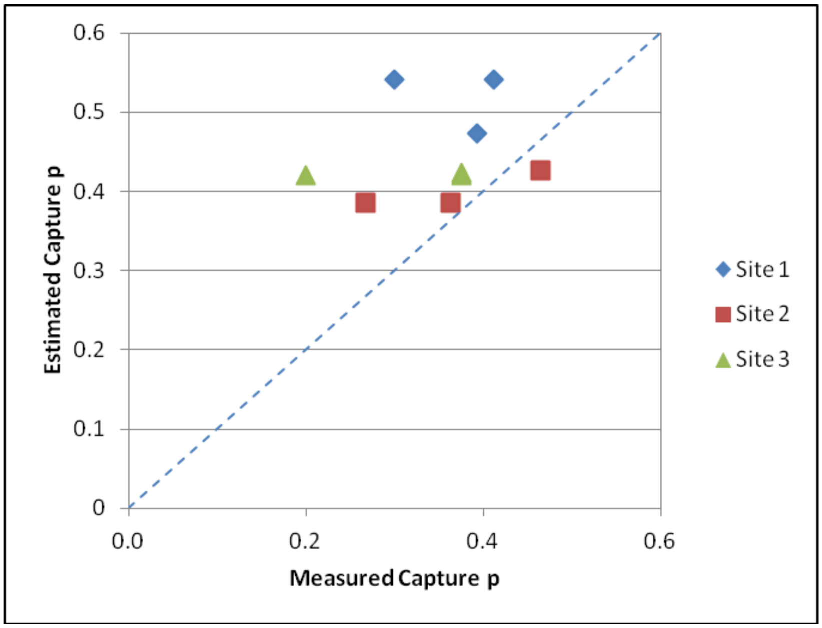

Figure 12. "Measured" capture probability compared to estimated capture probability for mottled sculpin in the Colorado River. Measured capture probability was calculated by comparing the number of marked fish captured in a pass to the number available. Estimated capture probability was from the model averaged results of the four models built in the Huggins Close Capture model in Program Mark.

Action #3- Sample mottled sculpin density at impacted and control sites before and after construction of whitewater parks.

- Level 1 Action Category: Data collection and analysis
- Level 2 Action Strategy: Research, survey or monitoring- fish and wildlife populations
- Level 3 Action Activity: Abundance determination

Mottled sculpin were sampled from representative sites above, at and below the whitewater park structures. The sampling reaches were concurrent with the invertebrate sampling riffles in the invertebrate study (Action #1) and were 101, 154, and 152 feet long with an average width of 17.7 ft. Three pass removal electrofishing with a concurrent mark recapture estimate was conducted to evaluate assumptions on capture probabilities between passes. Fish were measured to the nearest millimeter and density estimates were made for each site with the Huggins Closed Capture model in Program Mark and are presented in Table 4 (Huggins 1989, White and Burnham 1999). Mottled sculpin density dropped at all sites in 2015, only significantly (95%) at site 3. Monitoring will continue for three years after construction to evaluate changes over time.

Table 4. 2015 Mottled Sculpin Density Estimates from the Colorado River at Pumphouse.

	Capture Probability (SE)			Density	95% C.I.
	Pass 1	Pass 2	Pass 3	(Fish/Acre)	±
Launch 1	0.426 (0.06)	0.461 (0.12)	0.461 (0.12)	5,614.069	1,874.574
Wave	0.689 (0.04)	0.698 (0.06)	0.698 (0.06)	2,886.264	112.0879
Launch 3	0.667 (0.05)	0.736 (0.07)	0.736 (0.07)	2,312.075	143.7122

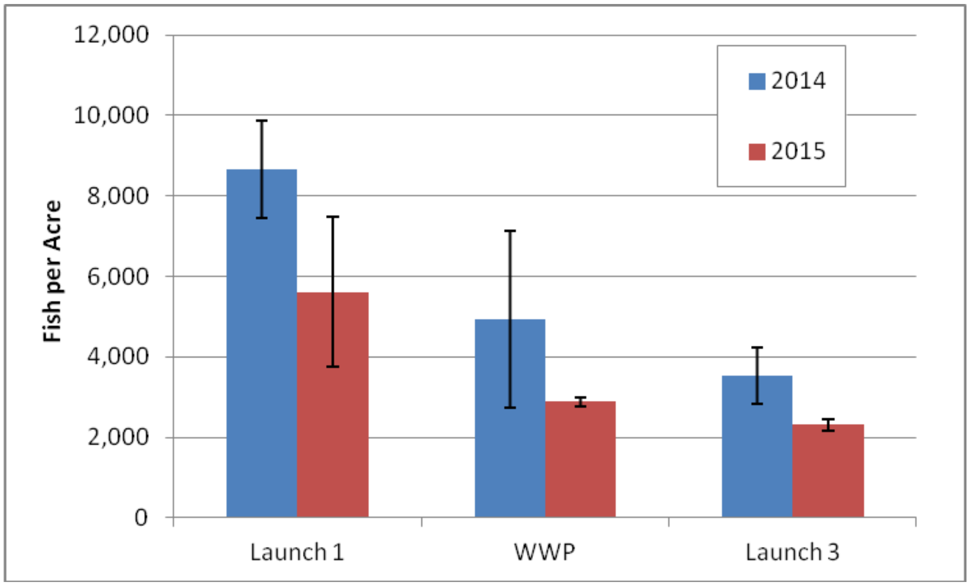

Figure 13. Mottled sculpin density estimates and 95% confidence intervals on the Colorado River at Pumphouse before and after construction of the whitewater park structure.

References

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach, 2nd edition. Springer-Verlag, New York.

Fox, B. 2013. Eco-evaluation of whitewater parks as fish passage barriers. Master's thesis. Colorado State University, Fort Collins, Colorado.

Huggins, R. M. 1989. On the statistical analysis of capture-recapture experiments. Biometrika 76:133–140.

Kolden, E. 2013. Modeling in a three-dimensional world: whitewater park hydraulics and their impact on aquatic habitat in Colorado. Master's thesis. Colorado State University, Fort Collins, Colorado.

Kondratieff, M.C. 2012. Stream habitat investigations and assistance. Colorado Parks and Wildlife Progress Report, Federal Aid in Sportfish Restoration F-161-R18n Progress Report, Fort Collins.

Moulton, S.R., II, Carter, J.L., Grotheer, S.A., Cuffney, T.F. & Short, T.M. 2000. Methods of analysis by the U. S. Geological Survey national water quality laboratory: processing, taxonomy, and quality control of benthic macroinvertebrate samples. Open-File Report 00-212, U.S. Geological Survey, Washington D.C.

Nehring, R.B. 2011. Colorado River aquatic resources investigations. Colorado Division of Wildlife, Federal Aid in Sportfish Restoration, Project F-237R-18, Final Report, Fort Collins.

Peterson, J.T., R.F. Thurow and J.W. Guzevich. 2004. An evaluation of multipass electrofishing for estimating the abundance of stream-dwelling salmonids. Transactions of the American Fisheries Society 133:2, 462-475.

Riley, S. C., and K. D. Fausch. 1992. Underestimation of trout population size by maximum likelihood removal estimates in small streams. North American Journal of Fisheries Management 12:768–776.

Saunders W.C., K.D. Fausch, and G.C. White. 2011. Accurate estimation of salmonid abundance in small streams using nighttime removal electrofishing: an evaluation using marked fish. North American Journal of Fisheries Management 31:403-415.

Seber, G. A. 1982. The estimation of animal abundance and related parameters, Second edition. Charles Griffin and Company, Ltd, London.

Vinson, M.R. and C.P. Hawkins. 1996. Effects of sampling area and subsampling procedure on comparisons of taxa richness among streams. Journal of the North American Benthological Society 15(3): 392-399.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46(Supplement): 120–139.

Job No. 3. Colorado River Water Project Mitigation and Ecology Investigations

Job Objective: Investigate the ecological impacts of stream flow alterations on aquatic invertebrates and fish of the Colorado River and assist in the planning and evaluation of mitigation efforts to address those impacts.

Need

Trans-basin and local water use divert approximately 67% of the flow of the upper Colorado River and future projects will deplete flows further. Previous work under Project F-237 identified ecological impacts of streamflow reductions and a main stem reservoir (Windy Gap) on the invertebrates and fish of the river. Native mottled sculpin, once common are now rare or extirpated immediately below the reservoir. The health of the invertebrate community declined after the construction of Windy Gap; there has been a 38% reduction in the diversity of aquatic invertebrates from 1980 to 2011 and 19 species of mayflies, 4 species of stoneflies and 8 species of caddisflies had been extirpated from the sampling site below Windy Gap (Erickson 1983, Nehring 2011). Previous work under F237 Kowalski (2014) included mottled sculpin sampling above and below WGR (as well as other impoundments of the upper Colorado River) corroborated patterns of sculpin distributions and established that sculpin have been functionally extirpated from the Colorado River below WGR. Once common in this reach, sculpin are now absent for many miles downstream of WGR but become increasingly common as tributaries increase streamflows as depletions are offset by reservoirs releases to satisfy downstream senior water rights.

Increased trans-basin water diversions are planned and there are ongoing discussions on how to implement mitigation measures to reduce the impact of the new projects. A large component of the mitigation plan is taking Windy Gap Reservoir off channel by constructing a bypass around the reservoir.

This would reconnect the river and ameliorate various impacts of a large on channel impoundment but would not reduce the impacts of water withdrawals from the system. The planned bypass channel offers a unique opportunity to evaluate the effects reconnecting the river around the reservoir as well as investigate if mitigation measures can offset the impacts of large water diversions on the ecology of the river. The need for this project is to assist stakeholder groups in planning mitigation efforts and then to evaluate those efforts (if they are completed). This need is evident in the "Key Habitats" designation of riparian/wetlands systems and West Slope rivers identified in Colorado State Wildlife Action Plan. The need is also highlighted by the description of the important salmonid sport fisheries in the Colorado River Basin Aquatic Management Plans as well as the designation of the Colorado River under the Gold Medal program.

Objectives

1. Assist CPW staff as needed in planning of mitigation efforts.
2. Continue monitoring invertebrate and fish populations of the upper Colorado and Fraser Rivers.
3. Evaluate the effectiveness of mitigation measures in restoring and improving the ecological function of the Colorado River in Middle Park (if they are completed).

Approach

Action #1- Provide technical assistance as needed to stakeholders in the Upper Colorado cooperative effort.

- Level 1 Action Category: Technical assistance
- Level 2 Action Strategy: Technical assistance
- Level 3 Action Activity: With individuals or groups involved in resource management decision making

Provide technical assistance as needed to stakeholders in the Upper Colorado cooperative effort.

Coordination is continuing among project stakeholders including CPW personnel, the Upper Colorado River Learning by Doing Management Committee, Windy Gap Technical Assistance Committee (TAC), Trout Unlimited, and private landowners downstream of Windy Gap. The two most relevant efforts to this research are the bypass channel planning and construction being handled mostly by the TAC and the planned stream habitat improvement that CPW will be heavily involved with. In the future, coordination with all of the stakeholders is planned to continue under project F237 and increase as projects move from the planning and fundraising stage to implementation.

Action #2- Sample aquatic invertebrates and fish above and below Windy Gap Reservoir to collect baseline data before mitigation projects occur.

- Level 1 Action Category: Data collection and analysis
- Level 2 Action Strategy: Research, survey or monitoring- fish and wildlife populations
- Level 3 Action Activity: Baseline inventory

A large amount of baseline data has already been collected previously under Project F-237. If mitigation measures are decided on and implementation appears eminent, routine sampling will continue at historic sites. The exact sampling protocols and sampling sites will depend on the specifics of mitigation measures and will be worked out in cooperation with other researchers. Currently it appears that the largest mitigation measure, a bypass channel around Windy Gap Reservoir could be constructed as early as 2018.

References

Erickson, R.C. 1983. Benthic field studies for the Windy Gap study reach, Colorado River, Colorado, fall, 1980 to fall, 1981. Prepared for The Northern Colorado Water Conservancy District, Municipal Sub-District.

Kowalski, D.A. 2014. Colorado River aquatic resources investigations. Colorado Division of Wildlife, Federal Aid in Sportfish Restoration, Project F-237-R21, Progress Report, Fort Collins.

Nehring, R.B. 2011. Colorado River aquatic resources investigations. Colorado Division of Wildlife, Federal Aid in Sportfish Restoration, Project F-237R-18, Final Report, Fort Collins.

Job No. 4. Gunnison River Aquatic Invertebrate and Pesticide Studies

Job Objective: Investigate the potential impacts of the application of common mosquito control insecticides on aquatic invertebrates.

This project has been suspended for budgetary reasons and in response to management needs. Water sampling for permethrin was cost prohibitive and CPW aquatic senior staff identified a more pressing management need for a project on the effects of bacterial kidney disease on sportfish in Colorado. All available time and resources for Job #4 will be dedicated to this issue in the future.

Job No. 5. Gunnison Tunnel Electric Fish Guidance System Evaluation

Job Objective: Evaluate the effectiveness of an electric fish guidance system on the South Canal of the Gunnison River

Need

The Gunnison Tunnel diverts an average of 360,600 acre feet of water annually from the Gunnison River, a Gold Medal trout fishery, and fish loss in the canal has been an ongoing concern. The construction of several hydropower plants on the canal was expected to increase mortality of entrained fish so an electric fish guidance system was installed at the diversion structure in 2012. The fish guidance system was a novel design and this type of system had not been tried in the orientation it was applied on the Gunnison. Fish entrainment in irrigation canals is a large and generally unquantified problem across the west and fish guidance technology is more commonly being applied to address the problem. The need for this specific project was to provide a rigorous evaluation of the effectiveness of this type of system. This need is apparent in the “Key Habitats” designation of riparian/wetlands systems and West Slope Rivers identified in Colorado State Wildlife Action Plan as well as the descriptions of the important salmonid sport fisheries and Gold Medal designation in the Gunnison Basin Aquatic Management Plans.

Objectives

1. Monitor entrainment of fish in the South Canal.
2. Evaluate the effectiveness of the electric guidance system by marking fish in the Gunnison River and sampling in the South Canal.

Approach

All sampling is now complete for Job #5 and a final report is currently being finalized. Results have been presented at the 2015 American Fisheries Society meeting in Portland Oregon (Kowalski and Gardunio 2015).

References

Kowalski, D.A. and E. Gardunio. 2015. Evaluation of an electric fish guidance system on the South Canal of the Gunnison River, Colorado. 2015 Annual Meeting of the Colorado/Wyoming Chapter of the American Fisheries Society. Fort Collins, Colorado. February 25, 2015.

Job No. 6. Technical Assistance

Job Objective: Provide information and assistance to aquatic biologists, aquatic researchers and managers in a variety of coldwater ecology applications.

Need

Aquatic researchers and aquatic biologist work closely to investigate and manage the aquatic resources of Colorado. The need for this job is to cooperate closely with biologist and other stakeholders to disseminate results from aquatic research projects and to more effectively and efficiently conduct meaningful research that addresses management needs.

Objectives

1. Provide technical assistance to biologists, managers, researchers, and other stakeholders as needed.

Approach

Action #1- Provide technical assistance as needed.

- Level 1 Action Category: Technical assistance
- Level 2 Action Strategy: Technical assistance
- Level 3 Action Activity: With individuals or groups involved in resource management decision making

Technical assistance is provided as necessary and requested by biologist and other stakeholders. Current technical assistance project include setting up an invertebrate monitoring program to evaluate the success of re-introducing the stonefly *Pteronarcys californica* to the Arkansas River basin, developing more effective and efficient methods of trout fry estimation using distance sampling models and identifying a new method to simplify using length covariates to improve trout population estimation.