Filename: Brown Trout Redd Surveys 2018
Version 1.0
Chapter X for Jordan River Report 2019

Jordan River Fisheries Studies

Part 1: Upper Jordan River Brown Trout Redd Surveys

<u>Draft Report To:</u>

Wasatch Front Water Quality Council

Salt Lake City, UT

<u>By:</u>

David C. Richards, Ph.D.

OreoHelix Consulting

Vineyard, UT 84058

email: oreohelix@icloud.com

phone: 406.580.7816

January 2, 2019

SUMMARY

We conducted Jordan River fisheries related research for several years. This report focuses on the upper Jordan River studies and primarily Brown Trout redd surveys. We surveyed 13 km of the upper Jordan River for Brown Trout redds during spawning season in late 2018. We did not find any evidence of active Brown Trout spawning or redd building. We used statistical models to conclude that spawning adult Brown Trout were most likely absent from the study area or at densities less than approximately one per 4 km or more of river. Most of the upper Jordan River substrate superficially appears to be ideal spawning habitat, gravel riffles, but on closer inspection, is embedded with fine sediments that preclude successful spawning. A major, intentional toxic spill of fine sediments from neighboring canals into sections of the study area occurred during our survey and apparently these spills occur on a regular basis. We conclude that chronic sedimentation of fines (< 0.06 mm) is one of the major limiting factors of Brown Trout population viability in the upper Jordan River and that much more research is needed to understand the ecology of fish assemblages in the river, particularly in relation to water quality standards.

Table of Contents

List of Figures

List of Tables

List of Appendices

Introduction

We reported in the Jordan River Report Chapter titled: Jordan River Macroinvertebrate Assemblages: Preliminary Findings that:

> "The Jordan River is a highly polluted, highly regulated, irrigational conveyance canal, often severely dewatered via pumps and diversion dams. The river has been known as the most polluted river in Utah and perhaps, the country (Giddings and Stephens 1999). Ecologically, the river has undergone what is known as 'catastrophic ecosystem shift' (Scheffer et al. 2001), and 'ecological hysteresis' (Scheffer and Carpenter 2003). The Jordan River is now a severely impaired analog river ecosystem and can never regain its past condition (Richards 2018b, Dakos et al. 2015)."

In this chapter, we examine fish assemblages in the Jordan River. The chapter is in two sections: 1) the upstream portion of the river upstream of I-215, and 2) the downstream lower portion of the river near Legacy Preserve and the State Canal.

The focus of our fisheries studies in the upper Jordan River was a survey of Brown Trout (*Salmo trutta*) spawning redds in late autumn-early winter, 2018. Additional research in the upper Jordan River is highlighted in the Discussion section. The second portion of the chapter will be made available shortly.

Brown Trout redd surveys, 2018

Figure 1. Data collecting for Brown Trout redd surveys, mollusk surveys, and macroinvertebrate sampling late autumn-early winter 2018. Site is an ongoing restoration site known as 'Big Bend' on the Jordan River approximately 200 meters downstream of 9000 South. Note gravel/sand/fine sediment banks on river left which naturally provide sediments to the river. Riffles are made of mostly embedded gravels, not cobbles. River levels are typically low during this time period exposing potential Brown Trout spawning habitat.

Justification

Although non-native Brown Trout (BT) are predators of native fishes, including cutthroat trout, and are considered to be one of the most ecosystem damaging invasive species, UDWQ tentatively considers their residency in the Jordan River as indicative of 'cool-water' beneficial use designation. Determining resident status is not straightforward and the presence or absence of early life stages of BT in the study site could potentially influence use designation. One of the most useful measures of determining BT 'residency', particularly early life stage presence/absence is from observing BT redds (Figure 1; Figure 2), eggs, and larvae. Many trout biologists consider counting BT redds to be more efficient for making population estimates than electroshocking and netting (Grost et al. 1990).

Methods

Background

Brown trout typically build redds (Figure 2) in late autumn when temperatures drop from 12 to 5 ^{0}C (Grost et al. 1990; Jones and Ball 1954; and Smith 1973; Spoon 1985). Temperatures in this range usually occur starting in November and continue through January in the reaches of the upper Jordan River upstream of 7800 South (Figure 3; Figure 4) and December in the lower reaches of the upper Jordan River downstream of 7800 South (Figure 5).

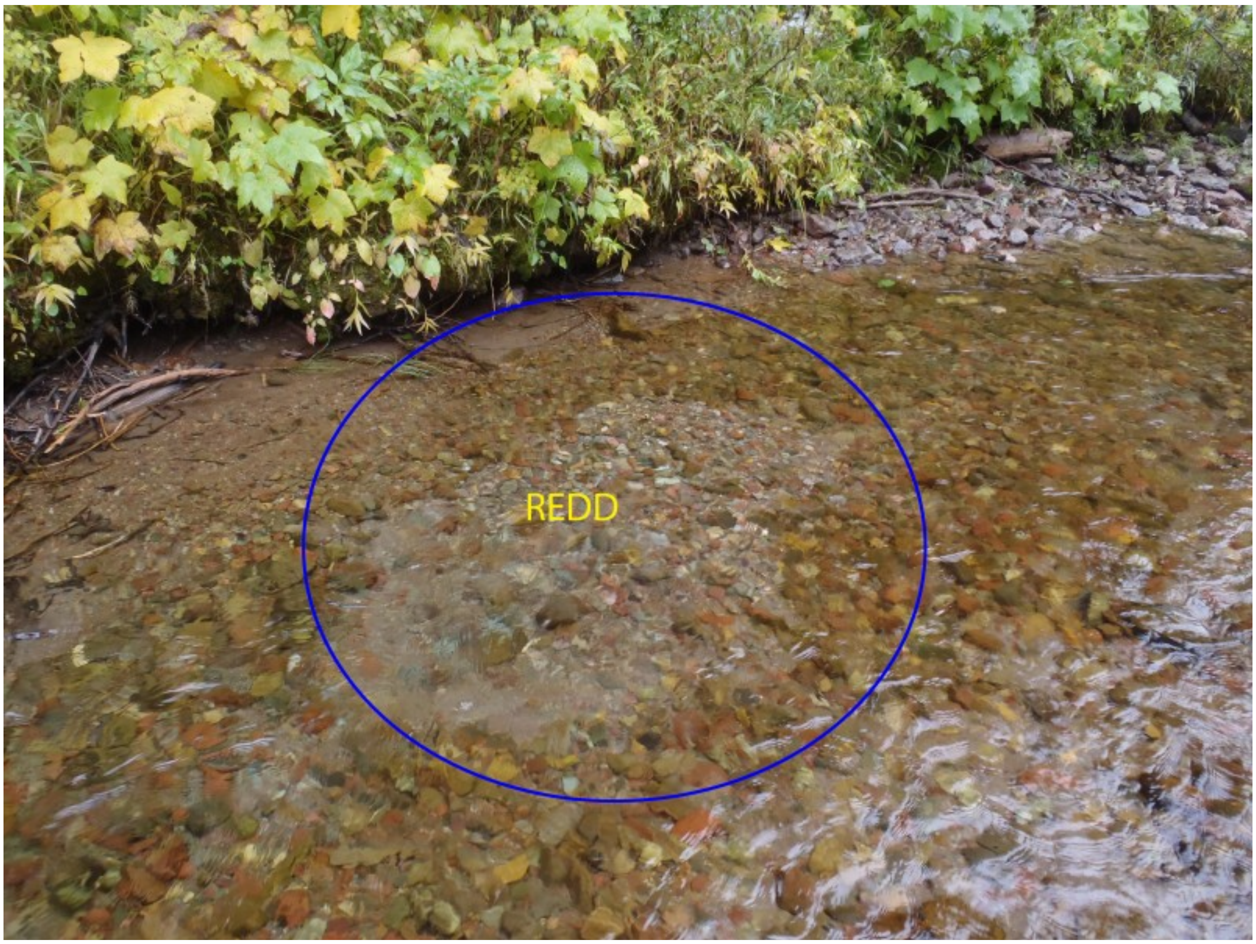


Figure 2. Brown Trout redd. From: https://currentseam.files.wordpress.com/2014/03/photo-of-trout-redd.jpg

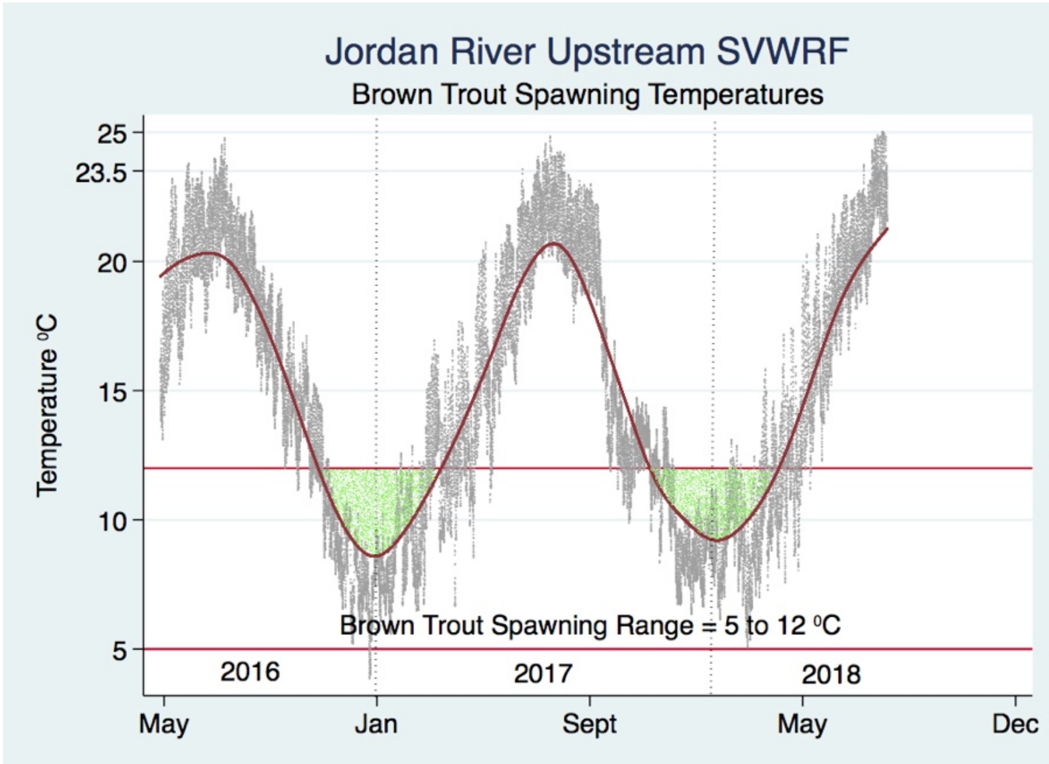


Figure 3. Brown trout spawning periods (green shading) upstream of South Valley Water Reclamation Facility, approximately 7800 South.

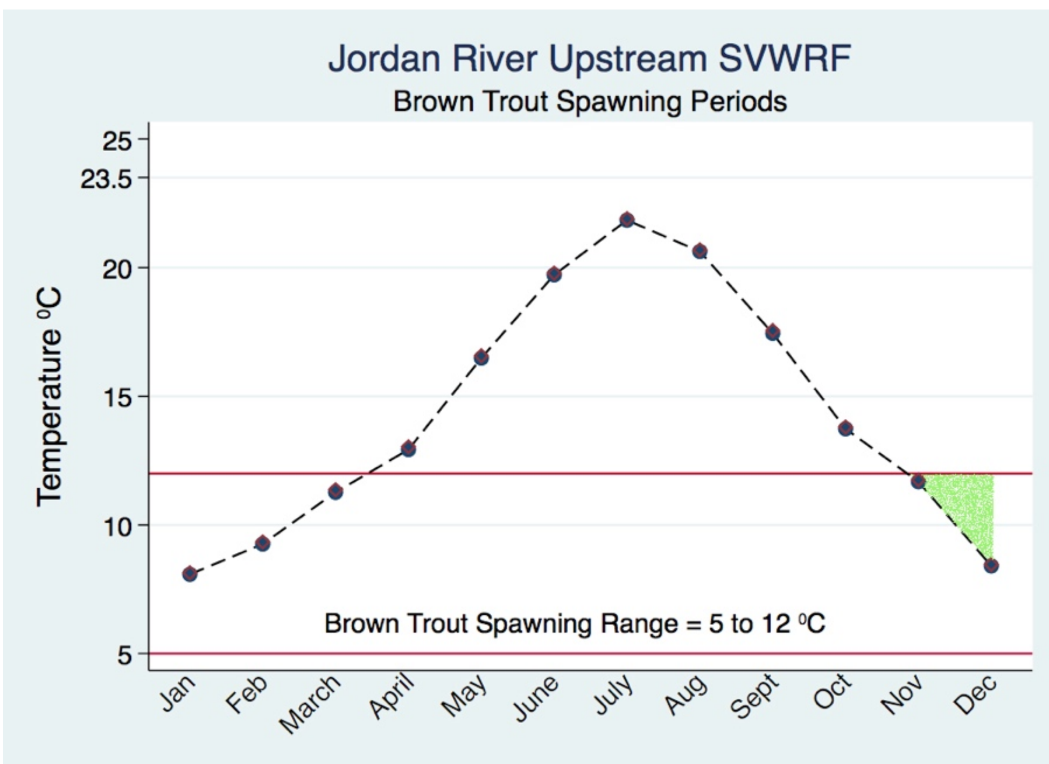


Figure 4. Brown Trout spawning period (green shaded area) upstream of South Valley Water Reclamation Facility based on mean and 99% CI estimates of temperatures.

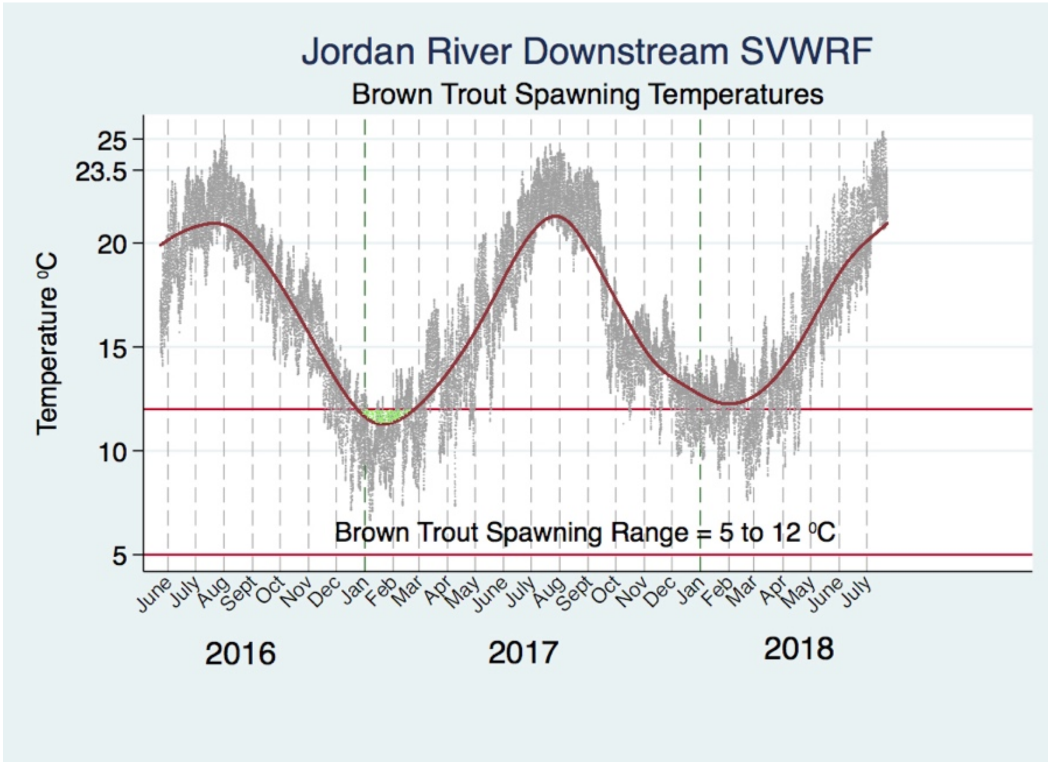


Figure 5. Brown trout spawning periods (green shading) downstream of South Valley Water Reclamation Facility.

BT usually become sexually mature at 3 years but sometimes 2, 4, and 5 years. Eggs laid in redds typically hatch the following spring depending on temperatures (e.g. in about 50 days at 50 degrees F). (Brown 1971). Trained surveyors can relatively easily identify redds by clean substrate and the presence of a tailspill and pit (Figure 6).

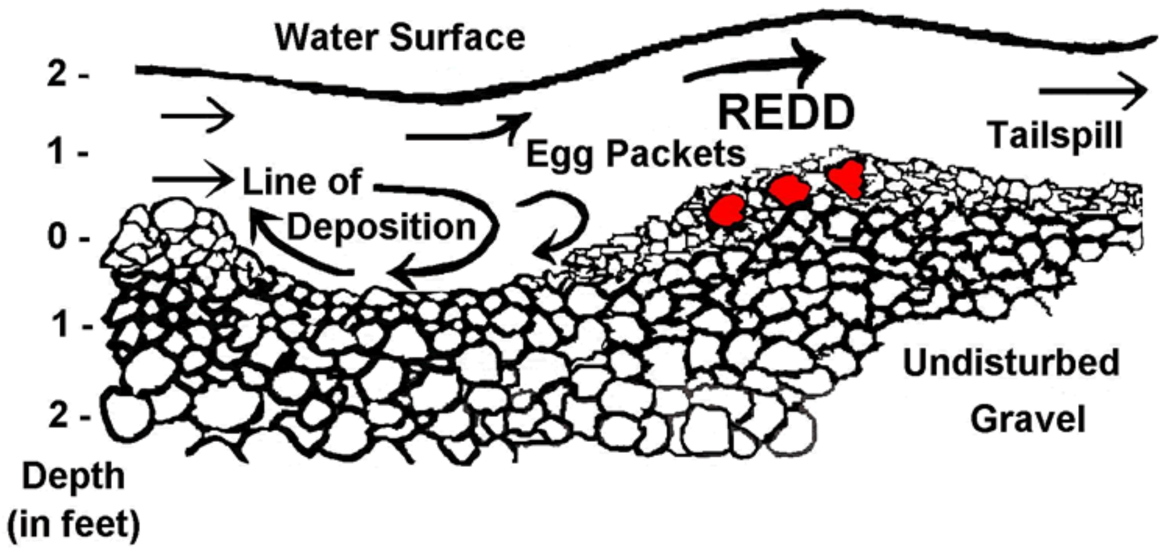


Figure 6. Diagram of typical Brown Trout redd. From: [*https://northyorkmoorsnationalpark.files.wordpress.com/2015/12/redd_diagram.gif*](https://northyorkmoorsnationalpark.files.wordpress.com/2015/12/redd_diagram.gif)

BT prefer to build redds in shallow stream reaches of fast-moving water and coarse gravel substrate near cover (Witzel and MacCrimmon 1983, Grost et al 1990, and Blain et al. 2018). Table 1 lists estimated surface characteristics of BT redds.

Table 1. Surface characteristics of BT redds[1]

Total red length	70 to 260 cm
Tailspill length	40 to 220 cm
Maximum red width	30 to 120 cm
Mean velocity	5 to 80 cm/s
Minimum velocity requirement	15-20 cm/s
Minimum depth criteria	12-24 cm
Substrate size	6 -74 mm (fine to coarse gravel)

[1] Based on Grost et al. (1990); Jones and Ball (1954); and Smith (1973)

Based on the above background information and our experience surveying redds in other rivers and streams throughout the western U.S.; we visually surveyed sections of the upper Jordan River for BT redds in mid-November to early- December 2018. The farthest upstream location in the survey was at 40.489571° N; -111.931953° downstream of Bluffdale bridge crossing, and the farthest downstream location of the survey was 40.638219° N; -111.921873° W, just upstream of I-215 bridge crossing. We used aquascopes (Figure 7) where water depths were approximately > 24 cm < 100 cm, or we used unaided visualization when depths were approximately < 24 cm. Pool habitat > 1.0 m were cursorily surveyed because pools were invariably filled with fine sediments, had low velocities, and assumed not to be suitable spawning habitat. We only surveyed locations when visibility was adequate enough to see the bottom substrate.

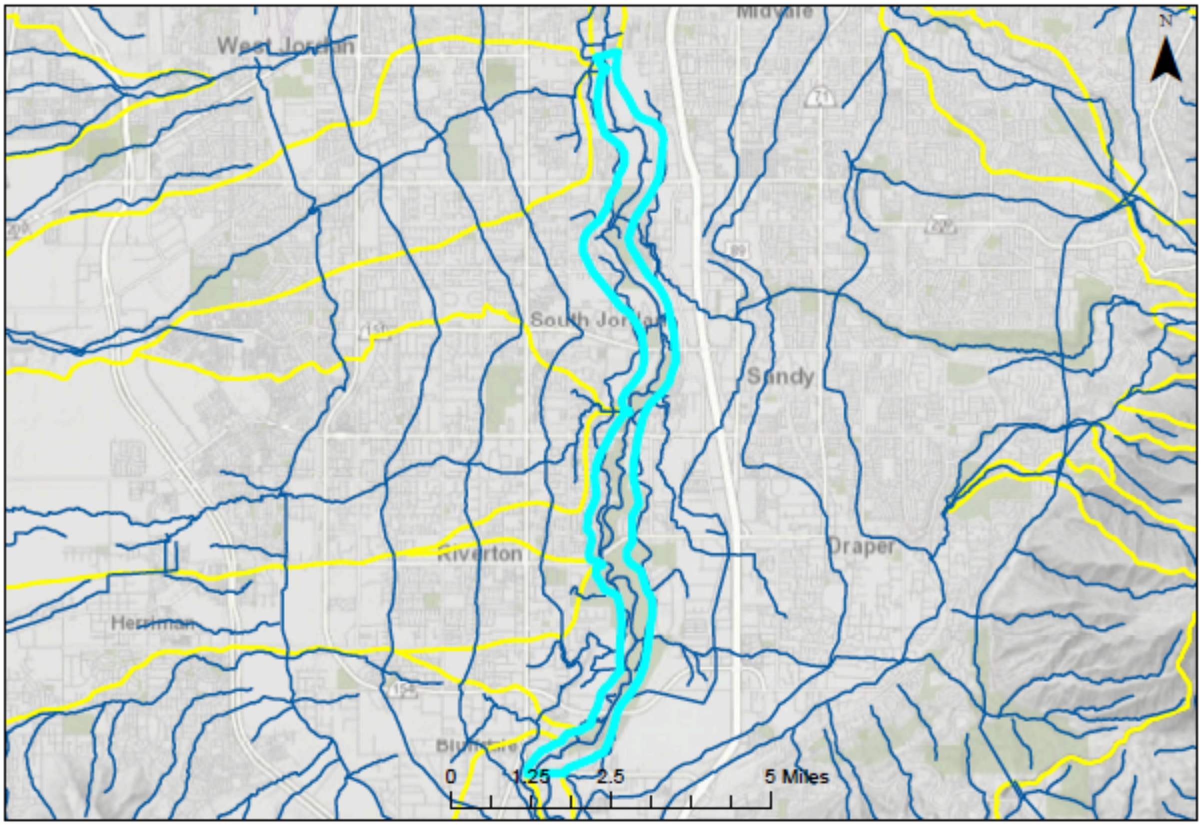
Figure 7. One type of aquascope used to visually survey study site for Brown Trout redds.

One to three surveyors (two WFWAC technicians and/or a volunteer, and Dr. Richards) walked abreast moving upstream to visually locate redds. The goal was to focus our survey on prime BT spawning redd habitat (see above discussion; Table 1) starting in DWQ Assessment Unit- 6 (Figure 8) in November and then Assessment Unit- 5 (Figure 9) in December. We started in Unit-6 (upstream sites) because temperatures are typically lower and closer to preferred spawning temperatures in this section than in Unit-5 (Figure 3; Figure 4; and Figure 5). Habitat characteristics were also measured and recorded.

Beneficial Uses and Water Quality Assessment Map

utah automated geographic reference center

8/8/2016



Assessment Unit Name: Jordan River-6
Unit ID: UT16020204-006
Unit Description: Jordan River from 7800 South to Bluffdale at 14600 South
Beneficial Uses: Use Class 2B = Infrequent primary contact recreation (e.g. wading, fishing); Use Class 3A = Cold water fishery/aquatic life; Use Class 4 = Agricultural uses (crop irrigation and stock watering)
RIVER_MILE: 12.544
Watershed Management Unit: Jordan River
2014 Assessment: Assessment Category 5 = Impaired: TMDL required (303d list)
Beneficial Use: Cause of Impairment: Use Class 3A: Dissolved Oxygen, OE Bioassessment, Selenium, Temperature; Use Class 4: Total Dissolved Solids
TMDL Required: 303d Cause of Impairment: Dissolved Oxygen, OE Bioassessment, Selenium, Temperature, Total Dissolved Solids
TMDL Approved: Cause of Impairment:
Aquatic Habitat Impairment:
CAT_2010: 5
CAUSE_2010: Use Class 3A: Water Temperature; Use Class 4: Total Dissolved Solids
TMDL_REQ10: Water Temperature, Total Dissolved Solids, poor Benthic Macro-invertebrate Community
TMDL_APP10: n/a
HAB_IMP_10: n/a
Protected: Secondary Contact Recreation, Cold Water Aquatic Life, Agricultural Uses
Blue Ribbon Fishery: none
TMDL Information:
Anti-Degradation Category: Category 3 = Water quality degradation may be allowed outside USFS boundary pursuant to antidegradation review

Figure 8.Utah Division of Water Quality's Beneficial Uses and Water Quality Map for Assessment Unit: Jordan River-6.

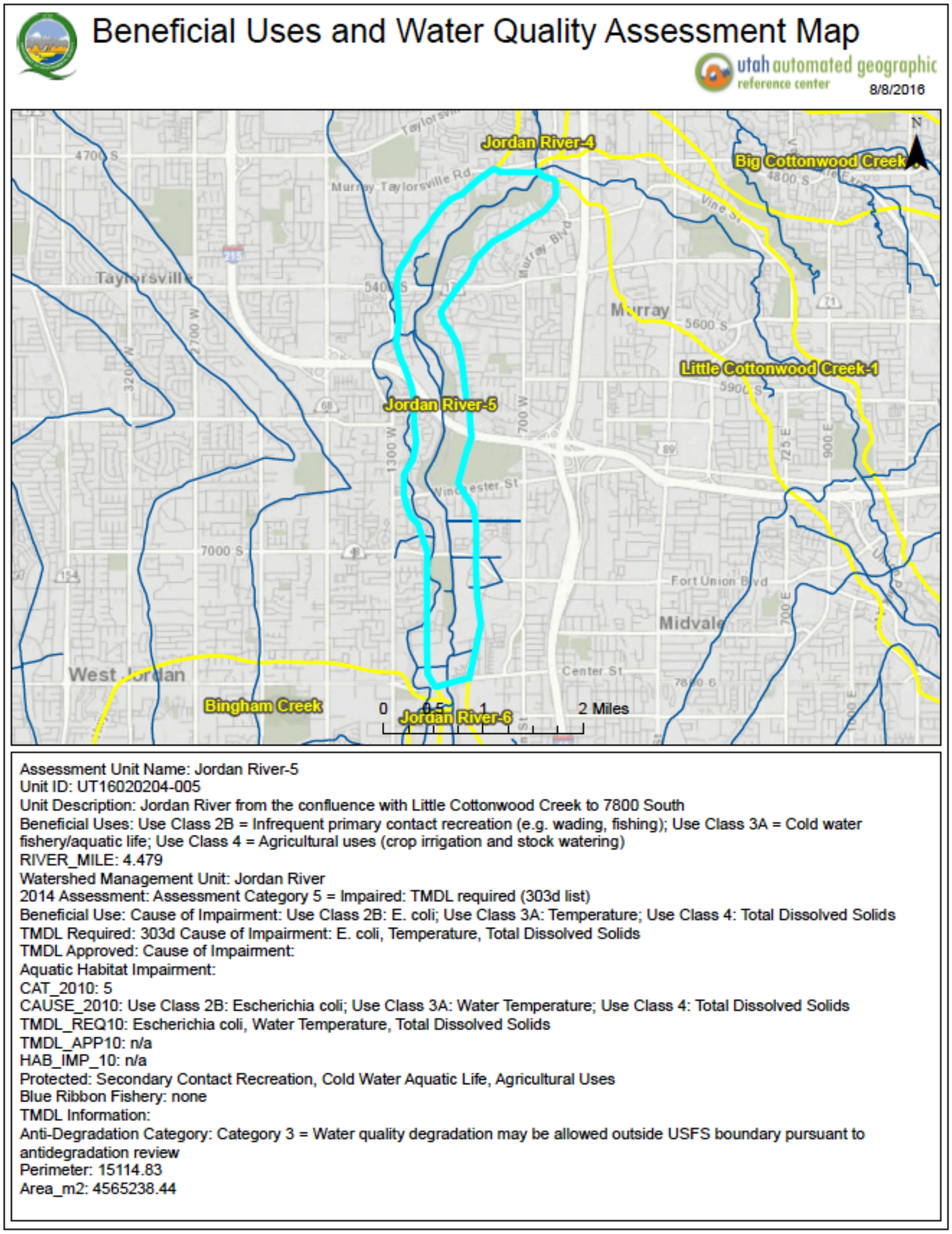


Figure 9.Utah Division of Water Quality's Beneficial Uses and Water Quality Map for Assessment Unit: Jordan River-5.

We surveyed the river between November 15 and December 10, 2018 for a total of ≈ 144 surveyor hours and a total river distance ≈ 13.3 km. Locations were surveyed by sectioning off the upper river into lengths based on highway crossings. The following figures, Figure 10 to Figure 18 show sections surveyed.

Figure 10. Section 1 from downstream of Bluffdale Rd crossing to Hwy 154 (Bangerter Hwy), ≈ 1.7 km surveyed.

Figure 11. Survey area from 12600 South upstream ≈ 2.0 km

Figure 12. Survey area from 11400 South upstream $\approx$ 1.5 km

Figure 13. Survey area from 11400 South (Willow Creek Ave; Hwy 175) downstream ≈ 1.5km. Started at downstream location and surveyed upstream.

Figure 14. Survey area from W 10000 South upstream ≈ 0.7 km. Started at downstream location and surveyed upstream.

Figure 15. Survey area from W 9000 South upstream ≈ 1.0km

Figure 16. Survey area from W. Center St., Midvale upstream to 9000 South $\approx$ 1.6km

Figure 17. Survey area from W 7000 South upstream to W Center St. Midvale ≈ 1.6 km

Figure 18. Survey area from I-205 upstream to W 7000 South, ≈ 1.7km

BT redd presence/absence

Determining presence/absence of BT redds is challenging. Fresh BT redds can be misidentified from other sediment disturbances to the casual observer. For example, waterfowl resting, actively foraging, or acting aggressively to other waterfowl can stir up sediments in an area in size similar to BT redds. Human foot prints are also somewhat similarly shaped, as are scouring of the river directly downstream of large cobbles or submerged vegetation. These 'pseudo redds' need to be examined closely for absence of tailspills (Figure 6), presence of attached algae, large cobbles, visible eggs, and general shape. All pseudo redds observed by technicians or volunteer were immediately brought to the attention of Dr. Richards for identification and verification.

Determining absence of BT redds in the river is of course not possible. A probability of detection is needed based on several factors including; search efficiency, area surveyed, and some measure or estimate of the probability that redds were absent or occurred less than a certain density. We used probability of detection estimates based on Smith (2006) and recommended by UDWQ for determining absence of native mussels in a waterbody.

The Smith (2006) formula (equation 4 page 703) used is:

$$POD = 1\text{-}e^{-\beta\alpha\mu}$$

where POD = probability of detecting at least one redd; β=search efficiency (SE), α=search area; and μ= density/river km. This method is similar to what was accomplished by Richards (2017a, 2017b) conducting mollusk surveys in the Jordan River. Results were then used to estimate densities of redds in the upper river.

Results

No Brown Trout redds were observed during the entire survey of approximately 13.3 river km. No actively spawning Brown Trout or otherwise were observed, although common carp (*Cyprinus carpio*) were often observed.

Only a few rare locations had unembedded cobbles/gravels that we considered ideal for BT spawning. An example is shown in Figure 19, which was located directly downstream of an active beaver dam, near Bluffdale. See Richards (2019) and Jones (2018) for a discussion on the importance of beaver dams on suitable substrate habitat for salmonids and macroinvertebrate assemblages.


Figure 19. Unembedded cobbles and gravels 10 m downstream of beaver dam in the Jordan River, near Bluffdale.

We estimated that > 95% of riffle habitats throughout of the upper Jordan River survey area were gravel or small cobble sized particles and all were > 85% embedded with sands, silts, clay, and other fines. Superficially almost all of the non-pool habitats appeared to be excellent BT spawning habitat, except for the fact that they were embedded with very fine sediments (< 0.06 mm) and had no secure cover.

Water levels were low during our surveys, which is typical for this time of year. However, because of low flows, some of the potentially best substrate occurred in very shallow (< 10 cm), exposed areas, with little security structure. Any eggs laid in viable redds in these shallow locations likely would freeze if low water levels continue throughout winter. Unfortunately, all of the deeper waters contained a higher percentage of fines.

Most of the river had very little cover except along the immediate shoreline, which was mostly comprised of Phragmites. Shallow riffles away from the shorelines provided inadequate security for potential spawners with very little instream structure.

Of major concern was several large plumes of dark (perhaps anoxic) fines and suspended sediments that occurred during our survey starting upstream of the City of West Jordan in the vicinity of 9000 South. We witnessed at least two turbid plume surges starting in mid-November. The largest of which was the second plume, which began several days before 28 November. These plumes darkened the river, reduced visibility to near zero, and deposited untold amounts of very fine sediment on to the substrate (Figure 20). We inquired about the nature of the plumes and were told by two agencies (City of West Jordan; Salt Lake County Watershed Planning and Restoration) that they were the result of flushing irrigation canals located west of the Jordan River. We were also told that canal flushing occurs on a regular basis. In addition, City of West Jordan managers observed major fish kills as a result of the plumes (toxic spills), including die-offs of carp (*Cyprinus carpio*), one of the most pollution tolerant species in the river. We reported these ecologically devastating plumes to UDWQ on November 28, 2018 (Appendix 2), but at this time do not know what their response was. Further investigation to these toxic spills is warranted and in immediate need of attention.

Figure 20. Large plume of black/gray fine sediment from flushing west irrigation canals into Jordan River, 50 m downstream of 9000 South, November 27, 2018. Photo taken several days after plume was first noticed. Notice dark gray sediments completely blocked visibility into the river. Depth was only several cm's in this location, visibility < 0.1cm. Flushing of canal water into the Jordan River confirms our conclusion that the Jordan River is still treated as a pollution depository.

Locations where ducks and geese were sitting or splashing in shallows, deer or other wildlife tracks, scouring downstream of cobbles or vegetation were easily detected because sediment from these activities was much lighter than the brown top sediment layers. Also, our footprints also left tell-tale impressions. We concluded that If recent redds were built, then we would have been able to observe them relatively easily.

Search efficiency, probability of detection and redd densities/km

As stated in the methods, concluding complete absence of BT redds in the upper Jordan River is not possible. However, using the probability of detection formula derived by Smith (2006), we made estimates of densities of BT redds likely to have occurred during our survey. Although, unknown, we conservatively assumed that our ability to detect a redd (search efficiency) was somewhere between 0.2 (20%) and 0.7 (70%). Also, because the width of the river varied, we derived density estimates from field measurements and Google Earth images at three river widths, a low estimate, best estimate, and high estimate of 10 m, 15 m, and 20 m, respectively. We used a high probability of detection of 0.90 (90%) that was greater than what Smith (2006) suggested (0.85) and equal to the value that UDWQ recommends for mussel survey probabilities.

Given these assumptions and values; our survey results provided strong evidence that BT redds, if they occurred at all, occurred at densities < one redd per 1.2 km to 2.3 km, if we had a poor search efficiency of 0.2, and < 1 redd per 4.0 km to 8.0 km, if we had a very good search efficiency of 0.7. At the estimated median width of the river (15 m), densities were likely < one redd per 1.6 km to 5.4 km. Other values of density estimates at different search efficiencies and the three river widths can be derived from Figure 21.

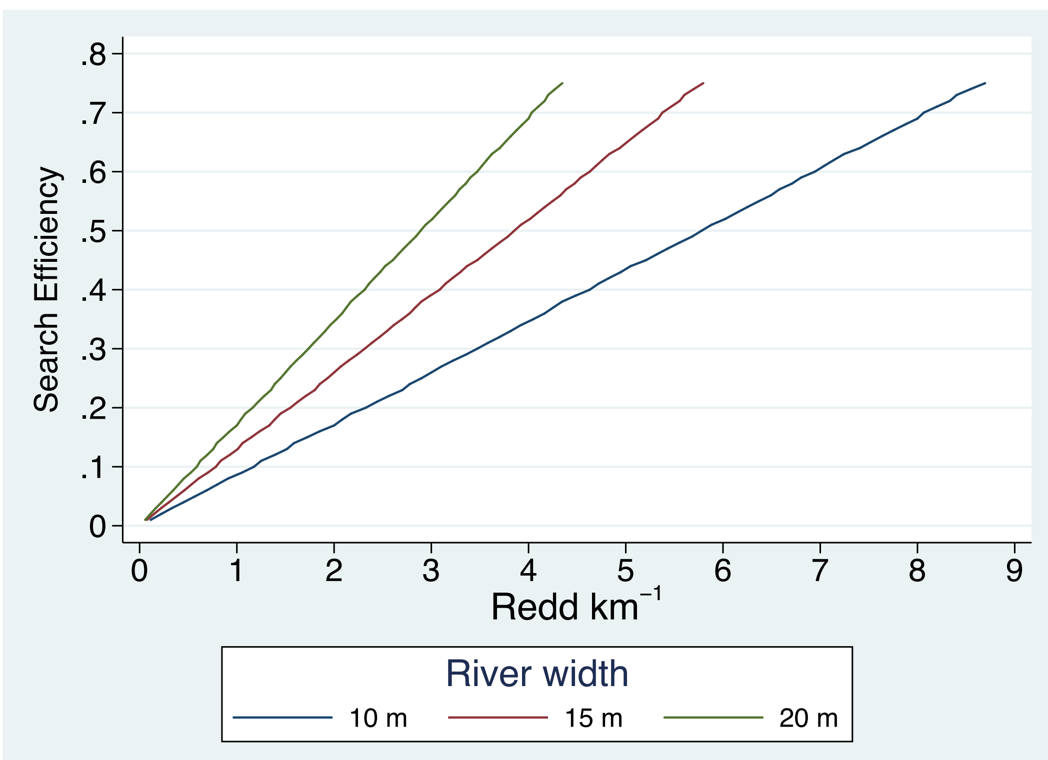


Figure 21. BT redd densities as a function of search efficiencies at three estimated river widths. Based on Smith (2006) formula.

Discussion

Our results suggest that BT spawning either does not occur in the upper Jordan River or if it does, it does so at very low abundance. If BT begin spawning at 3 years onward and our surveys were conducted when BT were spawning, then adult BT are either rare or absent from the upper Jordan River. Even though BT females can begin spawning without males; it takes two to tango, and BT densities may be so low that a sustainable population does not occur. Densities of adult BT, for instance < 1 adult per 4 km, are extremely low compared to other salmonid fisheries, which typically report BT densities at > 100 km^{-1}.

We do not know if adult BT occur upstream of our study area or spawn in these reaches, but from our past mollusk surveys conducted upstream, most of the habitat in the Narrows section is composed of very large cobbles and boulders. In addition, summer temperatures preclude BT from becoming full time residents in the upstream reaches (Richards 2018, Holden and Crist 1987) and UDWQ considers the Narrows reach a warm-water fishery.

Based on these analyses and our experience conducting ecological studies on the Jordan River and other rivers; fine sediment embeddedness appears to be the limiting factor for any BT that may exist in the study reaches. We conducted an impromptu experiment to test this assumption although we did not quantify results. We kicked away gravels in preferred habitat to simulate brown trout spawning at several locations and observed siltation rates. Fine sediments (< 0.06 mm) immediately began filling the 'pseudo redds' and it didn't take long, < 5 minutes for the 'pseudo redd' to be covered will fines up to 1 mm thickness. The fines visibly also visibly began to penetrate the gravels. This suggests that if a BT was fortunate enough to find a suitable redd site, it would have exhausted it spending many hours trying to continue removing fines from covering the red. The steady stream of fine sediments would have likely injured its sensitive gills as it dug the redd, reducing its fitness. In addition, if any eggs were laid, they would have been covered in fines and likely suffocated. We did these impromptu experiments in areas upstream of the sediment plume reported in the results section. Most certainly the plumes that occur on a regular basis drastically reduce BT spawning success and individual and population fitness. Simple deposition experiments need to be conducted to measure fine deposition in undisturbed and disturbed sediments.

We were fortunate to observe an uncommon mayfly hatch on the Jordan River on December 4, 2018 in a 50 m long run directly downstream of the riffle section below the beaver dam in the Bluffdale area. We tentatively identified the mayflies as *Fallceon quilleri,* (Family Baetidae) but this needs to be verified by our expert aquatic entomologist, Brett Marshall, at River Continuum Concepts, MT. Larval mayflies began emerging from the cobble riffles upstream and by the time they were sub-imagos, they were floating on the surface of the run. This run had sufficient in-stream cover, such as boulders and depth (> 1.0 m) that we expected to see fish feeding on the mayflies at or just below the surface. To our amazement, no fish were seen taking advantage of this late season, easily assessable food resource. Not even minnows. No fish were observed feeding near the surface within the 100 m long beaver pond upstream either, however mayfly sub-imago densities were much lower in the pond. We observed these sections for at least 30 minutes. Having worked and fished for countless hours on salmonid streams and rivers throughout the west and having experienced hundreds of mayfly hatches, Dr. Richards anticipated being able to quantify feeding fish in what he considered the best BT habitat within the entire river (excluding high summer temperatures). This absence of feeding fish, although mostly anecdotal, is unfortunately further evidence that salmonids, including BT, likely do not occur within our study area in the upper Jordan River or do so at extreme low densities.

Several credible observers have either caught or seen BT in the past in the Jordan River and within our study area. However, these captures occurred in the 1970's. Sam Taylor of Salt Lake County Watershed Protection and Restoration reported seeing BT at the confluence of Little Cottonwood Creek in 2017, but that is several km downstream of our study area.

BT redd surveys are just the beginning of our efforts to understand the ecology of fish assemblages in the upper Jordan River. An extensive collaborative fish survey will be conducted in 2019. Fisheries biologists with UDWR, WFWQC, and OreoHelix Consulting will electroshock and net fish from the study site pending discussions and logistics.

Consultation between WFWQC, OreoHelix Consulting, and fisheries biologists at DWR have commenced and discussion as to DWR's management plans for fisheries in the Jordan River are underway. Results from our fish survey will be used to help DWR's management planning. DWR's management plan and understanding of the Jordan River fishery will be extremely important in determining DWQ's beneficial use designation.

The BT redd survey coincided with our mollusk and macroinvertebrate surveys (Richards 2019). Benthic invertebrate results are presently being processed but preliminary results show that invertebrate densities in the upper Jordan River in riffle, run, and pool habitats is extremely low in spite of the high levels of nutrients available for primary production; benthic invertebrate's main food resources. These very low macroinvertebrate densities translate into subpar food resources for Brown Trout and reduce their population viability.

Conclusion

Even though, the section of the upper Jordan River that we surveyed superficially looks like almost continuous Brown Trout spawning habitat (i.e. gravel sized particles); it does not appear that Brown Trout successfully spawn there. The limiting factor for the occasional adult that inhabits the river appears to be fine sediment (< 0.06 mm) filling redds. Sedimentation by fines is exacerbated from canal dredging and flushing of toxic fines from the west side of the river and other human economic activity. As a consequence, we conclude that a viable, self-sustaining population of Brown Trout likely does not exist in the survey area. However, much more research is required to verify our conclusion.

Recommendations

From this study and our salmonid fisheries experience in other waterbodies in the western U.S.; several recommendations for understanding and managing Jordan River fisheries are as follows:

1. Conduct instream experiments to quantify the amount of fine sedimentation rates and how this relates to Brown Trout and benthic macroinvertebrates, their primary food resource at younger age classes.
2. Conduct additional fish surveys in the river in collaboration with UDWR fisheries biologists.
3. Collaborate with Salt Lake County Watershed Planning and Restoration group to further our understanding of fisheries in the river.
4. Increase efforts to determine UDWQ resident/non-resident status of Brown Trout and other 'cool-water' fishes as they related to water temperature and for setting water quality standards.
5. Explore potential locations where analog beaver dams can be installed in the river. These dams are being successfully used throughout the west to improve stream habitat and somewhat restore waters to historical conditions (Jones 2018).

Acknowledgements

We gratefully acknowledge the fine and dedicated assistance from Wasatch Front Water Quality Council technicians Frank Fluckiger and W.D. Robinson, as well as our part time volunteer, Julia German. Also, we are deeply grateful to the WFWQC for funding this and other studies in the Jordan River without which, the ecology and water quality of the river would remain poorly known.

Literature Cited and References

Bonada, N. N. Prat, V.H. Resh, and B. Statzner. 2006. Developments in aquatic insect biomonitoring: A comparative analysis of recent approaches. Annual Review of Entomology. Vol.51:495-523.

Brown, C.J.D. 1971. Fishes of Montana. Montana State University, Bozeman, MT. 207 pp.

DWQa. 2018. Use attainability analysis for water temperature for the Jordan River from confluence with Little Cottonwood Creek to Narrows Diversion Utah and Salt Lake Counties, Utah. July 18, 2018 review draft.

DWQb. 2018. Discharger-specific variance. Dischargers: South Valley Wastewater Reclamation Facility, UT0024384 Jordan Basin Water Reclamation Facility, UT0025852. July 18, 2018. Draft

Grost, R.T., W.A. Hubert, and T.A. Wesche. 1990. Redd site selection by Brown Trout in Douglas Creek, WY. Journal Freshwater Ecology. 5(3): 365-371.

Holden, P.B. and L.W. Crist. 1987. Fishery and Macroinvertebrate studies in the Jordan River in Salt Lake County, November, 1986. Report to Central Valley Water Reclamation Board. Salt Lake City, Utah.

Jones, J.W. and J.N. Ball. 1954. The spawning behavior of brown trout and salmon. British J. Animal Behavior. 2:103-114.

Jones, A. 2018. Beaver dam analouges: Implementation and monitoring. Presented at 12th Annual Watershed Symposium. Salt Lake County Watershed Protection and Restoration. Salt Lake City, UT.

Karr, J. R., and E. W. Chu. 1997. Biological Monitoring and Assessment: Using Multimetric Indexes Effectively. EPA 235-R97-001. University of Washington, Seattle.

Merritt, R.W., K.W. Cummins, and M.B. Berg. 2008. An introduction to the aquatic insects of North America. 4th Edition.

Miller, T.G. and F. Fluckiger. 2016. Standard operating procedures for YSI high-frequency data-logging sondes: Maintenance and calibration. Report to Utah DWQ and WFWQC.

Price, P.W. et al. 2011. Insect Ecology: Behavior, populations, and communities. 1rst Edition. Cambridge University Press. ISBN-13: 978-0521542609

Richards, D. C., Lester, G., Pfeiffer, J. and J. Pappani. 2018. Temperature Threshold Models for Benthic Macroinvertebrates in Idaho Wadeable Streams and Neighboring Ecoregions. Environmental Monitoring and Assessment. 190: 120. https://doi.org/10.1007/s10661-018-6478-9.

Richards, D. C. 2016a. Does phylogeny predict sensitivity to ammonia in freshwater animals using USEPA ammonia criteria data?

Richards, D.C. 2016b. Real and perceived macroinvertebrate assemblage variability in the Jordan River, Utah can affect water quality assessments. Technical Report to Jordan River/Farmington Bay Water Quality Council. OreoHelix Consulting, Vineyard, UT.

Richards, D.C. 2017a. Lower Mill Creek and Mid-Jordan River native mussel survey 2017: As it relates to the Central Valley Water Reclamation Facility Discharge. Report to: Wasatch Front Water Quality Council. Salt Lake City, UT. OreoHelix Consulting, Vineyard, UT.

Richards, D. C. 2017b. Native Unionoida Surveys, Distribution, and Metapopulation Dynamics in the Jordan River-Utah Lake Drainage, UT. Report to: Wasatch Front Water Quality Council. Salt Lake City, UT. OreoHelix Consulting, Vineyard, UT. Version 1.5 May, 26, 2017.

Richards, D. C. 2018a. A snail, a clam, and the River Jordan: A revealing novel. Version 1.5. Technical Report Submitted to The Wasatch Front Water Quality Council. OreoHelix Consulting, Vineyard, UT.

Richards, D. C. 2018b. The Jordan River: How to regulate an analog ecosystem. Scientific presentation at the Twelve Annual Salt Lake County Watershed Symposium, Salt Lake City, UT.

Richards, D.C. 2019. Jordan River macroinvertebrate assemblages: Preliminary findings. Draft report to Wasatch Front Water Quality Council. OreoHelix Consulting, Vineyard, UT.

Richards, D.C. and T. Miller. In Press. Apparent extinction of native mussels in Lower Mill Creek and Mid-Jordan River, UT. Western North American Naturalist.

Schowalter, T.D. 2016. Insect Ecology: An ecosystem approach. 4th Edition. Academic Press. Elsevier, UK.

Speight, M. R., M.D. Hunter, and A.D. Watt. Ecology of Insects: Concepts and applications. Wiley and Blackwell.

Spoon, R.L. 1985. Reproductive biology of Brown and Rainbow Trout below Hauser Dam, Missouri River, with reference to proposed hydroelectric peaking. MS Thesis. Montana State University, Bozeman, MT.

Thorp, J.H. and A.P. Covich. 2009. Ecology and classification of North American freshwater invertebrates. 3rd Edition. Elsevier Press.

US EPA, 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process. EPA Office of Environmental Information. Report No. EPA/240/B-06/001. Washington D.C.

Ward, J.V. and J.A. Stanford. 2003. Thermal responses in the evolutionary ecology of aquatic insects. Annual Review of Entomology. 27(1); 97-117.

Wagner, E. J. 2015. A review of the effects of flow on Brown Trout. https://wildlife.utah.gov/fes/pdf/review-effects_of_flow_on_brown_trout_redds.pdf

Appendices

Appendix 1 Qualifications of Dr. David Richards

Dr. Richards has been conducting freshwater aquatic research for several decades throughout the western U.S. He has a BS in Fish and Wildlife Management, MS in Entomology, and PhD in Ecology from Montana State University. He was a scientist for Cramer Fish Sciences based out of CA, worked as a fisheries biologist and technician in Alaska, Montana, Yellowstone National Park, and was lead researcher on several fisheries projects including the Columbia River, WA. Dr. Richards has surveyed salmonid redds routinely throughout his career and mentored several dozen students, volunteers, and other enthusiastic ecologists. His C.V. is available on request.

Appendix 2. Environmental Incident Report filled to UDWQ concerning toxic plumes in the upper Jordan River.

Utah Department of Environmental Quality
Division of Environmental Response and Remediation
195 North 1950 West Salt Lake City, Utah 84116
Bus. Hours: 801-536-4100
Report Spills 24/7/365: 801-536-4123

Report Number 13694

ENVIRONMENTAL INCIDENT REPORT - MIDVALE -- SEDIMENT DISCHARGE IN JORDAN RIVER

Report Taken By:	Kevin Okleberry		
Date / Time Reported:	11/27/2018 14:30		
REPORTING PARTY DATES AND TIMES			
Reporting Party:	Theron Miller	**Title:**	
Company:	Wasatch Front Water Quality Council	**Phone:**	(435) 640-3772
Date & Time Discovered:	11/27/2018 14:30		
Lead Agency:	Salt Lake County HD	**Agency Contact:**	Erik Nebeker
RESPONSIBLE PARTY			
Name:	Unknown	**Phone:**	
Address:			
INCIDENT LOCATION			
Incident Address:	7200 S. 1000 W., Midvale, Utah		
Nearest Town:	MIDVALE	**County:**	SALT LAKE
Highway:		**Mile Marker:**	
UTM:	(E) 422130 (N) 4496941	**Land Owner:**	Private
First Responders Notified?	No		

INCIDENT SUMMARY

Caller reported a large discharge of sediment and accompanying fish kill into the Jordan River between 7200 S. and 9000 S. Discharge is believed to be related to irrigation canal maintenance.

CHEMICAL(S) REPORTED	
	Other: (describe) Sediment and Debris N/A - Unknown

IMPACTED MEDIA	Media	Media Other	Land Use	Waterway Name	Near Water	Distance	NRC Rpt. #
	Surface Water	N/A	Mixed Use	Jordan River	In Surface Water	N/A	N/A

NOTIFICATIONS MADE	Agency	Contact	Phone	Date	Time	By	Active?
	DWQ	Kevin Okleberry	(801) 536-4054	11/27/2018	15:00	Reporting Party	
	Salt Lake County HD	Ron Lund	(385) 468-3962	11/27/2018	15:05	kmo	Active

ACTIONS TAKEN	Date	Agency	Action	Action Details
	11/27/2018	DWQ	DWQ No Enforcement	Salt Lake County HD is lead agency, no DWQ enforcement.

Incident notification reports are prepared by DEQ staff using information provided by the reporting party. The information is considered preliminary and is subject to revision. The reported incident and associated details may or may not be valid