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Jordan River DO TMDL Research Synthesis by Cirrus

Comments and Recommendations from OreoHelix Ecological

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Congratulations to Cirrus Ecological Solutions, LC for an excellent synthesis of Jordan River reports as they relate to DO TMDLs. There was a wealth of information to synthesize. I appreciate DWQ's concern for the Jordan River and an opportunity to participate on its science team.

My comments and recommendations to Cirrus and DWQ in regard to Jordan River DO TMDL research findings follow:

1 CORBICULA AND POTAMOPYRGUS

In my opinion, the most important outcome of Cirrus Ecological Solutions review and synthesis was the acknowledgement that two taxa, the Asian clam *Corbicula* sp. and the New Zealand mudsnail, *Potamopyrgus antipodarum*, likely govern many of the ecosystem functions in the now analog Jordan River, spatially and temporally. This is not supposition or speculation but is well-grounded in ecological literature and my many years' experience as an ecologist working with freshwater mollusks. As many on the TMDL science team are aware, or should be by now, the Jordan River drainage was and continues to be a molluskan hotspot in the western USA, both in diversity and production, primarily due to limestone geologic parent material and ample calcium from shallow seas eons past that allow mollusks to build their $CaCO_3$ matrix shells (Richards 2017). Mollusks, and in particular, bivalves are the consummate poster children of water quality. They filter entire water bodies on a daily to weekly basis and their net benefit should not be underappreciated (Richards 2017, and other Richards mollusk reports and scientific presentations). This acknowledgement is a major paradigm shift for those who study and manage the Jordan River and a major step forward in our understanding of its ecology. Hopefully, this enlightenment will stimulate researchers and managers to conduct much needed research on the entire biota in the river, not just microbes, and not just *Corbicula* and *Potamopyrgus*. Hopefully, the contribution of benthic invertebrates to the Jordan River ecosystem process will no longer be relegated to a 'black box' in water quality models.

I highly recommend **not** using values in 'A snail, a clam, and the River Jordan' report. Those values should be considered 'ballpark' or 'jumping off' values to elicit actual *Corbicula* and *Potamopyrgus* bioenergetics, nutrient cycling, and food web dynamics studies in the Jordan River

As you are aware after reading the report, my first and most important recommendation was:

> "RECOMMENDATIONS
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> 1. Conduct field research to verify and update estimated values calculated for Jordan River from literature and presented in this report. Specifically, estimate densities of *Corbicula* and *Potamopyrgus* in sections not surveyed by OreoHelix Consulting and The Wasatch Front Water Quality Council. Conduct in situ experiments using the most up to date methods for estimating: carbon, nitrogen, and phosphorous filtering and consumption rates, excretion rates, and carbon fixation rates, etc. (see Same and Olenin 2005). Relate these findings to water chemistry values in the Jordan River and determine the effects of the clam and snail. Update all Jordan River reports with this new information. Inform researchers and managers."

I did find discrepancies in Newall et al (2005) mussel consumption and excretion report. Consumption and excretion values in Newall were composited from different studies. Some data were based on oysters in Chesapeake Bay, not directly relevant to Jordan River. Upon further review, consumption rates are likely 1 to 2 orders of magnitude higher than what I reported, and a more recent find was that excretion rates could be 3 times less than what I reported. However, these values are from other ecosystems and should not be used in any Jordan River models. We would not use, for example, DO values from other rivers in Jordan River models.

I am updating the 'A snail, a clam, and the River Jordan' report with these revised values and emphasizing that those values are from other locations and sometimes other species. This updated version will be part of a mollusk compendium for the Jordan River-Utah Lake drainage that OreoHelix Ecological and WFWQC anticipate having available by end of August 2020.

Although *Potamopyrgus antipodarum* (New Zealand mudsnail) can reach densities up to 500,000/ m^2 in the Jordan River as I reported, this only happens when the snails occupy submerged aquatic vegetation (SAV) and only in a few areas of the river during peak abundance.

Typically, *P. antipodarum* densities will be much less and be highly variable throughout the river. *Potamopyrgus* need stable substrate, which is in short supply in most of the Jordan River, to reach high abundances. Much of the Jordan River substrate is shifting sand, clay, or OM which is not suitable for these snails (Richard 2004, Richards et al. 2001, many other reports). *Potamopyrgus* densities on stable substrates other than SAV can be as much as perhaps 200,000/m^2 during their peak abundance season, typically late summer. However, even at these highly variable densities, their effect on water chemistry, quality, nutrients, dynamics needs to be accounted for and the work that I cited is a good reference to illustrate what they are capable of.

I cannot emphasize enough that the Jordan River was and continues to be a molluskan hot spot in the Western USA and a Utah natural heritage; and that these native and invasive taxa are major ecosystem engineers and regulators of water quality. I do not agree with Cirrus that mollusk effects (or other macroinvertebrates) have been fully or even partially addressed in the DWQ models based on Hogsett SOD values. A more useful and ecologically relevant model would seek to understand these effects in more detail to better understand the contribution of benthic invertebrates to SOD and for DWQ to properly manage the Jordan River.

But again, the take home messages are clear:

1. ***We have acknowledged that Corbicula and to a lesser extent NZMS are driving nutrients, DO, water quality, and the food web in the Jordan River and these rates vary spatially and temporally.***
2. ***These two taxa are surrogates for extinct species that in the past cleaned the Jordan River. Without these two taxa (and the remaining natives), the JR would be putrid at certain times of year.***
3. ***The urgency of conducting experiments and measurements on the ecological and water quality contributions of these two species in the Jordan River ecosystem.***

2 Introductory Statement of why a DO TMDL is necessary

It would be helpful if Cirrus/DWQ included a sentence or paragraph on why low DO is a problem. We all realize that low DO can be harmful to fisheries and other biota, so a justification statement would benefit.

3 Macroinvertebrate Influence on Water Quality: *Macroinvertebrates* ***ARE*** *Water Quality*

Macroinvertebrates most certainly do influence Jordan River water quality, however, macroinvertebrates are more than *Corbicula* and *Potamopyrgus.* There are dozens of benthic invertebrate taxa in the river, each with a unique ecological niche and water quality requirements. Subsequently, each taxon provides unique insights into water quality conditions. More importantly, however, macroinvertebrates **are** water quality as the Clean Water Act and DWQ designated beneficial uses clearly state (see next section: ECOLOGICAL INTEGRITY, THE CLEAN WATER ACT, AND UDWQ DESIGNATED BENEFICIAL USES).

Benthic macroinvertebrates obviously contribute to oxygen demand in the water column and sediments, however benthic invertebrates **are** the reason DWQ was relegated with developing TMDLs (see next section). Benthic macroinvertebrate contributions, particularly positive contributions, need to be included in any TMDL model. One example of benthic invertebrate effects on SOD are chironomid larvae. It is well understood by freshwater ecologists that chironomid larvae increase O_2 levels in sediments up to 3 to 5 cm depth when larvae are present in their larval tubes (see Richards and Miller 2019). There are at least ten chironomid genera and an unknown number of species residing in the Jordan River (Richards 2019a, Richards 2019b) and each taxon has different life histories and ecologies and therefore contributes differently to SOD. Chironomids are on average the most abundant taxon in the Jordan River with mean densities > 2000 m^{-2} and are the indicator taxon for the Lower Jordan River (Richards 2019a). DWQ considers chironomids to be indicators of water quality impairment without taking into account their positive contribution to increased DO in the sediments. It is imperative for us to develop a better understanding of the ecologies of these midge taxa in the river to better manage it. At this time, DWQ DO TMDL models need to address benthic invertebrate influences on DO, or at least acknowledge model uncertainty due to this lack of understanding. DWQ models are heavy on chemistry data inputs, but sorely lacking actual biological and ecological inputs. Without such, models are only half useful.

4 GRAZING EFFECTS ON ALGAL PHOTOSYNTHESIS AND RESPIRATION

Cirrus stated that "Despite sufficient light and nutrients, measurements do not show additional growth of benthic algae in the LJR". In addition to unstable and unsuitable substrate, much of this lack of an additional benthic algal growth observation could be due to grazing by benthic invertebrates and fish benthic algaevores. Snails and other benthic invertebrates in the Jordan River are voracious algaevores, as are the highly abundant native Utah Sucker. It is well known that grazing increases nutrient uptake and benthic algal primary production often resulting in a positive feedback loop; the greater the grazing pressure, the greater the primary production. An incomplete explanation for the unobservable changes to benthic algal growth by our group could be the consequence of incomplete ecological knowledge and understanding of this grazing induced feedback loop.

5 ECOLOGICAL INTEGRITY, THE CLEAN WATER ACT, AND UDWQ DESIGNATED BENEFICIAL USES

One of the main goals of the Clean Water Act is to 'maintain and improve the physical, chemical, and biological integrity of our Nation's waters'. Biological integrity refers to 'the capacity to support and maintain a balanced, integrated, adaptive biological system having the full range of elements (genes, species, assemblages) and processes (mutation, demography, biotic interactions, nutrient and energy dynamics, and metapopulation processes) expected in the natural habitat …' (Angermeier and Karr, 1994; Frey, 1975; Karr and Dudley, 1981; Karr et al., 1986, all citations can be found in Richards and Miller 2019d). The combination of physical, chemical, and biological integrity equals ecological integrity (Karr 1996 in Richards and Miller 2019d). DWQ has designated the lower Jordan River beneficial use, "Class 3B -- Protected for warm water species of game fish and other warm water aquatic life, including the necessary aquatic organisms in their food chain".

As far as I am aware, DWQ does not utilize any metrics needed to evaluate the physical integrity of the Jordan River, even though the biggest contributor to loss of ecological integrity to the Jordan River is loss of physical integrity, which also directly and indirectly affects chemical and biological integrity, including DO impairment (Richards 2019a, see following section 6- JORDAN RIVER: AN ANALOG SYSTEM). Loss of a natural hydrologic cycle, channelization, and perhaps the biggest physical impairment, loss of flush flow events contributes to the loss of physical integrity (and chemical and biological integrity) in the Jordan River (Richards 2019a). Without assessing, monitoring, and alleviating these physical factors, eliminating DO impairment seems unlikely.

DWQ relies primarily on chemical integrity metrics (e.g. TMDLs for DO, metals, temperature, etc.) to evaluate the ecological integrity of the Jordan River. However, these chemical metrics do not appear to directly address biological integrity. How does DWQ know if chemical impairment, including low DO, effects biological integrity including designated beneficial uses, "Class 3B -- Protected for warm water species of game fish and other warm water aquatic life, including the necessary aquatic organisms in their food chain"?

The single superficial biological integrity metric that DWQ uses, O/E has limited utility in the Jordan River. I and others have determined that this metric is not useful or valid for the Jordan River and I strongly suggest that O/E needs to be replaced or supplemented with a more comprehensive suite of metrics, of which O/E can be but one (Richards 2016a, 2016b). In addition, DWQ has no metrics to evaluate fish assemblages in the river, even though the designated beneficial use is warm water fishery. This is the primary mandate for monitoring biological integrity, via beneficial use, in the Jordan River. Consequently, we have no way to determine if DO impairment has a negative effect on the Jordan River fishery and other warm water aquatic life. If DWQ does not effectively measure the fishery and aquatic life it depends on, how can we determine if DO is an impairment, other than EPA recommendations for DO levels? In addition to the macroinvertebrate surveys we conducted in the Jordan River (see literature cited in this comment letter and Cirrus synthesis), we also conducted the most comprehensive fish surveys in the river in over 30 years (see literature cited). Most of these reports have been submitted to Cirrus and DWQ. If DWQ would like us to conduct additional statistical analyses on these fisheries surveys in relation to DO TMDL, we would consider.

Also, the Clean Water Act necessitates protection and enhancement of shellfisheries, which many managers fail to realize, includes freshwater mollusks (mussels, snails, clams). The Clean Water Act (1987) states that: "It is the national goal that wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, **shellfish**, …." OreoHelix Ecological and the Wasatch Front Water Quality Council have conducted the most complete surveys and ecological assessments of mollusk in the Jordan River to date. Most of these reports and publications were cited by Cirrus and are available if DWQ does not already have them.

6 Jordan River: an analog system

I and other researchers consider the Jordan River a poor analog of its former self. Citing Richards 2019a:

> "The Jordan River has undergone unprecedented, anthropogenic-induced, deleterious ecosystem shifts[1] during the past one and a half centuries. These shifts were primarily induced by degradation of its physical and chemical integrity. However, the Jordan River's biological integrity has also been compromised. The river's biotic communities have most certainly suffered from severe bottlenecks and ecological hysteresis[2] paving the way for extirpation of native species and the establishment of highly invasive species. Consequently, the Jordan River is now a second-rate analog of its former self and its ecological integrity[3] has been vastly diminished (Richards 2019a; 2019d; and 2018b).
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> 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 shifts' (Scheffer et al.

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[1] Ecosystem shifts are large, abrupt, persistent changes in the structure and function of a system (Scheffer et al. 2001).

[2] Ecological hysteresis is the delayed recovery of an ecosystem after disturbance or when the state of a system is determined by external conditions that existed during the preceding period, not only at the moment of observation (Nikanorov and Sukhorukov 2008).

[3] Ecological integrity is the sum of physical, chemical, and biological integrity (Karr 1993, 1996).

> 2001), and 'ecological hysteresis' (sensu Scheffer and Carpenter). The Jordan River is now a severely impaired analog river ecosystem and can never regain its past condition (Richards 2018b, Dakos et al. 2015).
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> The Jordan River prior to Mormon settlement was a sinuous, low gradient meandering river with a wide floodplain and riparian ecosystem filled with willows and cottonwood trees; ideal beaver food, housing, and dam building material. Unquestionably, beaver dams dominated the river ecosystem and its riparian community. These dams, among other things, acted as sediment traps for sands and other fine sediments; a major component of the geological material within the floodplain. Directly below the dams, unembedded cobble riffle habitat dominated for several tens of meters, similar to what can be found today in upstream sections of the Jordan River near Bluffdale.
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> Utah Lake, the main source of the Jordan River, provided much cooler water to the river than it does at present and was fed by numerous unaltered and unimpeded springs and groundwater recharge. The combination of beaver dams and unembedded cobble riffles provided superior habitat for native fish species, including the Bonneville cutthroat trout, which no longer exists in the Jordan. Spring floods and summer storm events periodically removed beaver dams and the system began anew on a semi regular basis. Macroinvertebrate diversity and abundances reflected these conditions and along with beavers, governed Jordan River ecosystem function."

This analog condition has important ramifications for how we manage the Jordan River.

7 Management Remedy

Obviously the easiest and most prudent remedy for DO impairment in the Jordan River is to flush OM downstream out of the river system, somewhat simulating a natural hydraulic regime. It is my opinion that Surplus Canal is now hydraulically more similar to the past Jordan River than is the present Jordan River, mostly because the canal somewhat follows a natural flow regime and is allowed to flush accumulated OM. Dredging OM from the Lower Jordan River would be a second option and also easily accomplished. Because the river is a poor analog of its former self, these two options would not negatively affect the now analog Jordan River's ecological integrity, which has all but been lost, or even its designated beneficial use.

8 Conclusion

It is my opinion that the only reason for TMDL development for any type of pollutant, including DO, is to protect designated beneficial uses, e.g. "Class 3B -- Protected for warm water species of game fish and other warm water aquatic life, including the necessary aquatic organisms in their food chain" in the Jordan River. Without a more comprehensive ecological understanding of these biota, then we may not be able to fully justify TMDL values.

9 LITERATURE CITED

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Once again, a big thanks to Cirrus Ecological Solutions for their excellent summary of DO TMDL related data from the Jordan River and it is a professional pleasure to be involved with DWQ Jordan River scientific team.

Sincerely,
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Director, Owner, and Senior Research Ecologist
OreoHelix Ecological