Jordan River Watershed Mollusk Surveys: "Last of the Anodonta"

2016 Annual Report

September 19, 2016

To:
Jordan River/Farmington Bay Water Quality Council
Salt Lake City, UT

By
David C. Richards, Ph. D.
OreoHelix Consulting
Vineyard, UT
Phone: 406.580.7816
Email: oreohelix@icloud.com

Summary
Mollusk surveys focusing on native bivalves and in particular, Anodonta were conducted in 2016 at several locations in the Jordan River drainage following the more extensive and intensive surveys that were conducted in 2015 and reported in Richards 2015. Survey sites included additional limited surveys in Currant Creek, Burraston Ponds, Beer Creek, Spanish Fork River, Provo River, Spring Creek, Mill Pond, Jordan River, and along the shorelines of Utah Lake. Live Anodonta were only encountered at a known location in Currant Creek. None of the other locations produced live or recently dead Anodonta but as reported in 2015, Anodonta weathered shell fragments were found at most sites showing that this taxon likely occurred continuously throughout the drainage in the past. No live or empty Margaritifera shells or shell fragments were encountered. Fingernail clams (Family Sphaeriidae) also appear to have declined dramatically in the last century, as well as non-pulmonate snails. Invasive Asian clams, Corbicula and to a lesser extent New Zealand mudsnails, Potamopyrgus were often abundant. Loss of habitat and metapopulation dynamics are probably the key factors in native mollusk declines in the drainage. What limited habitat that remains does not appear to be protected, including critical spring fed waters entering Utah Lake and in Currant Creek and Beer Creeks, which supply most of the summer flows to these water bodies. Currant Creek and Beer Creek contain the two last known Anodonta populations in the Jordan River drainage. Protection of these water is critical but does not seem to be forth coming. Continued monitoring of known populations and surveying in additional locations is highly recommended. In addition, population dynamic studies of the last populations of native mollusks in the drainage are urgently needed to determine the causes of their disappearance, predict their extinction risk, and to establish management strategies that may postpone or circumvent their extinction.

Table of Contents

List of Figures

Introduction

The Jordan River watershed (drainage) encompasses an area of over 3,800 square miles (9842 km^2) with elevations ranging from 11,900 ft. (3627 meters) in the Wasatch Range to 4,200 ft. (1280 meters) at the confluence of the Jordan River into Farmington Bay, Great Salt Lake. This watershed includes Utah Lake, the fourth largest lake in the western U.S. The Jordan River watershed, until recently, had one of the most diverse freshwater mollusk assemblages in the western U.S. Native bivalves including the western Pearlshell mussel (*Margaritifera falcata*), the California floater mussel (*Anodonta californiensis/nuttalliana*), and fingernail clams (Familiy Sphaeriidae) were abundant. Well over a dozen species of freshwater snails also occurred in the drainage including many endemic springsnails (*Pyrgulopsis* spp.). However, waters in the Jordan River drainage have been heavily impacted by human economic activities in the last 1 ½ centuries and the status of the area's native freshwater mollusks is unknown.

In 2014 and 2015, Richards and a team of researchers conducted the most intensive and extensive mollusk surveys in the Jordan River drainage to date (Richards 2015a and 2015b). Surveys conducted in 2016 and the subject of this annual report were more limited in scope than the 2014/2015 surveys but are an important follow up based on recommendations of the 2015 reports. The primary focus of the 2016 survey was on the native mussel, Anodonta but other mollusks were included in the surveys. The following are survey locations and results of the 2016 surveys.

Survey Locations and Results

1. Utah Lake shoreline sampling

Figure 1. Shoreline and shallow water mollusk survey of Utah Lake at Sandy Beach. View is looking west.

a. Vineyard Springs Area

Utah Lake shoreline sampling occurred near Vineyard, UT (Figure 1) on the east side of the lake (Longitude 111°45'57.67" to 111°45'43.80") on several occasions in late August and early September. Approximately 834,000 m^2 (4.17 km x 200 m) was surveyed by Dr. Richards for live, recently dead, or weathered mollusks and their shells for a total of about twenty hours of surveying. Surveys of this site will continue in 2016 on a sporadic basis.

Figure 2. Location of mollusk survey along the shores of Utah Lake, 2016 near Vineyard, UT. Length of shoreline was approximately 4.2 km where many freshwater springs occurred. This type of spring influenced habitat is likely one of the best types for finding any remnant native mussel populations.

Utah Lake's low water levels this summer, 2016, resulted in exposed dewatered habitat up to at least 200 meters away from the normal meander line near Vineyard, UT and created ideal conditions to survey mollusks, particularly bivalves. In the extremely unlikely event that live Anodonta sp. still existed in the survey area or in Utah Lake, they would most certainly not have been able to anticipate or escape the rapidly receding water levels during 2016 drought conditions and most likely would have buried themselves into the damp/wetted sediments to avoid desiccation. Upon further drying and heating of the sediments, Anodonta would then have attempted to leave their burrows and thus become exposed to predators and surveyors. This response was all too evident with Corbicula in the survey area where these invasives exposed themselves to desiccation as they attempted to move to favorable conditions and then became fodder for predators (Figures 10 - 13). Predators are experts at locating and exposing bivalves hidden in the sediments as substantiated by the hundreds of empty Corbicula shells scattered along the shoreline.

Figure 3. Aerial view of northern springs of the Vineyard spring complex, between Lindon Marina and Powell Slough, Utah Lake. September 2016. These springs may have historically been a creek/river but are now inundated and covered by Geneva Steel Co. lands and recent subdivisions and presently only surface flow occurs at this location for a short distance before entering Utah Lake. Utah Lake is the green body of water in the foreground. Numerous subdivision developments are occurring up to the normal meander line of the lake.

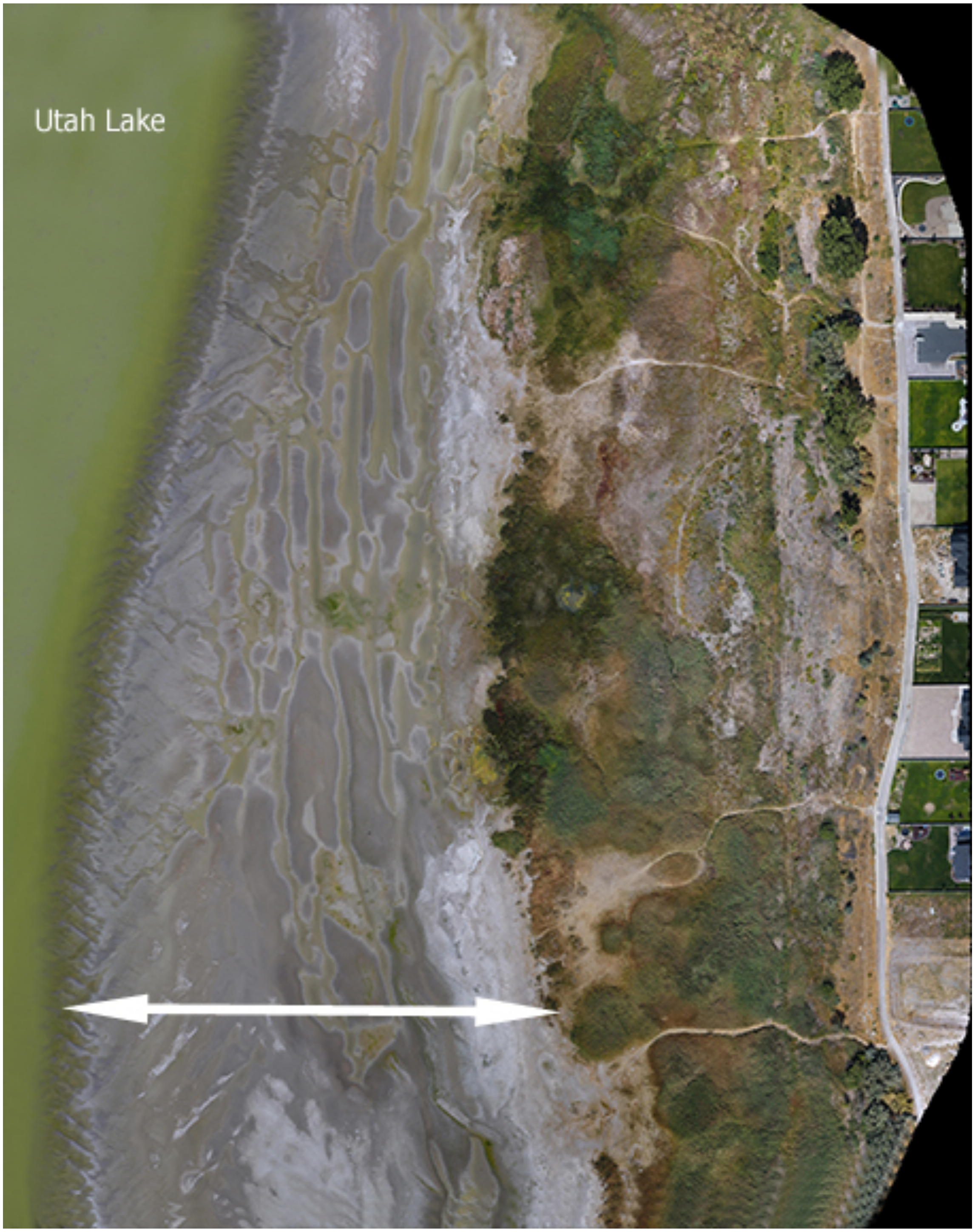

Figure 4. Aerial view of southern spring complex, spring pools, and Utah Lake at Vineyard, UT. Photo altitude = 100 m, original resolution = 3 cm/pixel. Utah Lake is the green area on the left. The area within the arrows is the exposed substrate up to the normal meander line towards the right that was surveyed and was due to low water levels from Utah Lake. The green connected oblongs in the exposed areas of Utah Lake's substrate are waters from springs that have algae and are mixed in a mosaic of gray colored dry areas. Springs and pools flow from the right of the image and empty to Utah Lake on the left. Far right is new subdivision with paved path.

Perennial spring tributaries and pools covered about 20 to 30% of the survey area and provided refuge for any surviving bivalves from desiccation as lake levels lowered. However, these survivors would have been visible to both predators and researchers alike in these shallow < 2 cm deep pools. These same spring waters likely provide substantially better habitat for native mussels than the lake itself during times of high lake waters. Indeed, spring influenced areas of Utah Lake were likely the sole remaining habitat during the 1930's drought when all of Utah Lake's tributaries were diverted for irrigation and Utah Lake almost completely dried up. The springs also may have been the last sanctuary for any surviving mollusks in winter during the 1930's drought when the lakebed froze solid, likely to several meters' depth. Spring fed waters are also prime habitat for spawning fish including carp, which could potentially be secondary hosts for Anodonta glochidia and are areas where young mussels would likely abandon their hosts and take up residence.

Figure 5. View of Utah Lake near Vineyard, UT looking SW. The lake is in the far distance with several pelicans observable on its shoreline. Water in foreground out to the Utah Lake shoreline is pools from the many springs in the area.

Figure 6. Flowing spring water and algae and aquatic vegetation at the most northerly spring in the survey near Vineyard, UT, September 5, 2016.

Figure 7. Researcher taking notes at one of the flowing springs along the eastern shores of Utah Lake, September 2016.

Results

No live or recently dead Anodonta were encountered. Very few highly fragmented Anodonta shells were found scattered across the survey site (Figures 8 and 9).

Figure 8. Weathered mollusk shells and fragments in the main channel of the most northerly spring surveyed. Shells are mostly fingernail clams (Family Sphaeriidae) with one large Anodonta sp. fragment visible in the center of the photo.

Figure 9. A highly weathered Anodonta shell fragment found in the most northerly spring.

There were many (N > 1000) widely scattered Corbicula popping out of the sediments near spring influenced substrate. Some Corbicula were still alive, while most were recently killed by predators. Shorebirds and raccoons pulled many of the Corbicula out of substrate, waited until the clams became dehydrated and exhausted and then were eaten. Even though there were thousands of Corbicula, they were more dispersed and at lower densities than anticipated. Corbicula tends to occur in habitats and conditions where Anodonta likely occurred in the past (Richards 2015 and personal observations). It is probable that Anodonta biomass (densities) was at least as much as what now occurs with Corbicula in Utah Lake and in the entire Jordan River drainage.

Figure 10. A live Corbicula exposed due to receding Utah Lake waters. Tracks of potential bird predators are also visible.

Figure 11. Another Corbicula exposed to predators during receding Utah Lake shoreline, September 2016.

Figure 12. Corbicula debating whether to leave receding Utah Lake waters and imminent desication or becoming exposed to predators near Vineyard, UT.

Figure 13. Corbicula that made the wrong choice and was eaten by predators, Vineyard, UT, September 2016.

Thousands and thousands of highly weathered fingernail clam shells (Family Sphaeriidae) were found along the normal meander line of the lake and there were very high densities of shells in the spring flows (Figure X).

Figure 14. Weathered mollusk shells, primarily native fingernail clams (Family Sphaeriidae) in one of the spring tributaries to Utah Lake near Vineyard, UT. This is typical of the number and densities of shells found covering the substrates in these spring tributaries.

The high densities of weathered mollusk shells in the springs and exposed areas of Utah Lake shoreline is typical of the entire lake and almost all of its tributaries. In every instance of surveying for the last several years and during benthic sampling in the lake, there is an often thick layer of sediment covering thousands of weathered mollusk shells including Anodonta, Sphaeriidae, Hydrobiidae, Valvatidae, Lymnaeidae, and Physidae. This is direct evidence of past favorable conditions in Utah Lake for a rich and diverse molluskan assemblage. At this time, it is only speculation as to what caused rapid sedimentation, often greater than several centimeters thick, which likely was a main contributor to the demise of Utah Lakes native mollusks.

The only live mollusks other than Corbicula that were found in the survey were Physa snails which were abundant in many of the spring pools (Figure 15).

Figure 15. The only living gastropods found in the springs were physa snails. Snails are all of the dark spots in the photo.

b. Goshen Bay shoreline at Goose Point North

Three surveyors examined the shoreline and wetted area up to 1 m depth for 2 hours using clam rakes at Goose Point North, Goshen Bay (Figure 16)(from Longitude 111°51'48.17"W to 111°52'5.38"W).

Results

No live or recently dead native mussels were encountered. A few highly weathered Anodonta fragments were found. There were wave washed piles of weathered pulmonates and prosobranch snail shells as well as fingernail clams. Several live Corbicula were also found. Again, the wave washed piles of highly weathered shells is typical of Utah Lake's shoreline indicating a once thriving native mollusk assemblage unique to the western USA.

Figure 16. Goshen Bay survey site.

c. Shoreline SW of Provo Airport

A total of approximately 2 km of the shoreline of Utah Lake near the SW corner of Provo City Airport (Figures 17 to 20) was surveyed by Richards on several occasions throughout the summer of 2016.

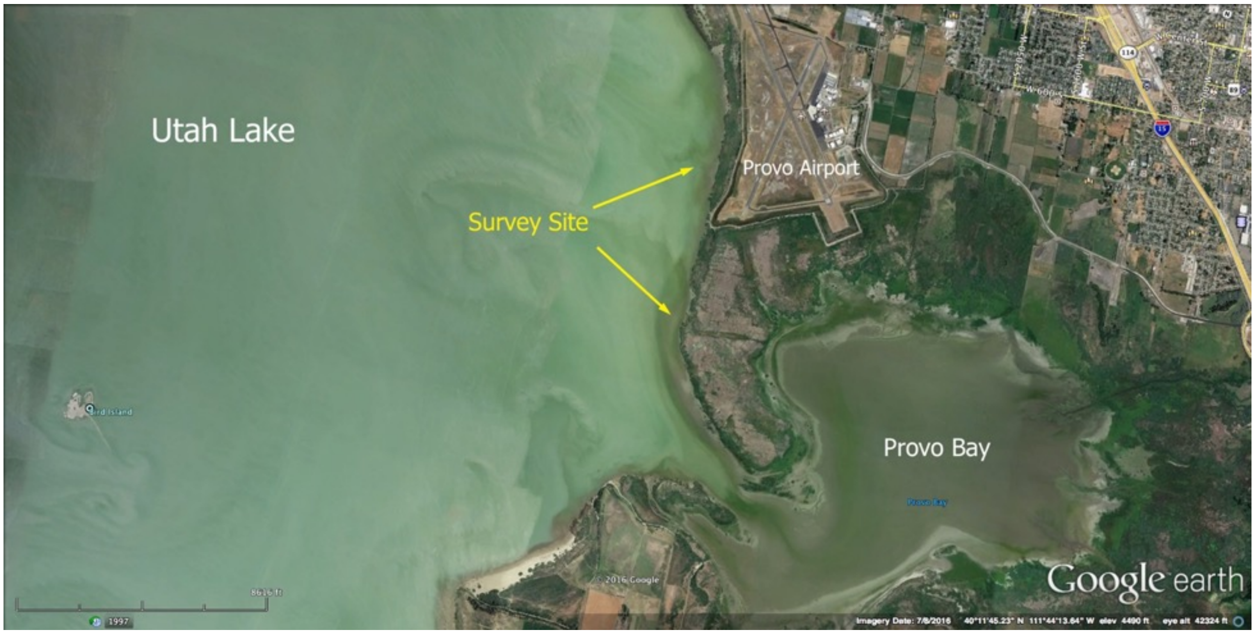

Figure 17. Locations of mollusk survey site near SW corner of Provo City Airport.

Figure 18. Shoreline of Utah Lake near SW corner of Provo City Airport looking south on August 17, 2016. Receding Utah Lake waters although indicative of the severe drought conditions the area is experiencing, were ideal for surveying exposed mollusks.

Figure 19. Shoreline of Utah Lake near SW corner of Provo City Airport looking southwest on August 17, 2016. Area in foreground is where weathered mollusk shells started to become more abundant and increased in abundance up to the lakes meander line (see next photo).

Figure 20. Area near normal meander line of Utah Lake shoreline near SW corner of Provo City Airport. Note weathered Anodonta shell in foreground right, near bulrush. Thousands of weathered shells including Anodonta and an occasional Utah valvata can be found all along this area for several kilometers. Utah Lake was a unique molluskan hotspot in the western U.S. in the not too distant past.

Results

No live or recently dead native mussels were encountered. Quite a few complete highly weathered Anodonta half- shells and shell fragments were encountered, mostly along the normal meander line along with piles of fingernail clams and a variety of snails shells including the heterobranch *Valvata utahensis* presumed to be extinct in Utah. This further confirms the mounting evidence that Utah Lake once supported vast numbers of mollusks and that this area of Utah Lake near the mouth of Provo Bay may have had large beds of Anodonta.

Figure 21. Weathered Anodonta shell at normal meander line of Utah Lake near SW corner of Provo Airport, July 29, 2016.

2. Beer Creek

Beer Creek is home to one of two known remaining isolated small populations of Anodonta in the Jordan River watershed. Unfortunately, Beer Creek is heavily used for agricultural purposes and its downstream sections from W 6400 S to its confluence with Utah Lake is often without water for many consecutive days and weeks throughout the summer. Freshwater mollusks can survive limited desiccation in cool damp conditions, however summer temperatures and humidity levels typically bake these sections of Beer Creek's mud/clay sediments to the consistency of hardened cement. Three surveyors, including Dr. Richards, examined Beer Creek for approximately 300 meters upstream of its confluence with Utah Lake (Figures 22-24) (Lat

40° 8'25.15"N; Long 111°47'36.61"W) using clam rakes and visual examination of shoreline and exposed substrates on August 15, 2016.

Figure 22. Mollusk survey location on Beer Creek at confluence with Utah Lake. Survey was conducted on August 15, 2016.

Figure 23. Stagnant pool of Beer Creek water at Lincoln Beach Road bridge looking north, August 15, 2016

Figure 24. Stagnant pool of Beer Creek water at Lincoln Beach Road bridge looking north, August 24, 2016. This is the same location as the previous photo.

Results

No live or recently dead native mussels were encountered. This was expected because this section of Beer Creek is often without water. Native mussels need water. Three highly weathered Anodonta shell fragments were found, further demonstrating that Beer Creek was once suitable habitat for Anodonta.

Several state and federal management agencies are aware of the demise of Utah's native mussels (Richards 2015 mollusk survey report was electronically sent to these agencies). In particular, these agencies have been informed in detail of the extinction risk that threatens the last remaining known Beer Creek population which consists of just a few individuals surviving in an upstream section of the creek and which is one of only two small highly fragmented isolated extant populations known in the entire Jordan River drainage. However, protection including maintaining critical summer flows and water quality does not seem to be forthcoming despite this threat and the fact that native mussels are specifically protected under the Clean Water Act (1977), “the protection and propagation of fish, **shellfish**, and wildlife and recreation in and on the water.”.

3. Spanish Fork River

The Spanish Fork River is one of the major tributaries to Utah Lake. However as with all of Utah Lake’s tributaries; the majority of Spanish Fork River flows are diverted for irrigation during irrigation season other than those waters that flow out of water treatment facilities. Flows in the section of Spanish Fork River downstream of W 4000 S to its confluence with Utah Lake often stop and become stagnant (Figure 25-28). Only minuscule amounts of irrigation water in the area infiltrates into the groundwater and is then able to somewhat recharge the Spanish Fork River’s flow into the lake. Several estimates of flow in these sections of the Spanish Fork River were made in the summer and ranged between 0 and < 5 cfs (SDSD dataset).

Dr. Richards surveyed 1.4 km of the Spanish Fork River from its confluence with Utah Lake upstream (Figure X) (Latitude: 40°10'5.76"N, Longitude: 111°45'3.07"W to Latitude: 40° 9'55.94", Longitude: N, 111°44'4.65"W) using aquascopes, clam rakes and visual surveys on August 16, 2016 for 10 hours. Flows were estimated between 0 and 1 cfs.

Figure 25. Mollusk survey site on Spanish Fork River at confluence with Utah Lake.

Figure 26. Spanish Fork River and algal bloom just upstream of a diversion dam and downstream of W 4000 S bridge on July 18, 2016. Flow was estimated to be << 1 cfs.

Figure 27. Green algal bloom on Spanish Fork River as it enters Utah Lake on July 18, 2016. Flows were estimated to be < 5 cfs and most of the water was pooling and stagnating before entering the lake.

Figure 28. Spanish Fork River between W 4000 S bridge and confluence with Utah Lake on July 18, 2016. Most of the river was diverted for irrigation and flows here were estimated at <3 cfs. Notice thick algal mats indicating nutrient overload.

Results

No live or recently dead mussels were encountered, although as was the case for most survey locations, several highly weathered Anodonta fragments were found indicating that the Spanish Fork River was also once prime habitat for native mussels.

5. Burraston Ponds

Burraston Ponds have been reported to support an Anodonta population in the recent past (Hovingh year, Mock et al. year, and Richards 2015). However, none were found by Richards and three technicians snorkel surveying in 2015 (Richards 2015). Dr. Richards snorkel surveyed the largest of Burraston Ponds for 2 hours on August 22, 2016.

Results

No live or recently dead native mussels were encountered. As was the situation in 2015 aquatic vegetation severely limited the area that could be surveyed. SAV dominated the pond but was mostly decadent and visibility was limited to areas with no SAV. It is hopeful that an isolated Anodonta population still survives in these ponds and that future more intensive surveys will verify.

6. Currant Creek: *Last Hope for Anodonta*

a. Outlet Burraston Ponds

Unfortunately, Currant Creek at the outlet of Burraston Ponds was almost completely dry with several stagnant pools when surveyed on August 22, 2016 (Figures 29-31).

Results

As was the case when surveyed in 2015, massive amounts of Corbicula covered the substrate for the entire 100 meters examined. However, in 2016 thousands of Corbicula were stranded and became desiccated due to the extreme low flows resulting in most of the substrate being exposed (Figure 32). As in 2015, no native live, recent dead or weathered native mussels or their shells were found.

Figure 29. Stagnant pool in Currant Creek looking upstream from outlet of Burraston Ponds, August 2016. Low flows, increased exposed substrates, algal blooms, stagnant conditions, and Corbicula dominate the creek.

Figure 30. Currant Creek looking downstream of Burraston Ponds outlet, August 2016. Low flows, increased exposed substrates, algal blooms, stagnant conditions, and Corbicula dominate the creek.

Figure 31. Trashed out, stagnant section of Currant Creek at outlet of Burraston Ponds, August 2016. Note all of the exposed Corbicula shells becoming exposed due to low flows.

Figure 32. Corbicula left high and dry. This was normally wetted substrate in Currant Creek at Burraston Ponds. Photo taken August 2016.

b. Currant Creek downstream, Mona Reservoir, and Goshen Canyon

There is an irrigation check dam at W 200 N bridge crossing in Mona, UT and Currant Creek appeared to have become dry downstream of the dam into Mona Reservoir. There may have been some seeps and flowing water in the channel between the bridge crossing and the dry Mona Reservoir but this section wasn't closely examined. Of course, Mona Reservoir was completely dry during the summer of 2016 (Figure 33).

Figure 33. Mona Reservoir high and dry. August 2016.

Currant Creek was completely dry for about 2 km downstream of the Mona Reservoir dam, (Figure 34).

Figure 34. Currant Creek dry from Mona Reservoir (also dry) downstream to about 100 meters of this photo where springs recharge occurs.

Several springs again recharged Currant Creek creating limited flows starting at the beginning of Goshen Canyon (latitude: 39°53'18.28"N, longitude 111°53'10.71"W). However, this section was heavily grazed by cattle (Figures 35 and 36). Most of the creek and riparian vegetation was trampled and the little water that flowed was filled with cattle excrement and algae (Figures 35 and 36).

Figure 35. Several cattle patrol one of the last remaining occupied Anodonta habitats in the Jordan River drainage at Currant Creek, near Goshen Canyon, August 2016. Currant Creek is recharged from springs about 10 meters upstream (right side of photo) but is immediately impaired from poorly managed cattle grazing practices.

Figure 36. Limited spring recharge in Currant Creek at beginning of Goshen Canyon becomes impaired by cattle.

Flows increased going downstream in Goshen Canyon from additional spring recharge and five live adult Anodonta were found just upstream of an irrigation check dam (Figure 37 and 38) (latitude: 39°53'47.03"N, longitude: 111°53'17.77"W).

Figure 37. Location of last reported Anodonta population in Currant Creek, Goshen Canyon, August 2016.

One recent dead and several relatively unweathered empty shells were also found at this site (Figure 41). The recently dead Anodonta was obviously killed and eaten by a raccoon by evidence of the tell-tale bite marks and shell breakage and tracks around it in the mud. Two of the live Anodonta were fully exposed from the sediments laying on their sides in the creek suggesting that they were moving from their current location for reasons unknown but presumable in search of better conditions (Figure 39 and cover photo). The entire substrate in this section was completely covered by Corbicula up to several centimeters depth making it difficult for any remaining Anodonta to burying themselves into the substrate (Figure 40).

Chemistry readings were collected at three locations in Goshen canyon (Table 1). Ammonia levels dropped by 38% and phosphate by 50% from the upstream cattle infested site to where Anodonta were found, a distance of about 1.2 km. Ammonia levels dropped by 72% from the upstream site at the start of the canyon to the mouth of Goshen Canyon and phosphate levels dropped by 70%, a distance of about 2.5 km. Nitrate levels (mg/l) were fairly constant but decreased from upstream (0.68) to down (0.60) (Table 1).

Table 1. Ammonia (NH_3), Nitrate (N), and Phosphate (P) readings at three locations in Currant Creek, Goshen Canyon, UT. Collected on September 2, 2016.

	Lat	Long	NH_3	N	P
Upstream at start of springs	39°53'18.28"	111°53'10.71"	1.65	0.68	0.1
Midstream (where live Anodonta were found)	39°53'47.03"	111°53'17.77"	1.03	0.66	0.05
Downstream (mouth of Goshen Canyon)	39°54'49.44"	111°54'3.44"	0.46	0.6	0.03

There is an urgent need to conduct more intensive research on Currant Creek in Goshen Canyon and to determine the viability of this remaining Anodonta population, which may number << 10 individuals.

Figure 38. Section of Currant Creek in Goshen Canyon where several Anodonta still survived, August 2016.

Figure 39."No Vacancy: Anodonta on the run", Currant Creek, Goshen Canyon. Exposed Anodonta apparently trying to escape surroundings including water quality problems or just too many Corbicula.

Figure 40. Corbicula are the substrate. Over several centimeters thick of live and empty Corbicula shells. Currant Creek, Goshen Canyon August 2016.

Figure 41. "Just not fast enough". Anodonta recently killed and fed on by raccoon. Notice some soft tissue remains.

Currant Creek continued to flow through the canyon but only cursory investigations were conducted. The water in the canyon was extremely turbid and the substrate at most locations was composed of large cobbles and boulders which made visual surveying using aquascopes and clam rakes unfeasible. Additional sampling needs to be conducted in the canyon.

Once Currant Creek leaves Goshen Canyon it is diverted for irrigation. At W 15200 S (Main St.) in the hamlet of Goshen just downstream of Goshen Reservoir, Currant Creek was dry (August 2016). Goshen Reservoir was also dry. It is assumed that Currant Creek remained dry downstream to its former confluence with Utah Lake.

Currant Creek was surveyed on May 26, 2016 from Goshen Bay, Utah Lake upstream for approximately 1 km. The creek was dry at this time also (Figure 42). Several highly weathered Anodonta shell fragments were encountered (Figures 43 and 44). Most were slightly exposed in the muddy substrate (Figure 42) substantiating the fact that Currant Creek historically was suitable habitat for Anodonta. Although Goshen Bay had water during the mollusk survey at this location on May 26, 2016, it later dried up for about 2 km north by the end of August 2016 (Figure 45).

Figure 42. Currant Creek streambed on May 26, 2016. This 1 km surveyed section of Currant Creek was dry. Only a few puddles from Utah Lake waters or rain events were present.

Figure 43. Anodonta weathered shell fragment in Currant Creek mud at mouth Utah Lake.

Figure 44. Several weathered Anodonta shells and large gastropod shells found in dry Currant Creek sediments near confluence with Utah Lake. Notice the large Lymnaeidae shell in whit jar top and the large Planorbidae shells.

Figure 45. Goshen Bay dry in late August 2016. View is looking south towards dry Currant Creek.

As with the last remaining Anodonta population in Beer Creek, the last isolated small population in Currant Creek has been known by management agencies for many years. However, there appears to be no habitat protection for these few remaining individuals in Currant Creek.

8. Mill Pond

Mill Pond near Lehi, UT cannot be completely ruled out for supporting a small population of Anodonta. Dr. Richards snorkel surveyed for Mill Pond for 2 hours on August 30, 2016. Visibility was up to 1 meter but most of the pond was covered in SAV which limited ability to survey completely.

Results

No live, recently dead, or weathered Anodonta shells were encountered, although many Corbicula were found. Continued surveying of Mill Pond is recommended.

9. Spring Creek

Spring Creek was surveyed by five surveyors including Richards for a total of 30 hours of searching. Most of Spring Creek is very shallow from the outlet of Mill Pond downstream for about 2 km but then becomes deeper and slower as a result of several irrigation and beaver dams (Figure 46). However, Spring Creek no longer reaches or is connected to Utah Lake because of diversions (Figure 47).

Figure 46. Spring creek beaver dam and trash.

Figure 47. Disjunct flow of Spring Creek at confluence with Utah Lake.

Results

No live Anodonta were found. Three complete somewhat weathered Anodonta half-shells were found at the upstream section just downstream of Saratoga Hwy crossing suggesting that Anodonta was present fairly recently in the past. Unfortunately, most of the available habitat is now occupied by Corbicula. Unfortunately, Spring Creek no longer connects to Utah Lake and its ample flows from cold water springs just several kilometers upstream either are used for irrigation and/or disappear as groundwater and reappear about 1 km west or as groundwater springs in Utah Lake. Thus, there is no connection between the remaining degraded but potentially suitable Anodonta habitat upstream in Spring Creek and Utah Lake.

10. Provo River in Orem

Two surveyors including Dr. Richards searched for native mussels in the Provo River in Orem, UT for 8 hours (40°17'52.37"N; 111°39'42.88"W) from the bridge on Center St. upstream for 300 m. No live, recently dead, or weathered native mussel shell fragments were found. The most likely native mussel to have been encountered would have been Margaritifera as the habitat was mostly cobbles and cold water. Several live Corbicula were found and two hydrobiid snails, Fluminicola and Pyrgulopsis occurred at high abundances, as well as the invasive New Zealand mudsnail (Potamopyrgus) (Family Tateidae).

11. Jordan River

Reports of large numbers of ‘clams’ in the Jordan River by Salt Lake County biologists prompted Dr. Richards and Dr. Miller to conduct a brief one-hour clam rake at the location reported near the W 1700 S bridge crossing (40°44'1.82"N; 111°55'23.68"W).

Results

Thousands of live and dead Corbicula were found in this section of the Jordan River. In one location, each rake of the clam rake produced hundreds of clams (Figure 48). No live, recently dead, or weathered Anodonta shell fragments were found. The Jordan River obviously was very good habitat for native mussels and their apparent disappearance is a tragic loss for this impaired ecosystem.

Figure 48. Dr. Theron Miller with a clam rake brimming with Corbicula. Densities were the highest yet found in the Jordan River and equaled or surpassed densities in other productive locations in the drainage.

Discussion and Conclusion

Based on recent searches conducted by the author and trained surveyors (Richards 2015a and 2015b and this report), it appears that Anodonta populations in the Jordan River drainage are in serious condition and their continued viability is precarious. Native fingernail clams (Family Sphaeriidae) also appear to be in severe decline throughout the drainage and particularly in the lower valley waters including Utah Lake. The invasive Asian clam, Corbicula now appears to be the Jordan River drainage's resident bivalve replacing the natives and can often occur at unimaginable densities; densities that were once reserved for native bivalves. Even though two Anodonta populations and several fingernail clam populations still exist; the Jordan River drainage native bivalves are functionally extinct and contribute little to ecosystem function. Native snails, in particular, heterobranchs and prosobranchs also occur in far fewer locations and densities than in the past. Utah Lake was once a tremendous haven for freshwater mollusks but this in no longer the case (Figures 49 and 50). Reasons for the decline of native mollusks, particularly Anodonta and Margaritifera in the drainage are discussed in detail in the Richards 2015 reports.

Figure 49. Wave washed piles of thousands of mollusk shells, mostly heterobranch and prosobranch snails but including fingernail clams, Corbicula, and an occasional Anodonta fragment, along the east shore of Goshen Bay, Utah Lake, September 2016. Utah Lake was once home to this amazing assemblage of mollusks and its loss is tragic.

Figure 50. Piles of wave washed mollusk on eastern shore of Goshen Bay, Utah Lake, September, 2016. Shell piles are white curved lines and shell layer is several cm thick.

Dr. Richards and Miller and colleagues are also currently conducting ecological research on Utah Lake. They are collecting benthic invertebrate samples from several locations on the lake and are finding that in most sites there is a thick sediment layer often several centimeters to almost a meter thick in the northern most portion of the lake under which is a layer of empty mollusk shells. Richards is also finding this to occur along the now dry shores of Utah Lake; a layer of sediment followed by the layer of mollusk shells. This is strong evidence that Utah Lake underwent a ‘catastrophic ecosystem shift’ and that the lake’s mollusk assemblage was extremely diverse and continuous across most of the lake but was rapidly lost during this shift due to increased and rapid sedimentation rates likely starting with the first settlers in the late

1800's. The Miller and Richards team is planning on conducting analyses to determine the dates and rates of this sedimentation and timing of the subsequent demise of Utah Lakes unique and irreplaceable mollusk assemblage.

Recommendations

Continued surveying in additional locations and monitoring of the last remaining known populations are needed. Also, population dynamic studies for each of the remaining native mollusk taxa and in particular the native bivalves and non-pulmonate snails are urgently required. Population dynamic studies of the last populations of native mollusks in the drainage are indispensable to determine the causes of their disappearance, predict their extinction risk, and suggest management strategies that may circumvent or postpone their extinction.

Acknowledgements

The author would like to thank the 2016 South Davis Sewer District crew for all of the surveying assistance including Dr. Theron Miller and to the continued collaboration and cooperation between UDWQ, UDNR, EPA, and the JRFBWQC.

Literature Cited

Richards, D. C. 2015a. Recalculation of Ammonia Criteria for Central Valley Water Reclamation Facilities' Discharge into Mill Creek, Salt Lake County, UT based on Native Unionoida Surveys and Metapopulation Dynamics. Final Report to Jordan River/Farmington Bay Water Quality Council. Salt Lake City. OreoHelix Consulting, Moab, UT 84532. Version 4.1. July 16, 2016.

Richards, D. C. 2015b. Unionoida Mussel and Non-Pulmonate Snail Survey and Status in the Jordan River, UT. Final Draft Report. Version 2.1 Revision January 2016. Report to Jordan River/Farmington Bay Water Quality Council, Salt Lake City. OreoHelix Consulting Moab, UT.