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Mercury Concentrations in Quagga Mussels, *Dreissena bugensis*, from Lakes Mead, Mohave and Havasu

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Abstract The recent invasion of the Dressenid species, the quagga mussel, *Dreissena bugensis*, into Lakes Mead, Mohave and Havasu has raised questions about their ability to alter contaminant cycling. Mussels were collected from 25 locations in the three lakes. The overall average was 0.036 ± 0.016 μg g^{-1} Hg dry wt. The range of the three lakes was from 0.014–0.093 μg g^{-1} Hg dry wt. There were no significant differences in mercury concentrations among the three lakes ($F = 0.07$; $p = 0.794$). From this baseline data of contaminants in quagga mussels from the lower Colorado River, this species may be used to biomonitor lake health.

Keywords Mercury · Quagga mussel · Lower colorado river · Invasive species

The quagga mussels' (*Dreissena bugensis*) ability to filter large quantities of water allows them to bioconcentrate toxicants in water. This ability to bioconcentrate toxicants makes mussels a useful biomonitoring organism and accordingly, can be used to estimate overall environmental health. Biomonitoring organisms are an effective way to estimate contaminant concentrations in water when concentrations are too low to measure using conventional water sampling methodologies (Richman and Somers 2005). For most studies conducted world-wide, concentrations of contaminants in a wide variety of mussel species' soft tissue is reflective of concentrations in the environment (Chiu et al. 2000; Marvin et al. 1994; Metcalfe and Charlton 1990; Muncaster et al. 1990; Peven et al. 1996; Rainbow et al. 2000). Similar findings have been reported for Dreissenid species in North America (Bruner et al. 1994; Mills et al. 1993; Rutzke et al. 2000; Secor et al. 1993; Table 1).

Mercury (Hg) is an element that has become a ubiquitous component of aquatic environments from overuse of pesticides, antiseptics and preservatives, the burning of fossil fuels and natural weathering processes (Clarkson et al. 2003). The most dangerous form of mercury, methyl mercury, bioaccumulates up the food web and may have adverse health affects on consumers (Williams et al. 2000). Mercury has been found in fish tissue, (Cizdziel et al. 2002, 2003; Kramer 2009) surface water, sediment and groundwater from Lake Mead (Cizdziel and Zhou 2005). Concentrations in fish mussel tissue ranged from 0.0084 to 0.309 μg g^{-1} depending on the species (Cizdziel et al. 2003). Mercury concentrations in surface and groundwater were under 10^{-6} μg g^{-1} and sediment concentrations averaged 0.034 μg g^{-1} (Cizdziel and Zhou 2005). Quagga and zebra mussels easily bioaccumulate organic mercury from the water column, suspended particles, sediment and interstitial water because they must filter massive amounts of water on a daily basis to get enough nutrients to survive. Mussels provide an easy way to monitor aquatic contaminants because of their ease of collection, sedentary lifestyle and relatively wide distribution (Kwan et al. 2003). No research on contaminant concentrations in quagga mussels from Lakes Mead, Mohave or Havasu quagga mussels have been conducted prior to this study. Previous studies have shown that the presence of quagga and zebra mussels will allow more contaminants to be bioavailable and travel up the food chain at higher concentrations (Hogan et al. 2007; Kwon et al. 2006). The potential for bioaccumulation of

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Table 1 Mercury concentrations in quagga and zebra mussels cited in the literature

Species	Hg μg g^{-1} dry wt	Location	References
D. bugensis[a]	0.09–0.28	Lake Ontario	Mills et al. (1993)
D. bugensis	ND[b]–0.15	Niagara River, NY	Richman and Somers (2005)
D. bugensis	0.11	Lake Ontario	Rutzke et al. (2000)
D. bugensis	0.15–0.22	Lake Erie	Rutzke et al. (2000)
D. polymorpha[c]	0.049–0.158	Insubria region, N. Italy	Camusso et al. (2001)
D. polymorpha	0.02–0.05	Upper Mississippi River	Cope et al. (1999)
D. polymorpha	0.109–0.22	St. Lawrence River, Canada	Kwan et al. (2003)
D. polymorpha	0.04–1.37	Lake Ontario, Erie and Niagara River, NY	Lowe and Day (2002)
D. polymorpha	0.1–0.25	Lake Ontario	Mills et al. (1993)
D. polymorpha	ND–0.12	Niagara River, NY	Richman and Somers (2005)
D. polymorpha	0.1	Lake Ontario	Rutzke et al. (2000)
D. polymorpha	0.26	Lake Erie	Rutzke et al. (2000)
D. polymorpha	0.05–0.38	Upper New York State	Secor et al. (1993)
D. polymorpha	0.817–0.102	Kleines Haff, Germany	Wiesner et al. (2001)

[a] *D. bugensis* = quagga mussel

[b] ND = none detected

[c] *D. polymorpha* = zebra mussel

mercury up the food chain in Lakes Mead, Mohave and Havasu may increase for species that ingest quagga mussels such as diving ducks and fish. The following study was designed to evaluate concentrations of mercury in quagga mussels from Lakes Mead, Mohave and Havasu of the lower Colorado River and to establish baseline concentrations of mercury in mussels that will be crucial for future comparisons.

Materials and Methods

Samples were collected from August 2007 to December 2008 (Table 2). Mussels were collected by National Park Service and Bureau of Reclamation SCUBA divers at locations in Lake Mead (n = 10), Mohave (n = 5) and Havasu (n = 6). Samples from Katherine's Landing in Lake Mohave and Las Vegas Boat Harbor in Lake Mead were collected by scraping the bottom of docks with gloved hands by UNLV employees (Fig. 1). Mussels were transferred from surfaces to 0.5 or 1 L plastic Nalgene bottles and stored on ice until they were placed in a −20°C freezer. All mussels were collected in accordance with Nevada Department of Wildlife collection and possession permit #S30712.

Only mussels with a shell length >10 mm were used. Soft tissue from each location was removed from the shell to make a composite sample, homogenized and then lyophilized for at least 24 h at −55°C in a Bench Top 4 K Freeze Dryer (SP Industries, New York). A composite sample consisted of enough soft tissue to reach a wet weight of at least 20 g. The number of individual mussels in a composite sample varied due to a wide range of mussel sizes. A sub-sample of 0.75–1.0 g dry tissue was digested in an Anton-Parr Multiwave 3000 microwave digestion system with 4 mL of nitric acid and 4 mL of water. Following digestion, the sample was brought up to a final volume of 15 mL. For analysis, a 4 mL aliquot of this raw digested material was transferred into a separate clean and labeled centrifuge tube containing 4 mL 3% HCl. This 1:2 solution was used in most cases for analysis.

Total mercury was analyzed in accordance with EPA Method 245.6 using a Perkin-Elmer FIMS 100 equipped with an AS-91 autosampler employing the flow-injection mercury cold-vapor technique (PerkinElmer Life and Analytical Sciences, Inc., Waltham, MA). The instrument detection limit was reported as 0.2 ng g^{-1}. The method detection limit was calculated to be 0.010 μg g^{-1}.

Quality Assurance/ Quality Control was conducted by performing a calibration blank each day prior to analysis. If the FIMS had a 0.995 or higher correlation coefficient, it was considered acceptable for the calibration curve. Standard reference materials (SRMs) were digested and analyzed with each quagga mussel analysis. The reference materials were National Research Council Canada dogfish muscle, DORM-3 (Ontario, Canada), and National Institute of Standards and Technology 1946 Lake Superior Fish Tissue (Gaithersburg, MD). SRMs had to be within 80–120% of their listed mercury concentrations. A one-way ANOVA using SPSS v.16 software (Spss Inc., Chicago, IL) was used to determine if there were any significant differences in mercury concentrations among the three lakes.

Table 2 Mercury concentrations in quagga mussels from Lakes Mead, Mohave and Havasu

Date collected	Location	Lake	Hg μg g^{-1} dry wt
8/22/2007	Indian Canyon Cove	Lake Mead	0.046
8/29/2007	Boulder Islands	Lake Mead	0.027
9/6/2007	Flamingo Reef	Lake Mead	0.043
3/27/2008	Swallow Cove	Lake Mead	0.020
4/17/2008	Middle Point Cove	Lake Mead	0.043
5/2/2008	Cottonwood Basin NE	Lake Mohave	0.040
5/6/2008	Mile Marker 36	Lake Mohave	0.039
5/7/2008	83 Dollar Cove	Lake Mohave	0.028
5/21/2008	Las Vegas Boat Harbor	Lake Mead	0.036
6/24/2008	Mesquite Cove	Lake Havasu	0.033
6/25/2008	Rufus Cove	Lake Mead	0.028
6/25/2008	Solitude Cove	Lake Havasu	0.031
6/25/2008	Teal Cove	Lake Havasu	0.028
6/25/2008	Wren Cove	Lake Havasu	0.028
6/26/2008	Bass Isles	Lake Havasu	0.041
6/26/2008	Cove of Little Foxes	Lake Havasu	0.030
7/9/2008	Black Canyon Wall	Lake Mead	0.017
7/16/2008	Davis Dam	Lake Mohave	0.034
8/5/2008	Boulder Islands	Lake Mead	0.067
8/6/2008	Sentinel Island	Lake Mead	0.028
9/17/2008	Sandy Point	Lake Mead	0.022
9/17/2008	South Cove	Lake Mead	0.027
11/17/2008	Katherine's Landing	Lake Mohave	0.027
12/2/2008	Red Cap Cove	Lake Mohave	0.093
12/2/2008	Yuma Cove	Lake Mohave	0.034

Results and Discussion

A total of 25 samples were analyzed. Results are reported in Table 2. The overall mean of mercury in quagga mussel soft tissue was 0.036 ± 0.016 μg g^{-1}dry weight of total Hg. Mussels from Lake Mead ($n = 12$) had an average of 0.031 ± 0.006 μg g^{-1}dry wt Hg, Lake Mohave mussels ($n = 7$) had 0.043 ± 0.023 μg g^{-1}dry wt and mussels from Lake Havasu ($n = 6$) had 0.037 ± 0.010 μg g^{-1} dry wt Hg. Mercury concentrations ranged from 0.017 μg g^{-1}dw at the Black Canyon Wall in Lake Mead location to 0.093 μg g^{-1}dw at Red Cap Cove in Lake Mohave.

The concentrations of mercury found in the Colorado River were low when compared to other studies. Only Richman and Somers (2005) found concentrations of mercury in quagga mussels from the Niagara River in New York to contain the range of concentrations in the present study (Table 1). The range of mercury concentrations in this study was well below the range of concentrations found in the other studies (Mills et al. 1993; Rutzke et al. 2000). When data from the present study were compared to contaminant concentrations in zebra mussels, the findings are similar (Table 1).

Using quagga mussels in the Lower Colorado River as a biomonitor is feasible based on the data from the current study. Sediment and water concentrations of mercury are very low and difficult to detect, but mussel tissue concentrations are within the range for simple analyses. Cope et al. (1999) reported methylmercury concentrations in zebra mussels to comprise 30–70% (average of 50%) of the total Hg in the mussels. The potential for bioaccumulation in Lakes Mead, Mohave and Havasu are evident. The overall average of total Hg in fish tissue from Lake Mead was found to be 0.119 ± 0.104 μg g^{-1} wet weight (Kramer 2009).

It will be important to monitor all trophic levels in these lakes for contaminants to better understand the influence of quagga mussels. Fish (Cizdziel et al. 2002, 2003) and diving ducks (Gerstenberger 2004) have been analyzed for mercury before the quagga mussel invasion in January 2007. Post-quagga mussel invasion concentrations of mercury in these species will allow a better understanding of the impact quagga mussels have had on the contaminant

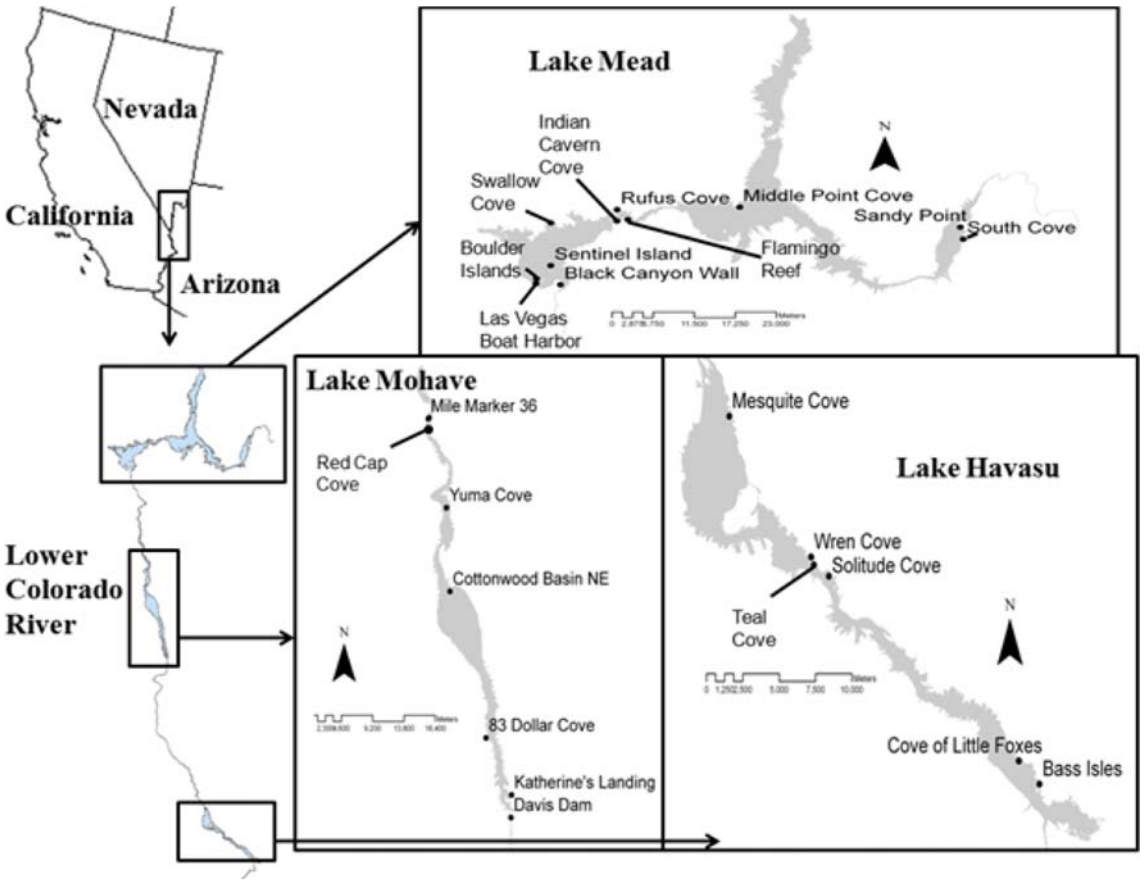

Fig. 1 Locations of quagga mussels collections

dynamics of these water systems. In conclusion, this is the first study to collect preliminary data for mercury in quagga mussels from Lakes Mead, Mohave and Havasu and it provides a baseline of data for future research. Based on this research there is potential to use quagga mussels as a biomonitor of overall lake health in Lakes Mead, Mohave and Havasu over the course of many years.

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