

Notes

A Comparison of Mercury Contamination in Mussel and Ammocoete Filter Feeders

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Abstract

The Trinity River, California, has an extensive history of gold and mercury mining, and recent studies demonstrated uptake of legacy mercury contamination by teleost fishes. We investigated mercury concentrations of larval lampreys (ammocoetes; *Entosphenus* spp.) and western pearlshell mussels (*Margaritifera falcata*) in the Trinity River to determine whether these two long-lived and sedentary filter feeders show site-specific differences in uptake of this contaminant. We analyzed ammocoetes from four sites in the Trinity River and one reference site in the Mad River for total mercury and mussels from three of the Trinity River sites for total and methyl mercury. We identified longitudinal gradients in ammocoete total mercury levels and methyl mercury in mussels. We found a 70% increase in total mercury in ammocoetes between two of the sample sites, suggesting a potential point source of contamination. Ammocoetes contained levels of mercury 12 to 25 times those of mussels from the same site. Our data indicate that ammocoetes may be a preferred organism to sample for mercury contamination and ecological effects compared with mussels in the Trinity River.

Keywords: mercury; Trinity River; lamprey; ammocoete; western pearlshell mussel; mussel

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Introduction

The Trinity River, California, has an extensive history of gold and mercury mining dating from the 1850s through the 1950s (Holmes 1965; Alpers et al. 2005). The mercury introduced into the Trinity River system has led to varying concentrations of mercury in sediments and biota. Reconnaissance surveys of mercury concentrations in game fish by May et al. (2005) demonstrated elevated levels in the watershed. Mercury can pose a threat to individual organisms via lethal and sublethal impacts such as immunosuppression, teratogenesis, and endocrine disruption (summary in Wiener and Spry 1996). At an ecosystem level, bioaccumulation of mercury in aquatic biota can result in biomagnification in higher order predators and is of particular human health concern when such organisms are used as a food source. Information on mercury contamination collected by the U.S. Geological Survey has led the state of California to

issue a health advisory for consumption of Trinity River fish upstream of Lewiston Dam (Klasing et al. 2005).

Focusing on taxa within a specific feeding guild provides the opportunity to elucidate the impacts of heavy metal contamination on biota in relation to life history strategies such as filter feeding. In this study, we evaluate the levels of mercury in two filter feeders, western pearlshell mussels (*Margaritifera falcata*; hereafter mussels) and larval lampreys (*Entosphenus* spp.; hereafter ammocoetes), at collocated sample sites. Several studies have demonstrated that mussels and ammocoetes uptake mercury in areas of environmental exposure (Mallatt et al. 1986; Malley et al. 1996; Renaud et al. 1998; Haas and Ichikawa 2004), but these filter feeders have never been evaluated in a comparative study. The objectives of this study were to 1) assess mercury concentrations in mussels and ammocoetes in the Trinity River and 2) examine the distribution of mercury concentration in mussels and ammocoetes at



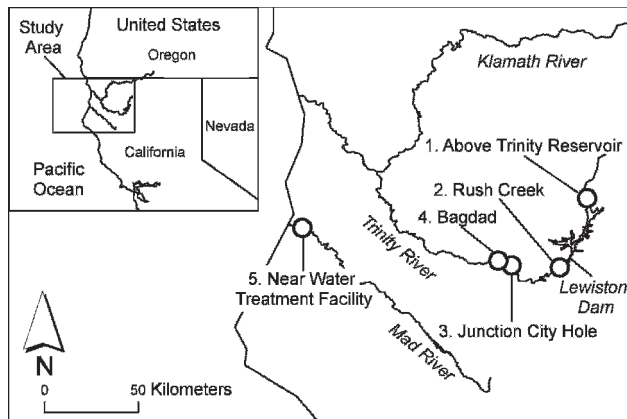


Figure 1. Map of the Trinity River study area and collection locations. Ammocoetes were collected at sites 1–5; mussels were collected at sites 2–4.

four sites within the upper Trinity River Basin and one reference site in the Mad River.

The use of filter feeders in this study has two advantages over the previously studied salmonids, centrarchids, and macroinvertebrates in the basin (May et al. 2005): 1) mussels and ammocoetes have extended freshwater residencies, with life spans of ~60–100 and ~4–6 y, respectively, providing a longer period of time for bioaccumulation (Close 2002; Nedeau et al. 2005); and 2) mussels feed primarily from the water column attached to the surface substrate, whereas ammocoetes feed near the water–sediment interface from burrows in soft sediments, providing two different mediums of potential mercury exposure on a site specific basis (Hardisty and Potter 1971).

Methods

We collected ammocoetes at three sites distributed below Lewiston Dam, one site above the Trinity Reservoir, and one reference site on the Mad River (Figure 1). In the study area, identification of ammocoetes to species is not possible using morphological characters; therefore, ammocoetes were identified to genus following Goodman et al. (2009). Mussel samples were collected at the three sites on the Trinity River below Lewiston Dam. We collected mussels by snorkeling and ammocoetes by using a backpack electroshocking unit (Smith-Root, Inc., Vancouver, WA). Sample sizes were 50 mussels and 5 ammocoetes at each site. All samples were collected in March 2007 and composited by site. We submitted samples to the California Department of Fish and Game, at the Moss Landing Marine Pollution Studies Laboratory. All samples were analyzed for total mercury by cold-vapor atomic absorption spectrometry following EPA Method 7473 (EPA 1998). We assumed that total mercury in ammocoetes is >95% methyl mercury (Bloom 1992); however, mussels were also analyzed for methyl mercury by EPA Method 1630 (EPA 2001). Analyses included appropriate blanks, duplicates, and spikes for quality assurance and quality control purposes, and all results are reported as

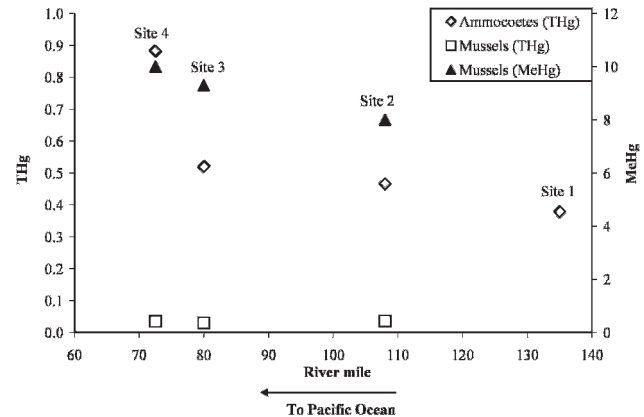


Figure 2. Total mercury (THg) concentrations in ammocoetes and mussels and methyl mercury (MeHg) concentrations in mussels by river mile in the Trinity River. THg is reported as μg/g wet weight and MeHg is reported as ng/g wet weight. River mile represents the river distance from the confluence of the Trinity and Klamath rivers at Weitchpec. Lewiston Dam is located at river mile 110 and the confluence of Canyon Creek and the upper extent of Hocker Flat restoration site is at river mile 78. Arrow represents direction of river flow towards the Pacific Ocean.

wet weight in μg/g (ppm) for total mercury or ng/g (ppb) for methyl mercury.

Results

Concentrations of total mercury in ammocoetes collected from the four sites in the Trinity River ranged from 0.379 to 0.882 μg/g wet weight (Table 1). All Trinity River ammocoete samples had greater concentrations of total mercury than the 0.291 μg/g measured at the reference site on the Mad River. Total mercury concentrations in mussels collected at the three sites on the mainstem Trinity River below Lewiston Dam ranged from 0.030 to 0.036 μg/g. Methyl mercury levels in mussel samples ranged from 8.0 to 10.0 ng/g. The percentage of methyl mercury in mussels was 22% of total mercury at site 2, 31% at site 3, and 29% at site 4. Total mercury concentrations in ammocoete samples varied longitudinally in the Trinity River (Figure 2). Concentrations increased in all downstream samples, particularly between sample sites 3 and 4, where a 70% increase was observed. An increasing downstream trend was also apparent in the methyl mercury concentrations in mussels, but this relationship was not mirrored in the total mercury concentrations in mussel samples, which were similar among the three sites. Statistical significance of these differences or trends was not tested due to small sample sizes.

Discussion

Overall, total mercury concentrations were more than an order of magnitude higher in ammocoetes than in mussels collected at the three mainstem locations on the Trinity River below Lewiston Dam. Similar differences in mercury accumulation were found between ammocoetes and mussels in the Châteauguay River in Quebec, Canada,

Table 1. River, sample site, river mile, date of collection, coordinates, sample size (*n*), and total mercury (THg), methyl mercury (MeHg) concentrations, and percentage of moisture in ammocoetes and mussels. Sample site numbers correspond to numbers on Figure 1. River mile represents the river distance from the confluence of the Trinity and Klamath rivers at Weitchpec. THg is reported as $\mu\text{g/g}$ wet weight and MeHg is reported as ng/g wet weight.^a

River	Site	River mile	Date	UTM (NAD 83)		Ammocoetes			Mussels				
				N	E	<i>n</i>	% Moisture	THg	<i>n</i>	% Moisture	THg	% Moisture	MeHg
Trinity	1. Above Trinity Reservoir	135	March 12, 2007	4544870	525432	7	67.8	0.379					
	2. Rush Creek	108	March 13, 2007	4507758	514504	9	77.9	0.466	50	86.4	0.036	88.6	9.0
	3. Junction City Hole	79	March 13, 2007	4508605	494769	6	70.8	0.520	50	90.4	0.030	86.3	9.3
	4. Bagdad	72	March 14, 2007	4513175	489465	5	80.6	0.882	50	88.0	0.035	87.5	10.0
Mad	5. Near water treatment facility	NA	March 19, 2007	4529094	411244	7	66.3	0.291					

^a UTM (NAD 83), Universal Transverse Mercator North American Datum 1983; NA, not applicable.

where ammocoetes had 5 times higher concentrations compared with mussels (Renaud et al. 1998). In an ontogenetic study of sea lamprey (*Petromyzon marinus*) in the Connecticut River, New England, ammocoetes were found to have high mercury concentrations for their trophic level compared with teleosts (Drevnick et al. 2006). Similarly, increased mercury concentrations in ammocoetes compared with other fish species surveyed have been detected in several watersheds in California where they exhibited order of magnitude higher levels of total mercury at several sites (Haas and Ichikawa 2004; Haas and Morrison 2004). Concentrations of total mercury in rainbow trout (*Oncorhynchus mykiss*) on the Trinity River averaged $0.0327 \mu\text{g/g}$ ($n = 10$) at Big Flat and $0.0499 \mu\text{g/g}$ ($n = 10$) at Hayden Flat; therefore, concentrations in our ammocoete samples were an order of magnitude higher than those in salmonids collected at nearby locations by May et al. (2005). Our results are similar those reported in the foregoing studies; however, differences in concentrations were more extreme in that ammocoetes had 12 to 25 times higher levels of total mercury compared with mussels from the same site, indicating that mussels may accumulate less mercury than ammocoetes in the same location.

The difference in total mercury concentrations between mussels and ammocoetes may be related to differences in life history strategies because mercury more readily accumulates in sediments compared with the water column (Boudou and Ribeyre 1997). Freshwater mussels reside primarily above sediments where they filter feed from the water column, whereas ammocoetes typically reside in subsurface burrows in direct contact with the substrate and filter feeder microflora and fauna near the sediment interface (Hardisty and Potter 1971; Potter 1980).

Increased accumulation of total mercury levels at successive downriver sites was apparent in ammocoetes; a similar pattern occurred in methyl mercury levels in the mussels. The ammocoete samples indicated a gradual increase of total mercury concentrations from above the Lewiston and Trinity dams to the downstream sites

sampled, with the furthest downstream sample showing a markedly higher concentration. This trend may be indicative of chronic mercury contamination in the system. A 70% increase in contamination between the two most downstream sample locations was observed (approximately 7 miles), indicating a possible point source of contamination. Our data cannot resolve the source of this contamination. However, several potential sources exist between the sample sites, including a major tributary (Canyon Creek) with a history of mining, historic mining along the Trinity River main channel, and the Hocker Flat Rehabilitation site (constructed in 2005), which includes large dredge pilings (Rytuba et al. 2005). These results indicate that further localized sampling is warranted to determine the source of the contamination.

Elevated concentrations of total mercury in ammocoetes pose two potential threats: 1) adverse health effects to the individual ammocoetes and 2) ecosystem effects on ammocoete predators through bioaccumulation. All of the ammocoete samples evaluated in this study had mercury concentrations considered detrimental to early life stages of fish ($0.2 \mu\text{g/g}$; Beckvar et al. 2005). In addition, mercury is known to biomagnify across trophic levels in aquatic systems (Watras and Bloom 1992). Our data indicate that ammocoetes are better bioindicators of mercury contamination than mussels in the Trinity River and elsewhere when the goal is to evaluate food web biomagnification and differentiate sources of contamination. We recommend further investigation of mercury contamination in the Trinity River system by using ammocoetes. Additional sampling could further refine the apparent longitudinal trend, as well as temporal trends of mercury contamination in the system by repeating the current sample sites, adding additional sites, and sampling seasonally.

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