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Mercury Levels in Gafftopsail Catfish (*Bagre marinus*) From Tarpon Bay, Sanibel, Florida, USA

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We captured 32 gafftopsail catfish, *Bagre marinus*, from J.N. 'Ding' Darling National Wildlife Refuge located in Sanibel, Florida in April-May, 2000 to determine the concentration of mercury in muscle tissue, and if mercury concentrations had reached the minimum state health advisory level (0.5ppm; wet weight), and to establish a data set for future comparison. We also compared year 2000 mercury levels against those of a 1990 study conducted in the refuge.

The gafftopsail catfish, is not considered to be commercially or recreationally important in Florida. Although it is considered to have good food value, residents do not generally consume it. However, as an opportunistic feeder it may serve as a barometer of bioaccumulated mercury within the estuarine system. This species is eurythermal and euryhaline, and its morphological, reproductive, feeding, and migratory patterns are linked to the heterogeneity of habitats encountered in estuaries (Yanez-Arancibia and Lara-Dominguez 1988). *B. marinus* ranges from Massachusetts to Panama and is reported to be common in bays and shallow areas of the northern Gulf of Mexico (Hoese and Moore 1998).

Through their diet fish bio-accumulate mercury as methyl mercury, an organic form that originates from natural and/or anthropogenic sources. Inorganic mercury, which is less efficiently absorbed and more readily eliminated from the body than methyl mercury, does not tend to bioaccumulate (United States Environmental Protection Agency 1997). Natural sources of mercury include volcanic activity, degassing of the Earth's crust, and marine phytoplankton activity, from which mercury is volitized to the atmosphere (Eisler 1987). Based on the United States Environmental Protection Agency (USEPA) Mercury Study Report to U.S. Congress (2000), the highest emitters of mercury to the air include coal burning electric utilities, municipal waste combustors, commercial and industrial boilers, medical waste incinerators, chlor-alkali plants, hazardous waste combustors, and cement manufacturers. This same report states that estimates of the global contribution of mercury emissions to the atmosphere from anthropogenic sources are 2,000 to 4,000 tons per year (tpy) and from natural sources are 2,200 to 4,000 tpy, resulting in total mercury air emissions of 4,200 to 8,000 typ. Consistent with USEPA estimates, The National Oceanic and Atmospheric Administration (1999) states that worldwide, between 2,000 and

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3,000 tons of mercury are deposited into the atmosphere from burning of coal and incineration of municipal and industrial waste. Mainly due to human activities, mercury levels in sediment and other abiotic materials are estimated to have increased up to five times pre-human levels (Eisler 1987).

In Florida, major sources of atmospheric mercury have been attributed to municipal solid waste combustors (MSW), the electric utility industry and medical waste incinerators (Atkeson 1999). The 1993 Florida Solid Waste Management Act required elimination of mercury from multiple commercial products and has reduced mercury content in municipal waste. Today it is estimated that there has been a 65% reduction in incineration of municipal solid waste in Florida (Atkeson 1999). Other investigations of atmospheric deposition of mercury indicate that trade-winds during summer months, which originate in the eastern Atlantic and are heavily laden with mercury contributed by various heavy industries within the Northern Hemisphere, eventually reach landfall in south Florida. Guentzel (1997) concludes that long range transport of reactive gaseous mercury (RGM) species coupled with strong convective thunderstorm activity during the summertime dominates mercury deposition in southern Florida. Improvements and tighter regulations on local incinerators and other sources of mercury contamination may be overshadowed by the summertime phenomenon occurring in south Florida.

MATERIALS AND METHODS

Field sampling was conducted in Tarpon Bay, which lies within the J.N. 'Ding' Darling National Wildlife Refuge. Tarpon Bay is a shallow 13 km^2 embayment that, with the exception of an area with several out-buildings on its south shore, is fringed by red mangrove, *Rhizophora mangle*. Additionally, three species of seagrasses are widely distributed in Tarpon Bay: *Thalassia testudinum*, *Syringodium filiforme*, and *Halodule wrightii*. In 1999, the salinity in Tarpon Bay ranged from 19 to 38 ppt. Tides are predominantly semi-diurnal (McNulty et. al. 1972), with a mean diurnal range of 0.5-1.1 m (Wilzbach et. al., 1999).

Using a single baited hook and line we captured 32 *B. marinus*, at various locations in the eastern half of Tarpon Bay approximately 200-300 meters from shore, over the interval April 19 –May 2, 2000. Immediately upon capture, fish were placed on ice. They were returned to the laboratory within two hours, weighed to the nearest gram, and dissected in a stainless steel tray. All instruments used in the dissection procedure were rinsed with acetone, which was allowed to evaporate from the surface prior to use. Fish weights ranged from 133 to 941 g (mean weight = 310 grams). A tissue sample was removed from the left dorsolateral musculature of each specimen, wrapped in aluminum foil, placed in a zip-loc™ bag, and frozen within 4 hours of capture for later analysis of mercury concentration. Shortly after collection of the last specimen tissue samples were placed on dry ice and shipped to University of Missouri-Rolla (UMR), Center for Environmental Science and Technology. Total mercury concentration was determined for individual samples in mg/kg (ppm) wet weight using the Mercury Cold Vapor Atomic Absorption procedure (a.k.a. 3A). UMR's 3A procedure does not distinguish between mono- or dimethyl mercury however the highly volatile dimethyl mercury is generally not persistent in aquatic environments (NOAA 1999). Quality assurance (QA) and quality control (QC) procedures employed by UMR included duplicate analysis of blanks measured for final mercury concentration and sample matrix (fish tissue) measured for percent deviation. Duplicate analysis of sample matrix spiked with 1 microgram of mercury, blind test of certified sample matrix (fish tissue), and reference spikes were each measured for percent recovery.

In 1990 Brim et al., (1994) collected specimens (n=3) from Tarpon Bay using hook and line, however no specific locations of capture within the bay are reported. Tissue samples were removed from the fillet (muscle tissue) using acetone washed instruments within 4 hours of collection and frozen at -10^0 C within 8 hours of collection (in accordance with standard operating procedures of the USFWS for collection of fish tissue samples). Tissue samples were submitted to the University of Missouri-Columbia for individual mercury analysis using the Mercury Cold Vapor Atomic Absorption technique. Weights of muscle tissue samples analyzed in both the 1990 and 2000 studies were approximately 0.5 grams wet weight.

With specimens collected in 2000, we employed a least squares regression to examine the relationship between concentration of mercury and whole body wet weight. Due to small, unequal sample sizes we employed the Mann-Whitney test (Mann and Whitney, 1947) to compare average body weight and mercury concentration of *B. marinus* collected in 1990 from Tarpon Bay against those collected in 2000.

RESULTS AND DISCUSSION

Results of QA and QC procedures showed blanks as <0.02 ug/g, and sample matrix duplicates as 8.5 and 3.4 percent deviation. Results of sample matrix spikes, certified sample matrix blind test, and reference spikes were 86 and 89, 89 and 91, and 85 and 85 percent recovery, respectively.

Testing found that the average fish weight in 1990 (n=3, mean=687g, ±S.D.=119.3) was significantly greater (U=86, p=0.025) than in 2000 (n=32, mean=310g, ±S.D.=240.6). To eliminate the influence of fish size on mercury concentration we selected the larger fish from the 2000 data (n=8) whose mean whole body wet weight was, as nearly as possible, equal to but not greater than the mean weight of the 1990 data (n=3). For comparison of mean mercury concentration and body weight respectively, between years we used the Mann-Whitney test. Statistical comparisons were repeated by adding the next lightest fish from the 2000 data per test until the relationship of whole body wet weight between 1990 and 2000 reached significance ($p < 0.05$). The maximum number

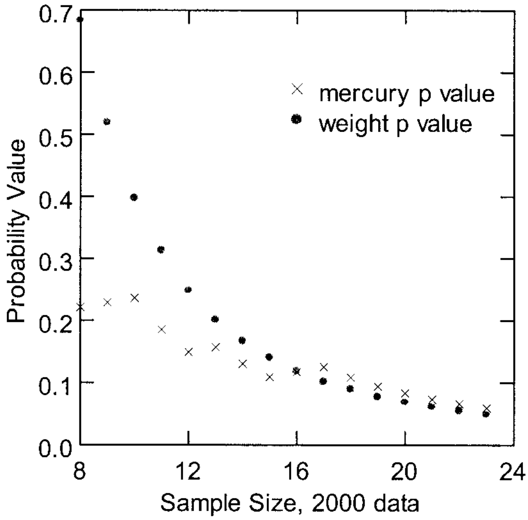

Figure 1. Results of Mann Whitney comparisons of mean weight and mean mercury concentration of *B. marinus* between 1990 and 2000 showing the sequential addition of successively lighter fish to the 2000 data set.

of cases from the 2000 data (n=22) that did not differ significantly in weight from the 1990 data (n=3) (U=56, p=0.054) also did not differ significantly in mercury concentration (U=55, p=0.066). Mean mercury concentration was not found to be significantly different between years in any of the comparisons made by the sequential addition of lighter fish to the 2000 data set prior to finding a significant difference in weight between the two years (Table 1, Figure 1).

The mean mercury concentration of specimens collected in 2000 was 0.228 ppm ($\pm$ S.D.=0.101). One of the 32 specimens collected in 2000 had a mercury concentration of 0.609 ppm, which exceeds the Florida lower-level consumption advisory of 0.5 ppm (Table 2).

Initial examination of the relationship between body weight of specimens collected in 2000 and their concentration of mercury, using least squares regression identified one mercury value as a potential outlier (0.609 ppm). The plot of residuals against predicted values of the regression also indicated slight heteroscedasticity of the data. Using the Grubbs test (1969) the single extreme mercury value was confirmed as a significant outlier (p=<0.05). Prior to recalculating the regression the outlier was first winsorized and mercury concentration values were then $\log_{10} + 1$ transformed to reduce heteroscedasticity. Recalculation of least squares regression found a significant relationship between body weight of specimens collected in 2000 and their concentration of mercury (F=40.027, p=0.0001). The fitted regression equation was:

$$y = 0.058 + 0.0001\ WW\ ;\ r^2=0.572$$

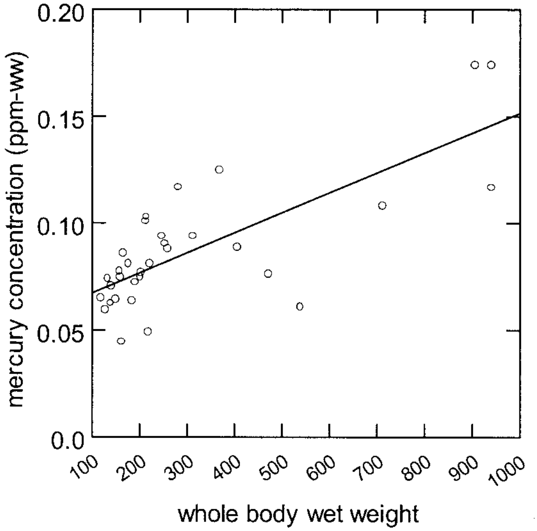

Figure 2. Result of mercury concentration regressed against whole body wet weight for 32 *B. marinus* collected from J.N. 'Ding' Darling National Wildlife Refuge in 2000.

where y is the dependent variable, mercury concentration wet weight (ppm) and WW is whole body wet weight (Figure 2).

In a similar study, we compared mercury concentration found in the spotted seatrout, *Cynoscion nebulosus* collected from the J.N. 'Ding' Darling Wildlife Refuge in 1990 (Brim et. al., 1994) with specimens collected in 1998 by Locascio and Rudershausen, (2000). In that study, we found significantly lower levels of mercury in 1998 specimens (n=30, $\pm$S.D.=0.068) than those collected in 1990 (n=11, $\pm$S.D.=0.127) (U=282, p=<0.001). Our comparison of mercury levels in *B. marinus* between 1990 and 2000 does not indicate a statistically significant lower level of mercury as did our findings with *C. nebulosus*.

B. marinus is a tertiary and quaternary level consumer, more so than *C. nebulosus* (*Rudershausen and Locascio*). This fact coupled with the low 1990 sample size may help to explain the lack of significant trend downward in mercury levels in *B. marinus* when compared against the results for *C. nebulosus*. We did, however, find a considerably lower mean mercury concentration in 2000 when comparing groups of fish between years that were similar in mean body weight. This is most evident when considering the results of the comparison between the heaviest fish from 2000 (n=8) to the 1990 data (Table 1, Figure 1). It should be emphasized that the sample size in 1990 might fail to adequately represent mercury levels, which occurred in *B. marinus* at that time. Despite this possibility the results are interpreted as indicating a decline, although not significant ($p<0.05$), in mercury concentrations found in *B. marinus* over the course of the decade.

Table 1. Results of Mann-Whitney comparisons of mean weight and methyl mercury concentrations of *B. marinus* between 1990 and 2000 showing the sequential addition of successively lighter fish to the 2000 data set.

	1990			2000					1990			2000			
n	weight	S.D.	n	weight	S.D.	U	p	n	Hg^+	S.D.	n	Hg^+	S.D.	U	p
3	686.7	119.3	8	660.8	245.1	14	0.683	3	0.467	0.156	8	0.324	0.156	18	0.221
			9	622.1	257.1	17	0.518				9	0.315	0.148	20	0.229
			10	588.0	265.3	20	0.398				10	0.314	0.140	22	0.236
			11	558.1	270.5	23	0.312				11	0.306	0.135	25	0.185
			12	532.7	272.4	26	0.248				12	0.30	0.131	28	0.149
			13	510.8	272.6	29	0.201				13	0.295	0.126	30	0.157
			14	490.2	273.0	32	0.166				14	0.289	0.124	33	0.130
			15	472.1	272.2	35	0.139				15	0.278	0.127	36	0.109
			16	456.0	270.8	38	0.118				16	0.277	0.123	38	0.117
			17	441.6	268.7	41	0.101				17	0.276	0.119	40	0.125
			18	428.4	266.7	44	0.088				18	0.271	0.117	43	0.108
			19	416.5	264.3	47	0.077				19	0.267	0.115	46	0.094
			20	405.3	262.2	50	0.068				20	0.263	0.114	49	0.083
			21	394.7	260.1	53	0.061				21	0.258	0.113	52	0.073
			22	384.8	258.0	56	0.054				22	0.255	0.111	55	0.066
			23	375.3	256.2	59	0.049				23	0.254	0.109	58	0.059

Table 2. Individual mercury concentrations (ppm wet weight) for 32 *B. marinus* captured in Tarpon Bay, J. N. 'Ding' Darling National Wildlife Refuge, Sanibel, Florida in April-May, 2000.

fork length (mm)	weight (g)	mercury wet weight (ppm)	sex	age otolith
379	940.9	0.493	NA	7
395	940.4	0.308	F	5
390	906.9	0.609	NA	9
357	713.0	0.283	F	6
327	538.7	0.150	NA	5
308	471.9	0.191	NA	5
301	407.2	0.226	F	6
297	367.6	0.333	F	4
268	312.1	0.241	NA	4
267	281.2	0.308	NA	4
267	259.4	0.224	F	4
260	254.1	0.231	NA	4
265	246.5	0.241	NA	4
240	223.1	0.205	F	4
248	218.7	0.120	F	4
248	214.0	0.267	F	4
247	212.0	0.261	F	4
247	203.5	0.193	NA	4
240	201.5	0.188	F	4
234	191.3	0.181	NA	4
236	184.0	0.157	NA	3
233	177.0	0.205	F	3
228	166.3	0.218	NA	4
228	162.8	0.108	NA	3
222	159.1	0.188	NA	3
220	158.3	0.196	NA	3
221	149.5	0.159	NA	3
204	139.7	0.177	NA	3
210	139.0	0.155	F	3
209	132.8	0.186	NA	3
209	129.5	0.146	NA	3
202	118.1	0.161	F	3

Results of the regression show that for fish we collected a positive, significant relationship exists between weight and mercury concentration. This is in contrast to our findings of trends in mercury levels in *C. nebulosos*, collected from the J.N. 'Ding' Darling National Wildlife Refuge, Locascio and Rudershausen (2000).

All specimens of *B. marinus* collected in 2000 were above the level of 0.1ppm wet weight (Table 2) that Eisler (1987) believed to be harmful to fish-eating birds.

One species known to consume *B. marinus* is the osprey (*Pandion haliaetus*) which uses the refuge throughout the year and may be exposed to levels of mercury capable of impairing physiological activity. USEPA (1997) reports that in computer simulations the osprey and kingfisher are among the most exposed (daily) to methyl mercury on a per kg body weight basis due to the concentration of fish in their diets and their status as trophic level 3 consumers. We recommend continued monitoring of mercury levels in *B. marinus* to gain a clearer understanding of any trends in mercury that may be occurring as represented by this species. We also recommend identification of existing levels and monitoring future levels of mercury in the osprey and kingfisher via analysis of feathers. Additional investigation of the dose response relationship in these species would provide valuable insight into understanding how mercury moves through south Florida estuarine food webs and the impairment of physiological activities that may be associated with it.

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