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Heavy Metals in Oyster Tissue Around Three Coastal Marinas

James M. Marcus* and Alfreda M. Thompson

South Carolina Department of Health and Environmental Control, Columbia, SC 29201

The past decade has presented an unprecedented period of growth and development along the coastline of South Carolina. The majority of this development has been to serve the recreation and tourism industry and, as such, has included the construction of numerous recreational marinas in the coastal waters of the State. During this time, these marinas have been sited in heavily-traveled and/or relatively large water systems. Recently, however, various plans have been presented for the siting of marinas in pristine estuarine waters. This has raised much concern due to the possible impacts of such development on the plentiful oyster resource found in those waters. Marinas present the potential for the introduction of pollutants such as heavy metals into the surrounding waters. Several reports have investigated the occurrence of heavy metals in natural oyster populations (Guthrie et al. 1979, Lytle and Lytle 1982) and concluded that elevated levels in shellstock were due to anthropogenic sources such as industrial and municipal wastewater effluents. One recent report has presented the possibility of shell thickening due to anti-fouling paint compounds used on marine vessels (Waldock and Thain 1983). However, no data have been presented addressing specifically the effects of recreational marinas on metals concentrations in shellfish.

This investigation was conducted by the South Carolina Department of Health and Environmental Control (SCDHEC) during 1983, and yielded a multifaceted data base composed of physicochemical and bacteriological analayses from water, chemical analyses from sediment and chemical/bacteriological physiological analyses from the American oyster, _Crassostrea virginica_ (Gmelin). _C. virginica_ was chosen as the organism of interest due to its wide distribution in the estuaries of South Carolina, its importance as an economic and recreational resource and its suitability as a sentinel organism for monitoring coastal pollution.

MATERIALS AND METHODS

Three marinas in coastal South Carolina were chosen for this project. A grid of ten stations was placed around each marina for intertidal oyster and sediment collections as depicted in Figure 1. Sediment was also collected from a station in the center channel between each right (R) and left (L) bank station. Analyses

*Correspondence and reprint requests

were conducted for the following heavy metals with each respective lower detection limit reported in parentheses: cadmium (0.2 mg/kg) chromium (1.0 mg/kg), copper (1.0 mg/kg), lead (1.0 mg/kg), mercury (0.25 mg/kg), nickel (1.0 mg/kg) and zinc (1.0 mg/kg).

Live oysters were collected manually from the mid-intertidal portion of the reefs at all stations. Each sample consisted of 15 adult oysters of marketable size (>7.5 cm in height). Sampling was conducted once per week per marina during March 29 - April 14, 1983, and again during July 26 - August 11, 1983. Fifteen additional oysters were collected from each R and L station once per sampling period for condition index (CI) analyses following the method of Lawrence and Scott (1982).

The top 3 cm of sediment within each reef was collected manually once per sampling period using a stainless steel spatula. Samples from the mid-channel stations were collected from a boat using a stainless steel Peterson dredge. Approximately 5 gm of sediment were dried overnight at 103°C on acid-washed watch glasses after which 1.000-1.005 gm of dry sediment was transferred to 100 ml beakers for digestion. All digestion procedures followed those specified by the Environmental Protection Agency (USEPA 1973a, USEPA 1973b). After digestion, the samples were aspirated to an atomic absorption spectrophotometer for analyses according to EPA methods (USEPA 1979).

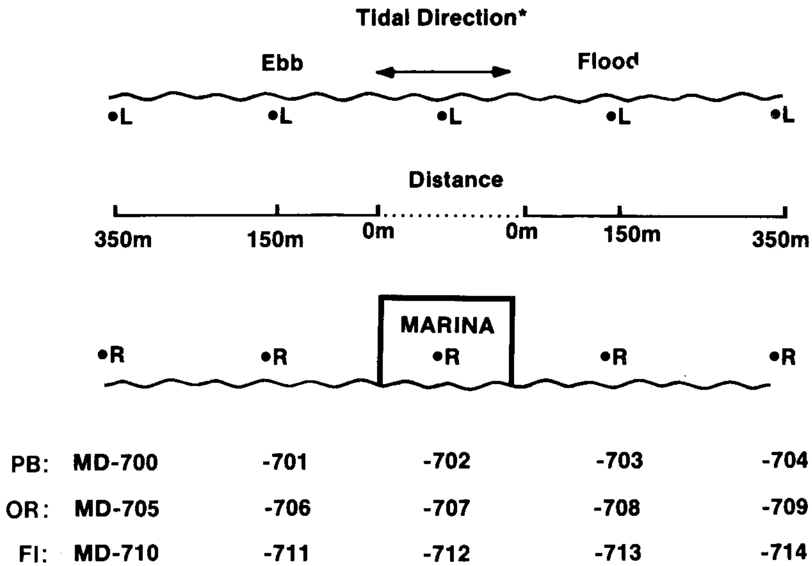
Approximately 5 gm of oyster tissue were placed in 50 ml acid-washed beakers and transferred to a cold muffle furnace where they were ashed at 450°C for 12-16 hours. Upon cooling, 2 ml of aqua regia were added to the samples and then warmed to dissolve the ash. The non-filtered samples were quantitatively transferred to 100 ml volumetric flasks, diluted with deionized water and then analyzed by atomic absorption spectrophotometry.

RESULTS AND DISCUSSION

Tables 1, 2 and 3 present the results of the tissue analyses from Palmetto Bay (PB) marina, Outdoor Resorts (OR) marina and Fripp Island (FI) marina, respectively. Six of the seven metals included in the assessment were detected at each marina during each sampling period. Mercury was not detected at any time at any station. Cadmium, copper and zinc were measured in tissue from every station while lead and nickel were found at all but a few stations. Chromium was rarely detected at any marina.

For a given metal within a sampling period, there was little variation in the mean values at all three marinas. Copper and zinc exhibited the widest range of mean values within a sampling period at each marina as well as the largest differences in mean values by station between sampling periods.

Total mean metals in tissue increased between the spring and summer periods. The increases ranged from 11.7 to 64.4 percent at Palmetto Bay, from 20.4 to 64.8 percent at Outdoor Resorts and



*Tidal flow direction reversed from this schematic at Fripp Island marina

Figure 1: Schematic illustration of grid placed around each marina for oyster sampling.

from 26.5 to 60.6 percent at Fripp Island. Initially, the assumption was made of increased metals input to the systems due to the seasonal increase in boating activities around the marinas. Upon considering sediment metals data and condition index data in conjunction with the tissue metals data, this was found not to be the likely major driving force.

Table 4 presents a summary of the metals in sediment data from each marina. As is evident, there was little change from spring to summer in the levels either by individual metals and or by total metals. These data indicated little, if any, increased temporal metals input to the water systems due to marina activities. Thus, the increased metals concentrations in tissue appeared to have been due to some other factor(s).

Condition index is a macroscopic measurement of the fatness of oysters and is strongly affected by the amount of glycogen and lipid present in the organism. Since these compounds are stored by the organism prior to spawning and then released during spawning, a pre-spawn CI value would be expected to be greater than a post-spawn CI value. This was the case here as all CI values from the spring were significantly greater ($p<.05$) than those from the summer.

Correlation coefficients of metal vs. CI and metal vs. metal are presented in Table 5. In almost every case the metal vs. CI computations revealed a negative correlation (although all were not significant) indicating that the increases in metals concentra-

Table 1. Mean heavy metals concentrations in *Crassostrea virginica* from Palmetto Bay Marina, South Carolina.

Metal		Mean wet weight concentration in mg/kg (a)									
		MD-700L	MD-700R	MD-701L	MD-701R	MD-702L	MD-702R	MD-703L	MD-703R	MD-704L	MD-704R
Cadmium:	Sp[b]	0.45(.06)	0.44(.05)	0.51(.09)	0.50(.70)	0.55(.03)	0.54(.07)	0.51(.02)	0.51(.03)	0.51(.01)	0.51(.05)
	Su	0.52(.02)	0.58(.07)	0.54(.09)	0.54(.16)	0.58(.12)	0.55(.05)	0.59(.15)	0.52(.13)	0.56(.15)	0.58(.18)
Chromium:	Sp	0.4(0.7)	*	*	*	*	*	0.5(0.9)	*	*	*
	Su	*	0.4(0.7)	0.3(0.6)	*	*	*	*	*	0.5(0.8)	*
Copper:	Sp	14(2)	13(2)	19(2)	19(1)	17(1)	17(1)	14(0)	19(1)	16(2)	22(4)
	Su	18(1)	18(2)	22(2)	18(2)	20(3)	29(3)	18(4)	23(5)	18(4)	28(5)
Lead:	Sp	0.8(0.7)	0.8(0.7)	0.7(0.6)	0.3(0.6)	0.3(0.6)	0.4(0.7)	0.5(0.8)	0.8(0.7)	0.3(0.6)	0.9(0.9)
	Su	1.0(1.0)	0.4(0.7)	0.6(1.0)	0.5(0.9)	0.6(1.0)	1.2(1.3)	0.7(1.1)	0.8(1.4)	1.9(0.8)	*
Nickel:	Sp	0.9(0.8)	1.2(0.2)	1.3(0.1)	1.3(0.2)	1.2(0)	1.1(0.1)	1.3(0.1)	1.4(0.7)	0.7(0.6)	1.5(0.5)
	Su	0.7(1.2)	0.9(0.8)	1.3(0.2)	1.7(2.0)	0.3(0.6)	1.1(1.0)	0.4(0.7)	*	1.2(0.2)	*
Zinc:	Sp	127(170)	187(145)	360(40)	353(73)	333(18)	313(12)	300(20)	360(40)	307(12)	373(42)
	Su	383(49)	423(32)	487(60)	403(71)	423(61)	580(111)	467(140)	510(76)	423(100)	533(110)
Total:	Sp	143.55	202.44	381.51	374.10	352.05	332.04	316.81	381.71	324.51	397.91
	Su	403.22	423.28	511.74	423.74	444.48	611.85	486.89	534.32	445.16	561.58

a. figures in parentheses represent one standard deviation (n=3)
b. Sp=Spring; Su=Summer
* non-detectable

Table 2. Mean heavy metals concentrations in *Crassostrea virginica* from Outdoor Resorts Marina, South Carolina.

Metal		Mean wet weight concentration in mg/kg (a,b)							
		MD-705L	MD-705R	MD-706L	MD-707L	MD-707R	MD-708R	MD-709L	MD-709R
Cadmium:	Sp[c]	0.57(.08)	0.44(.21)	0.58(.02)	0.37(.32)	0.41(.36)	0.48(.24)	0.61(.05)	0.55(.09)
	Su	0.71(.09)	0.77(.14)	0.71(.12)	0.69(.12)	0.67(.07)	0.79(.21)	0.77(.06)	0.58(.07)
Chromium:	Sp	*	0.5(0.8)	*	*	*	*	*	*
	Su	0.8(1.4)	*	*	*	0.3(0.6)	*	*	*
Copper:	Sp	16(3)	19(1)	13(3)	10(8)	22(10)	14(11)	14(2)	18(3)
	Su	21(6)	22(2)	21(3)	23(1)	46(21)	37(10)	19(.4)	20(3)
Lead:	Sp	0.7(0.6)	0.3(0.6)	0.4(0.7)	0.4(0.7)	0.7(0.6)	0.7(0.6)	0.9(0.9)	0.3(0.6)
	Su	0.5(0.9)	0.5(0.9)	0.7(1.2)	3.7(5.3)	0.6(1.0)	0.5(0.9)	1.3(1.3)	2.4(1.0)
Nickel:	Sp	0.8(0.7)	0.9(0.8)	0.9(0.8)	0.3(0.6)	*	*	1.2(0.0)	0.4(0.8)
	Su	1.2(1.2)	0.5(0.9)	0.9(0.8)	0.8(0.8)	0.8(0.7)	0.3(0.5)	5.2(7.7)	1.5(0.6)
Zinc:	Sp	330(26)	259(191)	265(41)	206(163)	281(228)	261(206)	307(46)	343(25)
	Su	433(90)	523(38)	530(70)	490(44)	740(236)	747(196)	400(72)	443(74)
Total:	Sp	348.07	277.10	279.88	217.07	304.11	276.18	327.71	372.25
	Su	457.21	546.77	553.31	518.19	788.37	785.59	426.27	467.48

a. figures in parentheses represent one standard deviation (n=3)
b. oysters not available at MD-706R and MD-708L
c. Sp=Spring; Su=Summer
* non-detectable

Table 3. Mean heavy metals concentrations in *Crassostrea virginica* from Fripp Island Marina, South Carolina.

Metal		Mean wet weight concentration in mg/kg (a,b)								
		MD-710L	MD-710R	MD-711L	MD-711R	MD-712L	MD-712R	MD-713R	MD-714L	MD-714R
Cadmium:	Sp[c]	0.43(.03)	0.44(.02)	0.47(.08)	0.46(.04)	0.48(.07)	0.49(.02)	0.49(.03)	0.60(.24)	0.49(.02)
	Su	0.57(.09)	0.54(.05)	0.49(.10)	0.53(.06)	0.67(.12)	0.56(.05)	0.67(.07)	0.72(.13)	0.68(.07)
Chromium:	Sp	2.0(3.5)	1.4(2.4)	*	*	*	*	*	0.5(0.9)	*
	Su	*	*	*	*	*	0.5(0.8)	*	*	0.3(0.6)
Copper:	Sp	11(2)	11(1)	9.6(.3)	11(2)	12(2)	13(1)	10(1)	12(5)	11(1)
	Su	17(1)	17(2)	13(3)	20(1)	14(3)	19(2)	18(4)	27(7)	16(1)
Lead:	Sp	0.9(0.8)	0.4(0.7)	0.3(0.6)	0.3(0.6)	1.1(1.2)	0.7(0.6)	0.7(0.6)	1.6(1.9)	0.7(0.6)
	Su	*	0.3(0.6)	1.0(1.8)	0.5(0.8)	0.9(0.8)	0.5(0.8)	0.5(0.9)	0.8(1.4)	*
Nickel:	Sp	2.5(3.2)	1.6(0.9)	1.1(0.1)	1.2(0.2)	0.8(0.7)	1.2(0.2)	0.9(0.8)	1.4(1.5)	0.9(0.8)
	Su	0.8(0.7)	0.3(0.6)	1.4(0.4)	1.2(0.2)	*	1.4(1.5)	*	0.5(0.8)	1.4(1.6)
Zinc:	Sp	213(12)	227(31)	173(42)	213(51)	247(31)	247(31)	178(38)	269(183)	132(105)
	Su	373(29)	390(56)	290(36)	420(20)	340(60)	390(30)	353(96)	423(146)	350(10)
Total:	Sp	229.83	241.84	184.47	225.96	261.38	262.39	190.09	285.10	145.09
	Su	391.37	408.14	305.89	442.24	355.57	411.96	372.17	452.02	368.38

a. figures in parentheses represent one standard deviation (n=3)
b. oysters not available at MD-713L
c. Sp=Spring; Su=Summer
* non-detectable

Table 4. Mean heavy metals concentrations in sediment from three South Carolina coastal marinas.

Metal	Mean dry weight concentration in mg/kg (a)		
	Palmetto Bay	Outdoor Resorts	Fripp Island
Chromium	51.0;40.4	42.6;33.8	60.4;65.2
Copper	16.6;16.0	14.4;13.0	20.6;22.6
Lead	51.6;53.4	60.4;74.0	57.2;64.2
Nickel	25.8;36.7	42.6;36.8	39.6;40.8
Zinc	85.2;77.8	76.2;70.2	87.8;101.2
Total	230.2;224.3	236.2;230.8	265.6;294.0

a. spring value; summer value

tion between sampling periods were related to a loss of oyster body weight. Metals are preferentially partitioned to the gills and mantle upon uptake. Some may also be incorporated into the glycogen and lipid compartments sometimes resulting in the reduction of metals body burden due to spawning. In this study, however, heavy metals body burden increased at each marina after spawning. The correlations in Table 5 along with the sediment data in Table 4 affirm two previously - proposed explanations for this observation. First, as body weight decreases, the size of the tissue pool for metals distribution decreases thereby driving the concentation upward for retained and newly - acquired metals (Zaroogian 1980). Second, metabolic rates and, thus, uptake rates from spring to summer increase by approximately 120% (Scott 1979). Taken together, these two mechanisms indicate that uptake/accumulation kinetics are interdependent on the basal metabolic rate and tissue absorption sites within the body.

The metal vs. metal correlations showed strong positive correlations between copper and cadmium at Outdoor Resorts and Fripp Island and between zinc/cadmium and zinc/copper at all three marinas. These values suggested that the constituents behaved in a similar fashion in the oysters and followed the pattern of efficient copper and zinc uptake as observed in a previous report (Lytle and Lytle 1982).

Finally, the metals concentrations observed in tissue from around these marinas were within the respective ranges seen in other South Carolina oysters (NMFS 1978). The data presented here indicated that zinc and copper were the two most dynamic metals around the marinas with elevated tissue levels due to marina activities limited essentially to shellstock from very near the marinas. This same association between copper and commercial shipyard proximity was observed by Mathews et al. (1979) for South Carolina oysters. This is the first report of metals concentrations from oysters intimately associated with recreational marinas and, as such, has indicated the need for further development of the understanding of the interactions of this anthropogenic activity on natural oyster populations.

Table 5. Spearman correlation coefficients of metal vs. CI and metal vs. metal in oyster tissue from three South Carolina coastal marinas.

Metal	Marina	CI	Cd	Cu	Pb	Ni
Cd	PB	-0.717*				
	OR	-0.689*				
	FI	-0.674*				
Cu	PB	-0.500	0.373			
	OR	-0.872*	0.774*			
	FI	-0.676*	0.747*			
Pb	PB	-0.418	0.237	0.400		
	OR	-0.440	0.380	0.427		
	FI	0.252	0.081	-0.093		
Ni	PB	0.484	-0.500	0.087	0.057	
	OR	-0.082	-0.031	-0.218	0.520	
	FI	0.278	-0.289	-0.226	0.189	
Zn	PB	-0.801*	0.739*	0.808*	0.552	-0.255
	OR	-0.787*	0.832*	0.893*	0.294	-0.265
	FI	-0.714*	0.746*	0.969*	-0.029	-0.204

*significant at 99% confidence interval

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