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Total and Methyl-Mercury Content in Bivalves, *Mytilus galloprovincialis* Lamarck and *Ostrea edulis* Linnaeus: Relationship of Biochemical Composition and Body Size

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Mussels and oysters are of interest to pollution ecologists because they are widely distributed, suspension feeding invertebrates and are likely to accumulate pollutants from their environment (Goldberg 1975). Many authors have estimated the relation between the concentration of metals in the flesh and various biotic and abiotic parameters. Body mass (estimated in dry weight) is evidently an important factor governing the uptake of metals by these organisms (Boyden 1974, 1977). Cossa et al. (1980) showed, furthermore, that the highest concentrations of certain metals were often found in the smallest individuals. The relation between metal content and body size can best be described using Boyden's model (Walne 1972; Boyden 1974) which is useful for quantifying any physiological activities in relation to the dry weight of the specimens.

The regression coefficient b in Boyden's model is a measure of an organism's control over metal accumulation in its tissues. In practice, widely different values can be obtained for regression coefficient b when investigating the same metal. Cossa et al. (1979) suggested that this variability is primarily correlated with differing amount of gonad development. Gonad growth and maturation are accompanied by numerous biochemical changes in the flesh, especially in relation to glycogen content. Moreover, rapid changes in both wet and dry weights occur during the spawning period (Zandee et al. 1980). These changes are more profound in the largest individuals. Fortunately, the reproductive cycle of the mussel Mytilus galloprovincialis Lam. and Ostrea edulis L. have been thoroughly studied in Limski kanal by Hrs-Brenko (1971).

In the present paper we describe our investigation into the relationship between total and methyl-mercury content and body mass in mussels and oysters collected in

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Limski kanal, situated on the Istrian Peninsula in the northern Adriatic Sea, in the winter and spring seasons of the year. These data are rigorously compared with the biochemical physiology of the selected species.

MATERIALS AND METHODS

Mussels and oysters were taken from Limski kanal (45x07' N 13x40' E) monthly from November 1983 to April 1984, and classified by linear size into 4 classes (a = up to 35, b = 35-45, c = 45-55, d = 55-65 mm) for mussels and 3 classes for oysters (c = up to 55, d = 55-65, e = 65-75 mm).

Dry weight, biochemical composition, total and methyl-mercury were determined from composite samples each containing 30-50 specimens in three replicates. Total protein content was determined by Kjeldahl after digestion. Lipid content was determined according to Folch et al. (1957), and glycogen according to Zandee et al. (1980). Methyl-mercury was determined by gas chromatography as already described (Najdek and Bazulic 1985). Total mercury was determined using atomic absorption spectrophotometry according to Hatch and Ott (1968).

To estimate the significance of the differences between classes of all parameters measured variance analysis was used. Significance of the regression coefficients was checked by Student t-test.

RESULTS AND DISCUSSION

Total and methyl-mercury concentration and content values were significantly higher in oysters than those found in mussels (Tables 1 and 2). This supports previous investigators who have claimed that oysters are faster bioaccumulators than mussels (Martincic 1981). It is possible that the differences found were due to differences in the metabolic rates of the two bivalve species. Of relevance here is the demonstration by Walne (1972) that Ostrea sp. has a filtration rate double that of Mytilus sp., even in suboptimal conditions. It is certainly known that oysters have a greater gill area (and thence a greater filtration capability) than mussels.

During the winter season, before the spring spawning period, the greater accumulation of mercury by oysters is associated with an overall active accumulation of biochemical components resulting in better shellfish condition (Table 3). Mussels, however, spawn in the winter and are in poor condition during the spring season (with low glycogen content, as shown in Table

3). Concerning the influence of body weight of mussels on the concentration of metals, it has been established that smaller individuals contain higher concentrations (Boyden 1974, 1977; Cossa et al. 1980).

Total and methyl-mercury concentrations decreased in inverse correlation with dry weight in the samples of mussels and oysters (Table 4). Walne (1972) has shown that the greatest metabolic activity in a bivalve species is found in the smallest individuals (by weight). In considering the relationship between the metal content and the dry weight of an organism, the accepted value for the regression coefficient is 0.67, which describes metabolic control over feeding and respiration (Walne 1972), those very activities by which pollutants enter the flesh (de Freitas et al. 1975). According to Fagerstrom (1977) if the metal pollutant is to be correlated with dry weight changes, the value has to be one.

Those values of regression coefficients which we obtained (Table 4) could mean that the uptake of methylmercury depends not on changes in the whole organism, but on a specific organ which varies independently of the whole organism (Wrench 1978). In other words, there may exist a more complex relationship than can be expressed as a direct correlation between pollutant concentration and total biochemical components of the flesh. It must also be emphasized that for any single species, a drop in either or both total or methyl-mercury may simply indicate reduced activity with aging or it may be the consequence of metal dilution with dry weight increase.

In the smaller individuals the stage of sexual maturing does not contribute to these changes, presumably because, as Hrs-Brenko (1973) has shown, the main energy outlay is connected with growth, which in the bivalves is most intensive during the first year of life.

Total and methyl-mercury content changes are not detectable in the smaller mussels. The relationship between dry weight and methyl-mercury content is more obvious in classes a and b ($b = 0.72$), in comparison with the larger individuals in classes c and d ($b = 0.48$).

The values of regression coefficients obtained correlate with intensive reproductive activity, the maturity of most of the individuals, and the low condition of the mussels. In the oyster the methyl-mercury content changes are relatively constant during the period of study; they indicate that the methyl-mercury changes arose from body weight changes.

Table 1. Methyl-mercury concentration (ng/g) and content (ng) (given in parentheses) in mussels and oysters

	Mussels				Oysters		
	a	b	c	d	c	d	e
Nov	63.7 (18.8)	62.7 (34.5)	36.5 (36.8)	38.5 (57.7)	112.5 (48.4)	149.7 (79.1)	298.9 (202.9)
Dec	110.3 (35.3)	78.1 (44.4)	55.2 (55.5)	52.9 (84.7)	122.8 (83.2)	80.6 (68.2)	153.8 (132.3)
Jan	166.8 (35.0)	145.4 (62.1)	88.9 (63.1)	105.9 (123.4)	106.6 (79.3)	74.2 (71.2)	116.5 (136.3)
Feb	122.7 (24.5)	88.2 (35.5)	116.7 (35.5)	79.5 (42.1)	93.2 (63.4)	155.0 (93.0)	224.2 (96.4)
Mar	94.8 (16.0)	57.5 (35.7)	69.9 (35.7)	104.9 (96.6)	103.8 (55.1)	110.6 (64.1)	91.8 (90.2)
Apr	120.3 (21.5)	59.5 (14.4)	104.5 (37.7)	176.3 (31.5)	206.3 (53.6)	230.8 (64.4)	219.4 (84.5)

Table 2. Total mercury concentration (ng/g) and content (ng) (given in parentheses) in mussels and oysters

	Mussels				Oysters		
	a	b	c	d	c	d	e
Nov	89.1 (26.3)	172.1 (94.7)	58.3 (58.3)	59.8 (89.1)	163.0 (70.1)	305.7 (162.0)	547.2 (372.1)
Dec	151.6 (48.5)	- -	144.1 (144.1)	122.9 (196.6)	234.3 (234.9)	144.9 (123.2)	342.1 (294.2)
Jan	294.8 (61.9)	250.0 (107.5)	269.7 (191.5)	269.9 (318.5)	196.3 (145.3)	280.7 (269.5)	282.2 (330.1)
Feb	312.9 (62.6)	267.5 (85.6)	156.6 (47.0)	244.6 (129.6)	269.4 (183.2)	209.9 (125.9)	- -
Mar	640.0 (108.8)	350.9 (112.3)	367.6 (187.5)	320.0 (294.4)	400.0 (212.0)	766.5 (444.6)	640.7 (627.9)
Apr	303.6 (54.6)	389.8 (97.5)	223.4 (80.4)	198.8 (35.8)	322.2 (83.8)	321.4 (90.0)	- -

Table 3. Total protein (mg) P; lipid (mg) L; and glycogen (mg) G content in mussels and oysters

		Mussels				Oysters		
		a	b	c	d	c	d	e
Nov	P	159	305	491	747	237	265	400
	L	26	50	104	152	33	52	59
	G	12	20	41	82	23	25	22
Dec	P	186	305	565	867	340	408	475
	L	25	54	107	210	50	77	102
	G	15	24	57	97	23	25	22
Jan	P	116	276	427	685	347	437	612
	L	20	41	69	130	81	135	176
	G	8	18	30	73	68	102	136
Feb	P	102	197	171	293	340	307	237
	L	10	21	21	35	64	81	57
	G	4	6	7	13	59	39	20
Mar	P	85	181	282	452	243	270	483
	L	14	27	46	80	61	82	137
	G	7	14	25	59	51	61	94
Apr	P	109	131	199	105	143	160	225
	L	17	25	32	17	20	23	31
	G	5	8	10	6	6	7	8

Table 4. Parameters of the log-log relationship between total and methyl-mercury content and dry weight (expressed monthly and summary - SUM) and biochemical composition (b = regression coefficient, a = intercept)

	Mussels				Oysters			
	bMeHg	aMeHg	bHgT	aHgT	bMeHg	aMeHg	bHgT	aHgT
Nov	0.62	2.03	0.59	1.87	3.13	3.11	3.68	3.20
Dec	0.53	1.98	0.89	2.13	0.66	2.16	-0.80	2.23
Jan	0.66	2.16	0.96	2.42	1.08	2.32	1.82	2.42
Feb	0.54	1.83	0.82	2.28	-0.73	1.12	1.00	2.79
Mar	0.98	2.18	0.62	2.45	0.72	1.83	1.38	2.83
Apr	0.38	1.62	0.97	2.14	1.06	2.20	0.83	2.41
SUM	0.61	1.80	0.56	2.17	0.41	1.99	0.02 NS	2.48
SUM*	-0.37	1.80	-0.43	3.35	-0.60	1.99	0.02 NS	2.48
Prot	0.64	1.98	0.58	0.58	0.56	2.19	1.07	-0.39
Lip	0.37	2.08	0.46	1.24	0.27	2.23	0.76	0.91
Gly	0.33	2.19	0.41	1.47	0.07 NS	2.01	0.46	1.55

Significance of correlation coefficients $P<0.05$; NS not significant; SUM* Relationship between total and methyl-mercury concentrations and dry weight

The results presented indicate that oysters are more effective bioaccumulators than mussels before the spawning season. In both species, total and methyl-mercury content increased in correlation with dry weight. Greater methyl-mercury changes were measured in the larger mussels during the reproductive period, but in oysters no such effect was noted. In both species the mercury content was influenced by the events of the reproductive cycle.

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