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Trace Metals in Common Marine Foods of the Pacific Coast

by

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Trace Metals in Marine Foods

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Abstract

Trace metal analysis of 23 species of common Pacific Coast marine foods revealed high cadmium values for Bent-nosed clams (Macoma nasuta), Bay mussels (Mytilus edulis), Bay oysters (Ostrea lurida), Pacific oysters (Crassostrea gigas), and Littleneck clams (Protothaca staminea). Metals were found to concentrate in the gills, heart, and visceral mass of all 10 species of bivalve mollusks examined. Swordfish (Xiphias gladius) and Salmon (Oncorhynchus tshawytscha) demonstrated the highest cadmium values for fish flesh.

Introduction

In light of the recent concern over contamination and toxicity of cadmium (Nilsson, 1969), (Schroeder, et al, 1966, 1967, 1968), (Pringle, 1968), an examination of cadmium, zinc, copper, and manganese concentrations in the edible portions of bivalve mollusks, 10 species of fish, and 3 species of crustaceans was undertaken. Particular attention was given to the soft bodies and organs of the mollusks since other workers have reported that they concentrate trace metals (Schroeder, 1967), (Brooks and Rumsby, 1965), (Pringle, 1968).

Six species of mollusks and 2 species of fish were collected from Elkhorn Slough, which flows into Monterey Bay near Moss Landing, California. This area is particularly abundant in estuarine animals although it has been condemned by the county health department as a health hazard due to high E.coli counts. It is also the receptor of both the Pacific Gas & Electric generator plant and the Kaiser Aluminum plant waste water effluents. No attempt was made to determine the metal contents of the effluents. According to Veith (1971), Monterey Bay sewage effluents pour as much as 175 grams of cadmium into the Bay per day.

Methods

Mollusks were collected and removed from shells, rinsed with distilled water and dissected (where applicable). Fish and crustacean samples were purchased at local fish markets. All samples were weighed, dried for about 12 hours at 100°C and reweighed. Digestion of dried material was accomplished

by adding 90% nitric acid and heating in acid-cleaned 30ml Pyrex beakers. Drops of capryl alcohol were added to minimize foaming where necessary, (as in Middleton and Stuckey, 1953). Blanks were treated exactly as the marine samples. Once the tissues were in solution, they were heated until charred, on hot plates, in order to burn off lipid particles. Samples were cooled, redissolved with 90% nitric acid, and cleared by adding hydrogen peroxide dropwise with heat. Once clear, samples were diluted with distilled water, covered, and analyzed within 3 days. Samples were analyzed for metal concentrations by atomic absorption spectrophotometry (Perkin-Elmer 303), using a triple slot burner head. The detection limits for cadmium, copper, and manganese were 0.05 ug/g dry weight, and for zinc was 0.5 ug/g dry weight.

Results & Discussion

Tables of the results indicate the common and scientific names of samples, which samples were dissected, and which samples were analyzed whole (since they are eaten whole). The right hand column of the tables lists the dry to wet weight ratio. Multiplication of this value by the dry parts per million (ppm or ug/g) figures gives the values for ppm wet weight.

Metals were clearly concentrated in bivalve mollusks of all species. The highest concentrations were found in the heart, gills and visceral mass of individual animals. The clams tended to concentrate the metals to a lesser degree than did the non-siphoned bivalves, i.e. the scallop, oysters, and mussels, in every case except for the Bent-nosed clams. Three Bent-nosed clams (*Macoma nasuta*) from Elkhorn Slough averaged 30 ppm dry weight of cadmium and 1,076 ppm dry weight of zinc (See Table 1). This particularly hardy

species of clam has a separated siphon which acts as a "vacuum cleaner" combing the surface of the slough bottom.

Whole oysters, and especially Ostrea lurida from San Francisco Bay, were noted to have high concentrations of zinc (900 ppm dry) and copper (173 ppm dry) (See Table 2). The nephridium of one scallop (Hinnites multi-rugosus) taken from San Pedro Harbor in Los Angeles, contained the highest cadmium level of the study (181 ppm dry) (See Table 4). Interestingly enough, the nephridium corresponds in function to the mammalian kidneys, which are also the site of cadmium concentration (Schroeder, 1967).

Although the Gaper clams (Tresus nuttalli) from Elkhorn Slough, had low metal concentrations, the outer skin, covering the neck was found to have the highest manganese content (1,200 ppm dry) (See Table 5). Since manganese is a common metal component of sediments, it is possible that the sample of neck skin included some clay particles, although it was thoroughly washed. Unfortunately a substrate analysis of the Slough sediment was not taken.

Although cadmium values in fish flesh were relatively low, (less than 1.5 ppm dry) Swordfish and Salmon contained more cadmium than the crustaceans and edible portions of the Gaper clam (Table 6).

The figures presented here should not be considered as representative for species from the entire Pacific Coast. Note, for example, that the cadmium concentration was 5 times higher in Littleneck clams (Protothaca staminea) from Elkhorn Slough than those from Canada (See Table 1).

According to Schroeder, a normal human intake of cadmium is 215 ug/day (Nilsson, 1969). Of this, 98% is excreted. Of the 2% retained, most is stored in the kidneys and liver. Bowen (1966) indicated that 3mg of cadmium ingested per day is "toxic" to humans. In order to achieve such an intake of cadmium per day, one would have to eat $1\frac{1}{2}$ pounds of Bent-nosed clams or 17 whole oysters from Elkhorn Slough. Likewise, $8\frac{1}{2}$ pounds of scallop muscles from San Pedro Harbor, or $17\frac{1}{2}$ pounds of Swordfish steak would account for such a quantity of cadmium. (These amounts were calculated from the cadmium concentrations in ppm wet weight.)

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Legend for Graph 1

The following bar graph represents cadmium concentrations in wet weight of edible samples. In the cases where the whole animal (shell-less) is eaten, such as the smaller clams and oysters, whole body concentrations are depicted. Samples listed as "ND" are the cleaned edible portions in which the metal concentration was below the detection limit.

Tables 1 through 7 list the genus species names of the animals examined, along with the ppm dry weight values and the dry/wet weight ratios.

CADMIUM in COMMON MARINE FOODS

ugr/gr wet weight of sample (ppm wet weight)

0 1 2 3 4 5 ppm

Bent-nosed Clam (Elkhorn Slough) [Bar extending to 4.8 ppm]

Pacific Oyster (Elkhorn Slough) [Bar extending to 3.2 ppm]

Bay Oyster (S.F. Bay) [Bar extending to 1.8 ppm]

Bay Mussel (Elkhorn Slough) [Bar extending to 1.2 ppm]

Pacific Oyster (Shelton, Wash.) [Bar extending to 1.0 ppm]

Little Neck Clam (Elkhorn Slough) [Bar extending to 1.0 ppm]

Scallop muscle* (L.A. Harbor) [Bar extending to 0.8 ppm]

*Cleaned, edible portion only

Razor Clam* [Bar extending to 0.5 ppm]

Swordfish* [Bar extending to 0.4 ppm]

Little Neck Clam (Canada) [Bar extending to 0.4 ppm]

Rosetta Clam (East Coast) [Bar extending to 0.4 ppm]

Dungeness Crab* (canned) [Bar extending to 0.3 ppm]

Dungeness Crab* (fresh) [Bar extending to 0.3 ppm]

Salmon* [Bar extending to 0.3 ppm]

Prawns* [Bar extending to 0.2 ppm]

Pacific Shrimp* [Bar extending to 0.2 ppm]

Gaper Clam*
Rock Cod*, Sole*
Sable fish*
Red Snapper*

ND

ND=concentration is not detectable

Table 1

Bivalve Mollusks

Concentrations of trace elements in whole individuals
(Average PPM dry weight)

	<u>Cadmium</u>	<u>Zinc</u>	<u>Copper</u>	<u>Manganese</u>	<u>dry/wet*</u>
<u>Mercenaria mercenaria</u>					
Eastern Rosetta clams average of 3 whole bodies	1.2 (.1)	62.0 (18.5)	15.0 (2.5)	10.8 (1.1)	.242 (standard deviation)
<u>Protothaca staminea</u>					
Little Neck clams; Elkhorn Slough average of 5 whole bodies	5.1 (0.8)	65.0 (9.2)	6.2 (1.5)	8.5 (3.2)	.208
average of 3 whole bodies from British Columbia	1.0 (0)	59.3 (44.4)	8.2 (8.3)	2.8 (0.3)	.260
<u>Macoma nasuta</u>					
Bent-nosed clams; Elkhorn Slough average of 3 whole bodies	30.0 (6.7)	1,076.0 (100.0)	42.0 (15.0)	29.0 (10.6)	.177
<u>Tresus nuttalli</u>					
Gaper clam; Elkhorn Slough one whole body	0.7	31.0	5.0	17.0	.564
<u>Saxidomus nuttalli</u>					
Butter clam; Elkhorn Slough one whole body	1.3	37.8	2.4	4.5	.220
<u>Siliqua patula</u>					
Razor clams; Sunset Beach, Oregon average of 3 by parts					
Neck and mantle	1.5 (0.3)	63.0 (10.0)	3.0 (1.4)	4.5 (1.8)	.213
Visceral mass + contents	nd**	65.0 (16.5)	6.3 (2.0)	18.0 (8.3)	.234
Gills	3.1 (1.2)	144.7 (36.0)	2.0 (1.4)	25.0 (0.9)	.293

(* ratio of grams dry weight/grams wet weight)

(** concentration not detectable)

Table 2

Bivalve Mollusks

Concentrations of trace elements in whole individuals
(Average PPM dry weight)

	<u>Cadmium</u>	<u>Zinc</u>	<u>Copper</u>	<u>Manganese</u>	<u>dry/wet*</u>
<u>Ostrea lurida</u>					
Olympia Oysters; San Francisco Bay average of 3 whole bodies	6.2 (.9)	906.0 (50.0)	173.0 (40.0)	21.7 (3.7)	.272 (Standard deviation)
<u>Crassostrea gigas</u>					
Pacific Oysters; Shelton Wash. Commercially harvested average of 3 whole bodies	2.5 (0.4)	290.0 (50.0)	28.5 (3.4)	6.1 (1.0)	.424
<u>Mytilus edulis</u>					
Mussels; Elkhorn Slough average of 3 whole bodies	5.6 (1.2)	37.7 (16.7)	3.7 (0.8)	3.9 (0.7)	.248

Table 3

Bivalve Mollusks

Concentrations of trace elements in individual organs
(PPM dry weight)

	<u>Cadmium</u>	<u>Zinc</u>	<u>Copper</u>	<u>Manganese</u>	<u>dry/wet*</u>
<u>Crassostrea gigas</u>					
Pacific Oyster; Elkhorn Slough					
Oyster #1					
Adductor muscle	3.0	256.0	8.0	nd**	.172
Mantle + gonad	10.0	574.0	65.0	2.0	.167
Gonad	3.0	320.0	31.0	25.0	.240
Gills	11.0	660.0	96.0	52.0	.190
Mouth palps	5.0	461.0	47.0	nd	.272
Heart	24.0	632.0	50.0	nd	.250
Digestive gland minus gonad	23.0	477.0	87.0	10.0	.228
Oyster #2					
Adductor muscle	1.5	174.0	8.0	6.0	.176
Mantle + gonad	24.0	458.0	57.0	17.0	.213
Gonad	3.4	154.0	27.0	5.0	.250
Gills	25.0	658.0	92.0	96.0	.195
Mouth palps	10.5	377.0	74.0	12.0	.286
Heart	64.0	415.0	84.0	13.0	.233
Digestive gland plus gonad	16.7	271.0	41.0	5.0	.244
Whole oyster	10.6	263.0	40.0	11.0	.270
63 grams wet--17 grams dry. Analyzed and dried by parts.					

(* ratio of grams dry weight/grams wet weight)

(** nd = concentration of element was not detectable)

Table 3 cont.

Bivalve Mollusks

Concentrations of trace elements in individual organs
(PFM dry weight)

	<u>Cadmium</u>	<u>Zinc</u>	<u>Copper</u>	<u>Manganese</u>	<u>dry/wet*</u>
<u>Crassostrea gigas</u>					
Pacific Oyster; Shelton Wash. Commercially harvested					
Adductor muscle	5.0	419.0	29.0	9.0	.200
Mantle + gonad	1.7	230.0	46.0	2.0	.222
Gonad	7.5	387.0	74.0	nd**	.230
Gills	15.0	628.0	197.0	6.0	.167
Mouth palps	5.6	287.0	34.0	nd	.250
Heart	7.0	442.0	130.0	nd	.200
Digestive gland minus gonad	10.0	567.0	94.0	7.5	.218

Table 4

Bivalve Mollusks

Concentrations of trace elements in individual organs
(PPM dry weight)

	<u>Cadmium</u>	<u>Zinc</u>	<u>Copper</u>	<u>Manganese</u>	<u>dry/wet*</u>
<u>Hinnites multirugosus</u>					
Scallop; San Pedro Harbor, L.A.					
Adductor muscle	3.5	83.0	1.4	1.0	.222
Mantle	12.0	90.0	3.0	3.0	.195
Foot	nd**	191.0	nd	nd	.085
Gills	8.6	467.0	21.0	105.0	.084
Labial palps	54.0	304.0	75.0	13.0	.065
Heart	31.0	212.0	41.0	7.3	.093
Nephridium	181.0	311.0	53.0	25.0	.104
Visceral mass plus gonad	37.6	77.0	87.0	5.5	.720

Table 5

Bivalve Mollusks

Concentrations of trace elements in individual organs
Values represent ugrams of metal/gram dry weight of tissue

	<u>Cadmium</u>	<u>Zinc</u>	<u>Copper</u>	<u>Manganese</u>	<u>dry/wet</u> *
<u>Saxidomus nuttalli</u>					
Butter clam; Elkhorn Slough					
Anterior adductor muscle	0.1	21.0	0.8	8.7	.264
Foot muscle	0.5	37.0	1.0	1.8	.273
Neck muscle	0.5	50.0	nd**	2.9	.234
Mantle	0.7	40.0	1.8	19.0	.250
Gills + contents	1.8	83.0	1.7	6.0	.164
Heart, palps, alimentary canal and contents	8.2	81.0	6.2	2.4	.198
Visceral mass + contents	3.2	123.0	12.0	3.7	.107

(* ratio of grams dry weight/grams wet weight of sample)
(** not detecable)

Tresus nuttalli

Gaper clam; Elkhorn S.
clam #1

Anterior adductor muscle	nd	58.0	nd	4.0	.234
Foot muscle	nd	101.0	nd	7.0	.139
Neck muscle (skinless)	nd	53.0	nd	8.7	.170
Gills	1.0	109.0	nd	17.0	.119
Heart and alimentary canal	15.0	81.0	16.0	59.0	.144
Visceral mass + contents	0.75	33.0	5.8	38.0	.530
Neck skin	nd	122.0	4.0	1200.0	.163

Table 5 cont.

Bivalve Mollusks

Concentrations of trace elements in individual organs
(PPM dry weight)

	<u>Cadmium</u>	<u>Zinc</u>	<u>Copper</u>	<u>Manganese</u>	<u>dry/wet</u> *
<u>Tresus nuttalli</u>					
Gaper clam; Elkhorn Slough Clam #2					
Anterior a ductor muscle	nd**	87.0	nd	nd	.149
Foot muscle	nd	73.0	nd	4.0	.135
Neck muscle (skinless)	0.9	47.0	nd	4.0	.149
Mantle	nd	103.0	nd	18.0	.135
Gills	nd	108.0	nd	21.6	.119
Heart and alimentary canal	18.0	190.0	8.5	42.0	.108
Visceral mass + contents	0.9	58.0	16.0	48.0	.192

(* ratio of grams dry weight/grams wet weight of tissue sampled)

(** concentration of element was not detectable = nd)

Table 6

Fishes

Concentrations of trace elements in fish flesh
(Average PPM dry weight)

	<u>Cadmium</u>	<u>Zinc</u>	<u>Copper</u>	<u>Manganese</u>	<u>dry/wet*</u>
<u>Oncorhynchus tshawytscha</u>					
King Salmon					
Average from 2 fillets	0.6 (0.0)	19.0 (7.0)	2.9 (1.0)	nd**	.308 (standard deviation)
<u>Xiphias gladius</u>					
Swordfish, one sample	1.5	39.0	1.25	nd	.250
<u>Gadus macrocephalus</u>					
Rock Cod; Monterey Bay					
Average from 3 fillets	nd	16.4 (2.0)	1.0 (0.0)	0.2 (0.0)	.229
<u>Sebastes miniatus</u>					
Vermillion Rockfish or Red Snapper					
Average of 3 fillets	nd	23.6 (7.0)	1.9 (0.6)	nd	.221
<u>Anoploma fimbria</u>					
Black Cod, Sable fish					
Average from 2 fillets	nd	15.5 (2.5)	2.5 (0.0)	0.6 (0.2)	.321
Sole--species unknown					
Average of 3 fillets	nd	23.0 (3.0)	2.0 (0.4)	1.2 (0.9)	.155
<u>Atherinos affinis #</u>					
Top Smelt; Pajaro River, Cal.					
average of 3 fillets	nd	66.0 (6.0)	0.8 (0.1)	0.7 (0.1)	
<u>Cymatogaster aggregata #</u>					
Shiner Perch; Elkhorn Slough					
Average of 10 fillets	0.2 (0.3)	43.0 (13.0)	3.6 (1.7)	2.0 (0.7)	
<u>Platichthys stellatus #</u>					
Starry Flounder; Elkhorn Slough					
Average of 5 fillets	0.5 (0.2)	nd	1.5 (0.2)	1.0 (0.2)	
<u>Roccus saxatilis #</u>					
Striped Bass; Pajaro River					
Average of 3 fillets	nd	20.0 (2.0)	1.2 (0.4)	1.5 (0.6)	

(* ratio of dry weight/wet weight of sample) (**concentration not detectable)
(# data from Jim Prickett, Hopkins Marine Station, Pacific Grove, California)

Table 6

Fishes

Concentrations of trace elements in fish flesh
(Average PPM dry weight)

	<u>Cadmium</u>	<u>Zinc</u>	<u>Copper</u>	<u>Manganese</u>	<u>dry/wet*</u>
<u>Oncorhynchus tshawytscha</u>					
King Salmon					
Average from 2 fillets	0.6 (0.0)	19.0 (7.0)	2.9 (1.0)	nd**	.308 (standard deviation)
<u>Xiphias gladius</u>					
Swordfish, one sample	1.5	39.0	1.25	nd	.250
<u>Gadus macrocephalus</u>					
Rock Cod; Monterey Bay					
Average from 3 fillets	nd	16.4 (2.0)	1.0 (0.0)	0.2 (0.0)	.229
<u>Sebastes miniatus</u>					
Vermillion Rockfish or Red Snapper					
Average of 3 fillets	nd	23.6 (7.0)	1.9 (0.6)	nd	.221
<u>Anoploma fimbria</u>					
Black Cod, Sable fish					
Average from 2 fillets	nd	15.5 (2.5)	2.5 (0.0)	0.6 (0.2)	.321
Sole--species unknown					
Average of 3 fillets	nd	23.0 (3.0)	2.0 (0.4)	1.2 (0.9)	.155
<u>Atherinos affinis #</u>					
Top Smelt; Pajaro River, Cal.					
average of 3 fillets	nd	66.0 (6.0)	0.8 (0.1)	0.7 (0.1)	
<u>Cymatogaster aggregata #</u>					
Shiner Perch; Elkhorn Slough					
Average of 10 fillets	0.2 (0.3)	43.0 (13.0)	3.6 (1.7)	2.0 (0.7)	
<u>Platichthys stellatus #</u>					
Starry Flounder; Elkhorn Slough					
Average of 5 fillets	0.5 (0.2)	nd	1.5 (0.2)	1.0 (0.2)	
<u>Roccus saxatilis #</u>					
Striped Bass; Pajaro River					
Average of 3 fillets	nd	20.0 (2.0)	1.2 (0.4)	1.5 (0.6)	

(* ratio of dry weight/wet weight of sample) (**concentration not detectable)
(# data from Jim Prickett, Hopkins Marine Station, Pacific Grove, California)

Table 7

Crustaceans

Concentrations of trace elements in flesh
(Average PPM dry weight)

	<u>Cadmium</u>	<u>Zinc</u>	<u>Copper</u>	<u>Manganese</u>	<u>dry/wet*</u>
<u>Pandalus jordani</u>					
Ocean Shrimp; fresh	0.6	48.5	7.8	4.3	.262
Average of 7 shelled tail portions	(0.0)	(3.5)	(8.0)	(0.5)	(standard deviation)
Prawns; species unknown					
Average of 3 shelled tails	0.2	47.0	12.0	nd**	.222
	(0.0)	(15.1)	(2.2)		
<u>Cancer magister</u>					
Dungeness Crab meat					
fresh	0.3	73.0	16.0	1.9	.350
	(0.1)	(6.0)	(1.6)	(0.8)	
canned	0.3	93.0	7.2	0.8	.350
	(0.1)	(7.6)	(1.5)	(0.1)	

(* ratio of dry weight to wet weight of sample)

(** concentration of element, not detectable)