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The Relative Contributions of Methylmercury from Food or Water to Rainbow Trout (*Salmo gairdneri*) in a Controlled Laboratory Environment

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ABSTRACT

Rainbow trout accumulated methylmercury linearly during 24 days when continually exposed to methylmercury. Exposure was by means of water solutions (0.07–1.33 μg Hg/liter), food consumption (8.0–380.5 ng Hg/g fish per day) or both. Methylmercury accumulated from one source had no influence on the rate of uptake from the second source. Methylmercury accumulated from both sources was quantitatively additive, which validates a frequently used assumption. Food consumption rate and therefore growth rate had no influence on the rate of mercury accumulation from water. Nearly 70% of the methylmercury ingested and 10% of the methylmercury passed over the gills was assimilated.

This study was initiated to quantify the efficiency with which rainbow trout absorb methylmercury from their diet and from water and to determine if one source of uptake influences accumulation from the other. The data obtained may be useful for predicting the relative importance of food and water as sources of methylmercury to fish in a natural environment.

Methylmercury and its derivatives are among the most widely studied water pollutants in recent years. Methylmercury accumulates in aquatic organisms to concentrations many orders of magnitude higher than those in water. The biological half-time of methylmercury is reportedly over 200 days in rainbow trout (Giblin and Massaro 1972) nearly 700 days in northern pike, *Esox lucius*, and more than 1,000 days in flounder, *Pleuronectes flesus* (Järvenpää et al. 1970).

Mercury may enter fish via the respiratory surfaces or the diet. However, water quality standards are usually derived from acute or chronic toxicity tests on fish exposed to water solutions of chemicals (NAS, NAE 1973). Because food may be an important route of accumulation in nature, standards derived only from water exposure could be dangerously liberal.

Conflicting reports exist regarding the relative importance of food and water as sources of mercury to fish. Hannerz (1968) exposed pond animal communities to methylmercury and observed that tissue concentrations in the organisms were not related to trophic level suggesting that water was the major route of methylmercury accumulation. Alternatively, Jernelöv and Lann (1971) attributed 60% of the mercury present in northern pike from three Swedish rivers to mercury from the fish's food. Other workers have observed what appeared to be a positive relationship between mercury concentration and trophic level among species of fish collected in the field, but the relationship was not always consistent (Buhler et al. 1973; Johnels et al. 1967). This disagreement results primarily from an absence of information concerning the specific mercury exposure regimes experienced by these fish and a lack of quantitative data relating food uptake to water uptake.

Bacteria are capable of converting most mercury compounds to methylmercury (Jensen and Jernelöv 1969); methylmercury is the predominant form of mercury present in fish tissue (Noren and Westöö 1967; Buhler et al. 1973). Since fish themselves do not appear capable of methylating mercury to any great degree (Uthe et al. 1972), it follows that most of the mercury present in fish must be derived from methylmercury in their environment. Methylmercury was, therefore, the form of mercury employed during these studies.

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TABLE 1.—*Methylmercury exposure regimes, food consumption rates, and actual and predicted methylmercury accumulation rates during the three experiments.*

Experiment	Methylmercury concentration in water (μg Hg/liter)[a]		Food consumption rate (mg/g per day)[b]	Methylmercury concentration in food (μg Hg/g)	Methylmercury consumption rate (ng Hg/g per day)[c]	Methylmercury accumulation rate (μg Hg/g per day)[d]	
	Measured	Adjusted				Actual	Predicted[e]
1[f]	0.21 ± 0.03	0.22	34	<0.01	0	0.021 ± 0.010 (8)	0.018
	0.21 ± 0.03	0.22	65	<0.01	0	0.020 ± 0.010 (8)	0.018
	0.21 ± 0.03	0.22	92	<0.01	0	0.022 ± 0.008 (8)	0.018
	0.32 ± 0.05	0.34	34	<0.01	0	0.025 ± 0.005 (8)	0.029
	0.32 ± 0.05	0.34	65	<0.01	0	0.022 ± 0.007 (8)	0.029
	0.32 ± 0.05	0.34	92	<0.01	0	0.032 ± 0.007 (8)	0.029
	0.64 ± 0.10	0.67	34	<0.01	0	0.057 ± 0.022 (7)	0.056
	0.64 ± 0.10	0.67	65	<0.01	0	0.055 ± 0.011 (8)	0.056
	0.64 ± 0.10	0.67	92	<0.01	0	0.058 ± 0.015 (8)	0.056
	1.28 ± 0.20	1.34	34	<0.01	0	0.114 ± 0.030 (8)	0.113
	1.28 ± 0.20	1.34	65	<0.01	0	0.111 ± 0.034 (8)	0.113
	1.28 ± 0.20	1.34	92	<0.01	0	0.102 ± 0.015 (8)	0.113
2[f]	Control	0	45	3.08	139	0.103 ± 0.023 (8)	0.095
	Control	0	86	3.08	265	0.164 ± 0.026 (8)	0.180
	Control	0	123	3.08	379	0.255 ± 0.049 (8)	0.258
	0.33 ± 0.04	0.35	45	<0.01	0	0.029 ± 0.005 (8)	0.029
	0.33 ± 0.04	0.35	86	<0.01	0	0.033 ± 0.007 (7)	0.029
	0.33 ± 0.04	0.35	123	<0.01	0	0.031 ± 0.007 (8)	0.029
	0.33 ± 0.04	0.35	45	3.08	139	0.139 ± 0.018 (7)	0.124
	0.33 ± 0.04	0.35	86	3.08	265	0.186 ± 0.026 (7)	0.210
	0.33 ± 0.04	0.35	123	3.08	379	0.251 ± 0.053 (8)	0.287
	1.33 ± 0.16	1.38	45	3.08	0	0.127 ± 0.033 (8)	0.116
	1.33 ± 0.16	1.38	86	3.08	0	0.125 ± 0.013 (8)	0.116
	1.33 ± 0.16	1.38	123	3.08	0	0.135 ± 0.032 (8)	0.116
	1.33 ± 0.16	1.38	45	3.08	139	0.213 ± 0.050 (7)	0.210
	1.33 ± 0.16	1.38	86	3.08	265	0.316 ± 0.070 (8)	0.296
	1.33 ± 0.16	1.38	123	3.08	379	0.412 ± 0.081 (8)	0.374
3	Control	0	65	0.12	8	0.005 ± 0.002 (15)	0.005
	Control	0	65	0.51	33	0.025 ± 0.005 (15)	0.022
	Control	0	65	1.34	87	0.063 ± 0.011 (13)	0.059
	0.07 ± 0.01	0.07	65	0.12	8	0.010 ± 0.001 (15)	0.011
	0.07 ± 0.01	0.07	65	0.51	33	0.027 ± 0.009 (14)	0.028
	0.07 ± 0.01	0.07	65	1.34	87	0.068 ± 0.011 (13)	0.065
	0.14 ± 0.02	0.14	65	0.12	8	0.017 ± 0.003 (15)	0.017
	0.14 ± 0.02	0.14	65	0.51	33	0.034 ± 0.008 (14)	0.034
	0.14 ± 0.02	0.14	65	1.34	87	0.071 ± 0.011 (14)	0.071
	0.29 ± 0.04	0.27	65	0.12	8	0.029 ± 0.006 (15)	0.028
	0.29 ± 0.04	0.27	65	0.51	33	0.043 ± 0.005 (15)	0.045
	0.29 ± 0.04	0.27	65	1.34	87	0.082 ± 0.011 (14)	0.082
	0.57 ± 0.06	0.54	65	0.12	8	0.049 ± 0.007 (15)	0.051
	0.57 ± 0.06	0.54	65	0.51	33	0.066 ± 0.010 (14)	0.068
	0.57 ± 0.06	0.54	65	1.34	87	0.102 ± 0.011 (15)	0.105

[a] Mean ± SD.
[b] Milligrams of food consumed per g fish per day.
[c] Nanograms of mercury consumed per g fish per day.
[d] Micrograms of mercury consumed per g fish per day; mean ± SD, sample size in parentheses.
[e] Predicted from regression of data from all three experiments ($y = 0.0084x_w + 0.00068x_c$).
[f] These experiments also had one or more control treatments for which the methylmercury accumulation rates were zero.

METHODS

Rainbow trout were acquired as fingerlings (3–10 g) from the Oregon Department of Fish and Wildlife's Roaring River Fish Hatchery located near Scio, Oregon. Fish were acclimated to the laboratory environment and fed the experimental diet (uncontaminated) for at least 2 wk before being tested. Selections of fish for each test were based on size uniformity, diet acceptance, and apparent fitness.

Three experiments were conducted between July 1973 and August 1974; protocols are given in Table 1. In experiment 1, fish were exposed only to water solutions of methylmercury; they were fed locally collected tubificid worms (*Tubifex* sp.). In experiments 2 and 3, fish were exposed to methylmercury via both their water and

their food (Oregon test diet),[2] separately and in combination. Methylmercury consumption rates (ng Hg consumed/g mean fish biomass per day) were varied during experiment 2 by feeding different amounts of diet[3] containing a single concentration of mercury. During experiment 3 variations in methylmercury consumption rates were achieved by feeding separate diets containing different methylmercury concentrations. Fish were weighed weekly and the amount of food presented to each group of fish (treatment) was adjusted to maintain a constant feeding rate within that treatment. Several food consumption rates were employed during the test (Table 1). Fish were sacrificed for analysis at approximately 8-day intervals during experiments 1 and 2 (duration, 24 days) and at weekly intervals during experiment 3 (duration, 21 days). Two fish were sacrificed at each of the first two intervals during experiments 1 and 2 and four fish were sacrificed at the end of the test. During experiment 3 five fish were sacrificed at each interval.

Methylmercuric chloride (Alpha Ventura Co., Beverly, Massachusetts) was dissolved in the salmon oil component of the Oregon test diet prior to diet formulation. Analyses demonstrated that both the tubificid diet and the control Oregon test diet contained negligible amounts of mercury (less than 0.01 μg Hg/g wet weight).

A continual-flow proportional diluter of the type described by Mount and Brungs (1967) delivered the various solutions to 30-liter glass aquaria (three per treatment). The diluter cycled once every 1.75 min resulting in mean flow rates of 385, 385, and 390 ml/min through each aquarium during experiments 1, 2, and 3, respectively. The stock solution was prepared by dissolving methylmercuric chloride in 20 ml of acetone and then diluting the acetone with distilled water to produce the desired concentration.

Fish receiving no methylmercury through their water were held in aquaria identical to those holding the exposed fish; flow rates through these aquaria averaged 380, 381, and 375 ml/min during experiments 1, 2, and 3, respectively. Water was initially passed through a head box where a thermoregulator maintained temperatures near 15 C; photoperiods were 16 h light:8 h dark during each experiment.

Dechlorinated city water was employed during all tests. Dissolved oxygen ranged from 9.6 to 10.1 mg/liter, temperature from 14.8 to 15.5 C, and pH from 7.3 to 7.6 during the three experiments.

Water samples were analyzed for mercury once each week during each experiment. Samples were first oxidized (Omang 1971), and total mercury was finally quantified by atomic absorption spectrophotometry with a Coleman Model 50 mercury analyzer equipped with a Soltec Model 252A integrating recorder. All mercury detected in these samples was assumed to be methylmercury. Concentrations below 0.5 μg Hg/liter exceeded the detection limits of our equipment but were estimated from the known mercury dilution volumes.

To measure Hg concentrations in whole experimental fish or food, samples were first digested for 3 h in hot concentrated nitric acid (2 ml HNO_3/g sample). Thirty percent hydrogen peroxide (1 ml H_2O_2/g sample) was then added and the samples were boiled for an additional hour. Next the samples were air-cooled, solidified lipids were filtered from the solution and mercury concentrations in subsamples were determined by flameless atomic absorption spectrophotometry. As with water samples, we assumed that the majority of mercury detected was methylmercury.

Control fish from each experiment contained small but measurable quantities of mercury. These were, in ng Hg/g wet weight, 0.03–0.09 for experiment 1; 0.08–0.12 for experiment 2; and 0.02–0.04 for experiment 3. Concentrations of Hg in exposed fish were adjusted for the respective mean background values in each experiment.

Mercury accumulation rates were calculated for each experimental fish by dividing

[2] Oregon test diet (NRC 1973) obtained from and formulated by George Putnam, of the Fish Hepatoma Laboratory, Department of Food Science and Technology, Oregon State University.

[3] To achieve a closer approximation of natural diets, the dietary methylmercury concentrations are represented as what they would have been had the Oregon test diet contained 20% dry substance and 80% water.

TABLE 2.—*Methylmercury exposure regimes and uptake of methylmercury by rainbow trout.*

Experiment	Methylmercury concentration in water (μg Hg/liter)[a]	Methylmercury consumption rate (ng Hg/g fish per day)	Body burden of mercury (μg Hg/g wet fish)[a]		
			Sample 1[b]	Sample 2[c]	Sample 3[d]
1	0.21 ± 0.03	0	0.28 ± 0.09 (5)	0.28 ± 0.03 (6)	0.39 ± 0.12 (11)
	0.32 ± 0.05	0	0.26 ± 0.06 (6)	0.40 ± 0.07 (6)	0.59 ± 0.14 (12)
	0.64 ± 0.10	0	0.65 ± 0.12 (5)	0.83 ± 0.08 (6)	1.16 ± 0.15 (12)
	1.28 ± 0.20	0	1.11 ± 0.24 (6)	1.71 ± 0.33 (6)	2.28 ± 0.32 (12)
2	Control	139	0.87, 0.99 (2)	1.78, 1.93 (2)	2.06 ± 0.43 (4)
	Control	265	1.41, 1.59 (2)	2.62, 2.88 (2)	3.41 ± 0.35 (4)
	Control	379	1.83, 2.78 (2)	3.63, 4.20 (2)	5.67 ± 1.03 (4)
	0.33 ± 0.04	0	0.27 ± 0.04 (6)	0.38 ± 0.05 (6)	0.76 ± 0.16 (11)
	0.33 ± 0.04	139	1.11, 1.13 (2)	1.62, 3.55 (2)	3.30 ± 0.14 (3)
	0.33 ± 0.04	265	1.73 (1)	2.91, 3.17 (2)	4.08 ± 0.50 (4)
	0.33 ± 0.04	379	1.55, 2.68 (2)	3.85, 4.87 (2)	5.38 ± 0.44 (4)
	1.33 ± 0.16	0	1.29 ± 0.17 (6)	1.86 ± 0.16 (6)	2.70 ± 0.48 (12)
	1.33 ± 0.16	139	1.11, 2.36 (2)	3.44 (1)	4.95 ± 0.71 (4)
	1.33 ± 0.16	265	2.83, 3.63 (2)	4.22, 5.28 (2)	6.53 ± 0.84 (4)
	1.33 ± 0.16	379	3.65, 4.56 (2)	5.42, 709 (2)	8.63 ± 0.59 (4)
3	Control	8	0.03 ± 0.02 (5)	0.07 ± 0.02 (5)	0.11 ± 0.01 (5)
	Control	33	0.20 ± 0.05 (5)	0.35 ± 0.04 (5)	0.49 ± 0.11 (4)
	Control	87	0.48 ± 0.10 (4)	0.90 ± 0.15 (5)	1.19 ± 0.15 (4)
	0.07 ± 0.01	8	0.07 ± 0.01 (5)	0.13 ± 0.02 (5)	0.21 ± 0.02 (5)
	0.07 ± 0.01	33	0.19 ± 0.09 (5)	0.36 ± 0.17 (4)	0.60 ± 0.07 (5)
	0.07 ± 0.01	87	0.55 ± 0.07 (4)	0.94 ± 0.19 (4)	1.29 ± 0.27 (5)
	0.14 ± 0.02	8	0.11 ± 0.03 (5)	0.22 ± 0.04 (5)	0.38 ± 0.06 (5)
	0.14 ± 0.02	33	0.27 ± 0.10 (4)	0.46 ± 0.08 (5)	0.68 ± 0.08 (5)
	0.14 ± 0.02	87	0.57 ± 0.09 (4)	0.87 ± 0.12 (5)	1.48 ± 0.08 (5)
	0.29 ± 0.04	8	0.18 ± 0.01 (5)	0.39 ± 0.05 (5)	0.73 ± 0.11 (5)
	0.29 ± 0.04	33	0.29 ± 0.03 (5)	0.60 ± 0.08 (5)	0.97 ± 0.06 (5)
	0.29 ± 0.04	87	0.59 ± 0.09 (5)	1.17 ± 0.19 (5)	1.62 ± 0.13 (4)
	0.57 ± 0.06	8	0.30 ± 0.02 (5)	0.69 ± 0.07 (5)	1.17 ± 0.11 (5)
	0.57 ± 0.06	33	0.44 ± 0.02 (5)	0.89 ± 0.16 (5)	1.50 ± 0.30 (4)
	0.57 ± 0.06	87	0.69 ± 0.06 (5)	1.44 ± 0.14 (5)	2.18 ± 0.30 (5)

[a] Mean ± SD, sample sizes in parentheses.
[b] On 8th day in experiments 1 and 2; 7th day in experiment 3.
[c] On 16th day in experiment 1, 15th day in experiment 2, 14th day in experiment 3.
[d] On 24th day in experiments 1 and 2; 21st day in experiment 3.

the concentration of mercury accumulated (μg Hg/g) by the exposure interval (days). Since the mean methylmercury concentrations in water varied from week to week and because different numbers of individuals were sacrificed at each time interval, the mean methylmercury water concentrations for the entire experimental period were not representative of the mean methylmercury accumulation rate derived from all individuals from a given treatment. Adjusted methylmercury water concentrations were therefore calculated from the number of fish sacrificed at each interval and the mean concentration to which individuals sacrificed after each interval had been exposed. The adjusted values were derived by multiplying the number of fish sacrificed from each treatment at each sampling interval by the mean methylmercury concentration to which they had been exposed, adding the products of these multiplications for a given water concentration and finally dividing this sum by the total number of fish sacrificed from each treatment during the entire experiment. The adjusted water concentrations were then used for comparisons between and within experiments. Adjusted values were slightly different from the observed values (Table 1).

Statistical procedures employed are from Steel and Torrie (1960).

RESULTS

Mercury was taken up at a constant rate by fish exposed to methylmercury in their diet, in the water, or in both media simultaneously (Table 2). Linear regressions of mercury concentration in the fish against time were extended through the origin. The

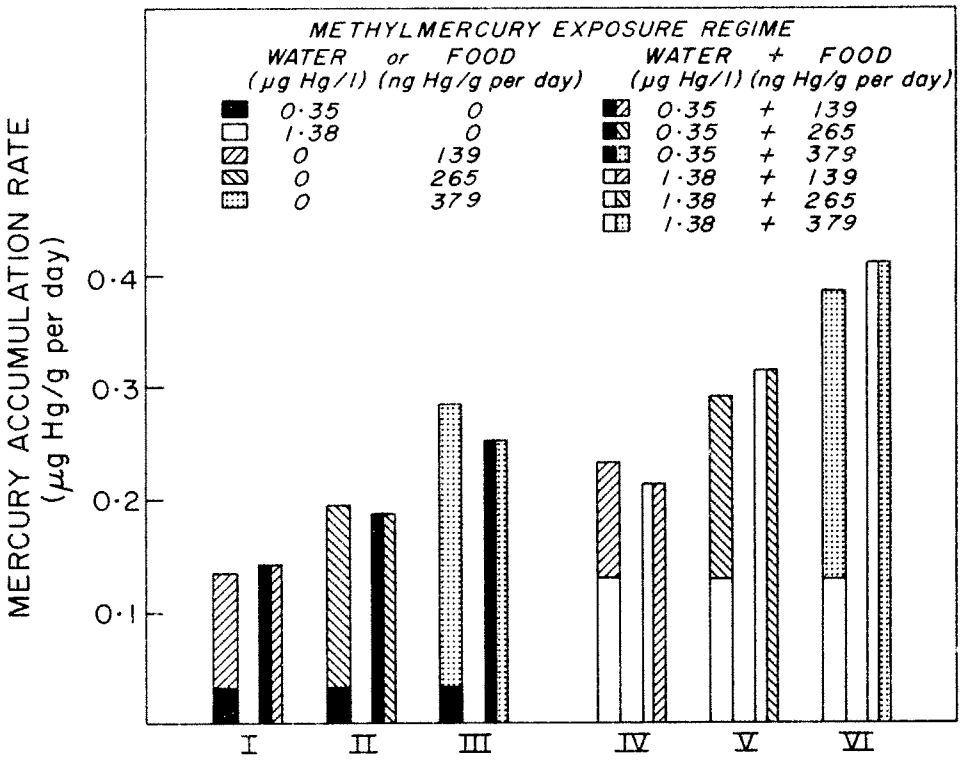

FIGURE 1.—*The additive relationship between mercury accumulated from food and water (data from experiment 2, Table 1). The left column of each pair marked by Roman numerals shows accumulation rates for separate Hg exposures via water or food. The right column of each pair shows accumulation rate when exposure was via water and food simultaneously.*

mean coefficient of determination was 0.97 for all treatments; only one coefficient was below 0.93. This allowed us to apply a mean mercury accumulation rate for all fish from a given treatment regardless of the time a particular fish was killed for analyses (Table 1).

Mercury concurrently accumulated from food and water was quantitatively additive; accumulation rates from food or water separately, when summed, nearly equaled that from both sources presented together (Fig. 1). The relationship between concentration of methylmercury in water (μg Hg/liter), methylmercury consumption rate (ng Hg/g per day), and mercury accumulation rate (μg Hg/g per day) is described by the regression equation $y = 0.084x_w + 0.00068x_c$ (combined data of all three experiments: $r^2 = 0.87$), where (x_w) is the methylmercury concentration in water and (x_c) is methylmercury consumption rate. The slopes of the water component of uptake were 0.082, 0.098, and 0.078 for experiments 1 (N = 96), 2 (N = 120), and 3 (N = 225), respectively (Fig. 2). The slope of the food component was 0.00065 for experiment 2 and 0.00070 for experiment 3 (Fig. 3). Mercury accumulation rates predicted for individual treatments from the combined data of all three experiments were very similar to the observed values (Table 1). This further demonstrates the additive nature of methylmercury uptake from food and water and attests to the repeatability of the experiments over a variety of methylmercury exposure regimes.

No differences between growth rates of fish in any of the treatments were observed during any experiment; however, this does not rule out the possibility that growth would have been affected over a longer ex-

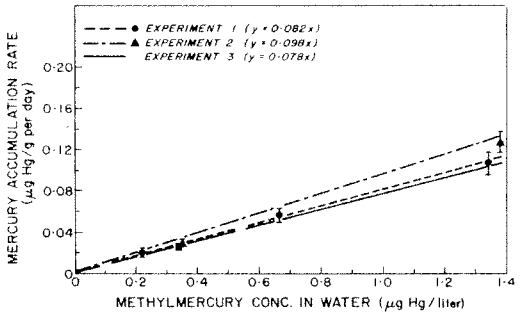

FIGURE 2.—*The relationship between methylmercury consumption rate and mercury accumulation rate (μg Hg/g per day) during experiments 2 and 3. Vertical bars indicate 95% confidence intervals for those treatments receiving methylmercury exposure through food only.*

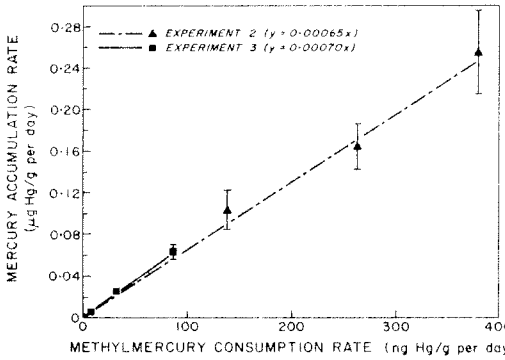

FIGURE 3.—*The relationship between concentration of methylmercury in water and mercury accumulation rate during each experiment. Vertical bars represent 95% confidence intervals for those treatments receiving methylmercury exposure through water only.*

posure. One might expect that increased growth resulting from increased food consumption would dilute mercury accumulation by fish for a given water mercury exposure regime; however, food consumption rate (control diet) did not influence the rate of mercury accumulation by fish experiencing the same methylmercury concentration in water (Table 1). Since fish growth was related to the ration fed, the increased metabolic activity of the faster growing fish somehow compensated for the growth dilution, perhaps by necessitating a greater respiratory water volume and therefore more methylmercury exposure and uptake at the gill surfaces. This observation is in agreement with the finding that the mercury concentrations present in fish representing the same year class from a contaminated reservoir were independent of size differences (Phillips 1976).

Mercury uptake via the gills is directly related to metabolic rate, which, among other things, is determined by fish size, water temperature, and dissolved oxygen concentration in water. Brett (1965) has shown that sockeye salmon (*Oncorhynchus nerka*) weighing nearly 3 g consumed about 230 mg O_2/kg body weight per h when kept in still water at 15 C. Similarly, Negilski (1973) reported a value of 280 mg/kg per hour for 6.7-g chinook salmon (*Oncorhynchus tschawytscha*) exposed to similar conditions. Further, several species of freshwater fishes assimilated 75% of all oxygen passed over their gills regardless of temperature, at oxygen concentrations near saturation; only slight variations were observed among species (Dolinin 1974). If these relationships were similar for rainbow trout during our experiments, it is possible to estimate the methylmercury ventilation rate and subsequently the efficiency with which these fish extracted methylmercury from water. We further assume that nearly all of the mercury accumulated was retained by the fish. This assumption appears valid in view of the extremely long biological half-time for methylmercury in fish (Giblin and Massaro 1972; Järvenpää et al. 1970).

Negilski's oxygen consumption rate was chosen for our calculations because his fish approximated the size of fish used during our experiments. Negilski's oxygen consumption rate divided by Dolinin's oxygen extraction efficiency yields oxygen ventilation rate (6.72 mg O_2/g per day/0.75 = 8.96 mg O_2/g per day). Dividing this quotient by the oxygen concentration in water results in the water ventilation rate (8.96 mg O_2/g per day/10 mg liter = 0.896 liter/g per day). The relationship between methylmercury concentration in water and mercury accumulation rate observed during the laboratory experiments ($y = 0.084x_w + 0.00068x_c$) can now be used to derive mercury ventilation rate ($x_w \cdot 0.896$ liter/g per day) and mercury extraction efficiency ($y/x_w \cdot 0.896$ liter/g per day). If the assumptions are valid, about

10% of all the methylmercury passed over the gills of the experimental fish was assimilated.

On the average, 68% of all the methylmercury consumed during experiments 2 and 3 was accumulated (Table 1). There was no apparent decrease in mercury extraction efficiency from food with either an increase in methylmercury consumption rate or an increase in mercury body burden during either mercury feeding experiment.

DISCUSSION

Estimates of the efficiency with which the experimental fish extracted methylmercury from water averaged 10% for all of the concentrations employed. This value agrees with the 12% figure reported by Norstrom et al. (1976). but is much lower than the 100% value arbitrarily assigned to fish by Fagerström and Asell (1973). Further methylmercury uptake models should incorporate values based on experimental evidence.

During these experiments rainbow trout assimilated on the average 68% of all the methylmercury they consumed. Various other workers have artificially incorporated methylmercury into fish diets and observed extraction efficiencies of 67–87% (Hannerz 1968; Miettinen et al. 1970; Stillings and Lagally 1974; Suzuki and Hatanka 1975; Norstrom et al. 1976). However, Jernelöv (1969) reported that only 10–15% of the methylmercury present in fodder fish that were contaminated in a natural environment was incorporated by a predator species during a laboratory feeding study. Conceivably the dietary matrix or the mode of accumulation by a food organism influences the rate of methylmercury assimilation by a predator. Fish, for example, contain high concentrations of selenium (Ganther et al. 1972), and ingestion of this element influences the uptake and distribution of methylmercury in animals (Rimerman et al. 1977). Schiffman (1959) showed that 21% of the isotopic strontium fed to rainbow trout in gelatin capsules was incorporated while only 7% of the strontium present in natural food organisms (insects and small fish) was retained. Similarly, Pentreath (1973) demonstrated that 71–72% of the ^{65}Zn present in a gelatin or starch matrix was assimilated by plaice (*Pleuronectes platessa*) but when ^{65}Zn was fed to plaice in a natural food organism (*Nereis* sp.) only 36% was retained. Further studies are necessary to quantify the influence of dietary matrix on the availability of consumed methylmercury to fish.

Methylmercury residues accumulated from food and water were shown to be additive during the present study. Predicting the relative importance to fish of methylmercury from natural foods or water is complicated by geographical and seasonal variations in methylmercury availability. Methylmercury concentrations in food organisms vary seasonally as do the consumptive habits of fish. Hakonson et al. (1975) have shown that rainbow trout from a Colorado bog lake consumed 8% of their body weight per day in early summer but only 0.5% per day in midwinter. Moreover, there are seasonal fluctuations in the rates of bacterial methylation and in the amounts of inorganic mercury available for methylation. Other variables that influence the metabolic rates of fish include dissolved oxygen concentration (Fagerström and Asell 1973) and temperature (Reinert et al. 1974).

In spite of these variables, rough predictions can be made of the relative importance of food and water as sources of methylmercury to wild fish. We postulate that the linear phase of mercury uptake displayed by fish in nature during their first several months in a contaminated environment (Phillips 1976) is characterized by a constant methylmercury accumulation rate. This accumulation rate is in turn characteristic of a particular methylmercury exposure regime. Although it is technically difficult to measure the low methylmercury concentrations existing in natural waters, it may be possible to estimate the proportion of methylmercury absorbed from food and water from a knowledge of food alone. The proportion of methylmercury accumulation ascribable to food in a particular environment can be quantitatively evaluated by estimating the food consumption rates of fish in nature from their growth rates and then estimating their mercury consumption rates from data on the methylmercury concentrations present in their diets. The amount of methylmercury accumulated from water

could then be estimated by difference. This approach may be useful in evaluating field situations once the question of methylmercury availability from different dietary matrices is resolved.

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