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Factors Affecting Mercury and Selenium Levels-in New Jersey Flatfish: Low Risk to Human Consumers

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Abstract

Some fish contain high levels of mercury (Hg), which could pose a risk to fish eaters themselves or their children. In making decisions about fish consumption, people must decide whether to eat fish, how much to eat, what species to eat, and what size fish to eat, as well as suitable (or unsuitable) locations, among other factors. Yet to make sound decisions, people need to know the levels of Hg in fish as a function of species, size, and location of capture. Levels of Hg and selenium (Se) were examined in three species of flatfish (fluke or summer flounder [*Paralichthys dentatus*], winter flounder [*Pseudopleuronectes americanus*], and windowpane [*Scophthalmus aquosus*]) from New Jersey as a function of species, fish size, season, and location. Flatfish were postulated to have low levels of Hg because they are low on the food chain and are bottom feeders, and data were generated to provide individuals with information on a species that might be safe to eat regularly. Although there were interspecific differences in Hg levels in the 3 species, total Hg levels averaged 0.18, 0.14, and 0.06 ppm ($\mu\text{g/g}$, wet weigh) in windowpane, fluke, and winter flounder, and selenium levels averaged 0.36, 0.35, and 0.25 ppm, respectively. For windowpane, 15% had Hg levels above 0.3 ppm, but no individual fish had Hg levels over 0.5 ppm. There were no significant seasonal differences in Hg levels, although Se was significantly higher in fluke in summer compared to spring. There were few geographical differences among New Jersey locations. Correlations between Hg and Se levels were low. Data, based on 464 fish samples, indicate that Hg levels are below various advisory levels and pose little risk to typical New Jersey fish consumers. A 70-kg person eating 1 meal (8 oz or 227 g) per week would not exceed the U.S. Environmental Protection Agency reference dose of 0.1 $\mu\text{g/kg}$ body weight/d of methylmercury (MeHg). However, high-end fish eaters consuming several such meals per week may exceed recommended levels.

Many Americans have increased their consumption of fish for health reasons, and fishing is a popular pastime. In interviews, people report that they fish because it provides a way to relax with family and friends, be outside, and commune with nature (Burger, 2004). For some people, it also provides protein not otherwise available (Toth & Brown, 1997; Burger,

2002; Knuth et al., 2003; Burger & Gochfeld, 2006). Fishing is important in rural regions, for Native Americans, for subsistence people (whether Native Americans or not), and for recreationists of all economic levels (Harris & Harper, 1997, 2000; Burger et al., 1999a, 1999b, 2001b, 2007; Ramos & Crain, 2001; Hamrick & Smith, 2003; Burger, 2004; Stumpff, 2006; Dellinger, 2007; Silver et al., 2007; Harper & Harris, 2008).

Fish are a good source of low-fat protein and provide many health benefits, including omega-3 (*n*-3) fatty acids that (1) reduce cholesterol levels and incidence of stroke and heart disease, (2) reduce the rate of preterm deliveries, and (3) enhance cognitive development in fetuses and young children (Daviglus et al., 2002; Patterson, 2002; Willett, 2005; Konig et al., 2005; McMichael & Butler, 2005; Bouzan et al., 2005; Cohen et al., 2005a, 2005b). However, contaminants, such as mercury (Hg) and polychlorinated biphenyls (PCB), are sufficiently high in some fish and seafood to pose a health risk to consumers, particularly during pregnancy (NRC, 2000; Gochfeld, 2003; Hightower & Moore, 2003; IOM, 2006). Fish consumption is the most significant source of methylmercury (MeHg) exposure for the public (Rice et al., 2000), and poses a risk to susceptible adults, fetuses, neonates, and young children. In addition, methylmercury (MeHg) may counteract the cardioprotective effects of omega-3 fatty acids (Guallar et al., 2002).

The U.S. Food and Drug Administration (FDA) has issued advisories for four species of commercial fish (FDA, 2001, 2003, 2005FDA, 2006a; Burger & Gochfeld, 2004), but little attention has been devoted to self-caught saltwater fish, contaminants in saltwater fish, or consumption patterns of people fishing in coastal waters, despite the importance of recreational fishing to the economies of coastal states (NOAA, 2008). States respond to the potential risk from contaminants in fish by issuing state advisories for self-caught fish (usually freshwater); however, they rarely address consumption of commercial fish or saltwater fish (Burger & Gochfeld, 2004). Further, the FDA and states do not advise the public, including pregnant women, on what species of fish might be suitable for frequent consumption. There is clearly a trade-off between the health benefits of fish consumption and the possible harm from contaminants in these fish (McMichael & Butler, 2005; Willett, 2005; Cohen et al., 2005a).

This study partly addresses this issue by reporting levels of Hg and Se in three species of flatfish: fluke (*Paralichthys dentatus*), winter flounder (*Pseudopleuronectes* [= *Pleuronectes*] *americanus*), and windowpane (*Scophthalmus aquosus*), collected by recreational anglers in coastal New Jersey from 2005 through 2008. Fluke is also called summer flounder because it is a flatfish normally caught in the summer. Hg was selected because of the potential adverse human health effects from high levels of mercury (NRC, 2000; IOM, 2006) and Se was selected because it is thought to have a protective effect in terms of Hg (Ganter et al., 1972; Kim et al., 1977; Ringdal & Julshamn, 1985; Satoh et al., 1985).

All three species are important recreational and commercial fish in coastal New Jersey and New York (MacKenzie, 1991; Gobeille et al., 2005). Flatfish are bottom feeders that usually have low levels of Hg. This assumption, however, requires documentation for the U.S. Atlantic coast since other species of flatfish from Europe have mercury levels that are

sufficiently high to suggest a potential human health risk to consumers (Collings et al., 1996). Further seasonal, geographical, and size-related differences were examined, as contaminant levels usually increase with the age and size of fish (Lange et al., 1994; Bidone et al., 1997; Burger et al., 2001a; Pinho et al., 2002; Green & Knutzen, 2003). However, this is not always the case (Stafford & Haines, 2001); the size relationships may not occur at low levels of Hg (Park & Curtis, 1997; Polak-Juszczak & Sobolewska, 1999). One important aspect of this study is that most fluke samples were obtained from fish caught by anglers and most were taken home for consumption.

METHODS

Fluke ($n = 258$) was a primary interest of the study and is one of the most important sport fishes in coastal New Jersey waters, although windowpane ($n = 48$) and winter flounder ($n = 58$) were also sampled. Fluke samples were collected from several locations along coastal New Jersey from 2005 through 2008. Less than 15% of the fluke samples were taken from New Jersey Department of Environmental Protection (NJDEP) trawls, largely so that it was possible to examine fish that were less than the legal size limit for anglers. Winter flounder and windowpane were largely collected on the NJDEP trawls because they are difficult to catch and are caught sporadically by anglers. The overall protocol was to collect a small sample (<10 g) of muscle from fish caught by anglers, who kept the fish to take home for consumption by the anglers and their families. Samples were taken from the center of the fish, using clean techniques, and washing knives and other equipment between sample collection. Since sample collection was dependent upon the fishing abilities and inclinations of anglers, sample sizes reflect this constraint. While this method did not result in a balanced design by location and season, it did reflect levels in the fish that New Jersey coastal anglers caught and consumed.

Fish were weighed and measured (standard length from tip of snout to base of tail fin). Three fishing seasons were defined based on when large numbers of anglers fished: spring (14 April to 13 June), summer (1 July through 15 August), and autumn (1 October–31 October). Samples were not obtained from other months. The New Jersey coast was divided into three regions, based on the three major bays and estuaries in New Jersey (Figure 1).

Fish were shipped frozen to the Environmental and Occupational Health Sciences Institute (EOHSI) of Rutgers University for metal analysis. At EOHSI, the skin was removed carefully to prevent contamination from other tissues, and a 2-g (wet weight) sample of fish tissue was digested in Ultrex ultrapure nitric acid in a microwave (MD 2000 CEM), using a digestion protocol of 3 stages of 10 min each under 50, 100, and 150 pounds per square inch (3.5 , 7 , and 10.6 kg/cm²) at $80 \times$ power. Digested samples were subsequently diluted to 25 ml with deionized water. All laboratory equipment and containers were washed in 10% nitric acid solution followed by a deionized water rinse prior to each use (Burger et al., 2001a).

Total Hg was analyzed by the cold vapor technique using the Perkin Elmer FIMS-100 Hg analyzer, with an instrument detection level of 0.2 ng/g and a matrix level of quantification of 0.002 µg/g. Se was analyzed by graphite furnace atomic absorption, with Zeeman

correction. All concentrations of total Hg and Se are reported in parts per million (ppm= $\mu\text{g/g}$) on a wet weight basis. Almost all of the Hg in fish tissue is MeHg, and 90% is a reasonable approximation of this proportion (Lansens et al., 1991).

A DORM-2 certified dogfish tissue was used as the calibration verification standard. All specimens were run in batches that included blanks, a standard calibration curve, two spiked specimens, and one duplicate. The accepted recoveries for spikes of both Hg and Se ranged from 85 to 115%; no batches were outside of these limits. Ten percent of samples were digested twice and analyzed as blind replicates (with agreement within 15%). For further quality control on Hg, our laboratory periodically runs a random subset of samples in the Quebec Laboratory of Public Health; the correlation between the labs is over 0.9 (Burger & Gochfeld, 2004).

For analysis, the New Jersey coast was divided into three regions, which partly reflect the major bays/estuary systems (see Figure 1). Kruskal–Wallis nonparametric one-way analysis of variance (generating a χ^2 statistic) was used to examine differences among tissues and size measurements. Multivariate regression was also performed using the General Linear Models Procedure on log-transformed data to identify variables (length, weight, season, or location) contributing significantly to the variance in the dependent measures (Hg and Se concentrations). Nonparametric Kendall tau correlations were used to examine relationships among metals and size variables. The level for significance was designated as $p < .05$.

RESULTS

There were interspecific differences in levels of both Se and Hg. Windowpane had the highest and winter flounder had the lowest levels of both Hg and Se (Table 1). None of the individual flatfish we examined had Hg levels above 0.5 ppm, but 15% of windowpane and 5% of fluke had Hg levels over 0.3 ppm. There were significant size differences among species (Table 1). Fluke were much longer and heavier and windowpane much smaller than the other species. There was a significant positive correlation between Se and Hg in fluke, a negative correlation in windowpane, and no correlation in winter flounder (Table 2, Figure 2).

Although Hg levels were significantly correlated with length and weight in fluke, the correlations were low (Table 2, Figure. 2). Hg and Se, however, were more strongly correlated with increasing size for windowpane (Table 2, Figure 2). Winter flounder showed no significant relationships between size and Hg or Se levels (Table 2).

There were no significant differences in Hg levels in muscle tissue as a function of season for any species, although autumn windowpane were quantitatively larger than summer fish (and had higher Hg levels, Table 3). Se levels varied by season for fluke and windowpane (Table 3). Although there were significant seasonal size differences, the average differences were not marked (Table 3).

There were significant regional differences in Hg levels for fluke and windowpane (the two species with the greatest number of samples from different locations, Table 4). Hg levels in fluke (the species with the greatest sample size) were lowest in central New Jersey. These

differences were not directly a function of size since the fish from central New Jersey were larger than those collected in northern or southern New Jersey. Winter flounder were collected only in the north.

The multiple regression models indicated that only a small amount of the variation in Hg ($r^2 = .13$) or Se ($r^2 = .09$) levels was explained by season, location, or size variables for fluke, although season and location were significant (Table 5). For windowpane, the models were more predictive for Hg ($r^2 = .70$) and Se ($r^2 = .47$). Neither model was significant for winter flounder (Table 5).

DISCUSSION

Interspecific Differences

Fluke typically grow much larger than winter flounder (Bigelow & Schroeder, 1953). In this investigation, there were also interspecific differences in size (length, weight) and levels of Se and Hg. Fluke were the largest fish and windowpane were the smallest; however, the latter had the highest levels of both Hg and Se, while winter flounder, intermediate in size, had the lowest levels of both elements. The differences, however, were small. These differences might reflect foraging behavior, prey and prey foods, growth rates, or seasonal migration patterns (Able & Fahay, 1998). Fluke eat mainly small fish and crustaceans, winter flounder eat sedentary, bottom-living invertebrates, and windowpane feed on a range of invertebrates and small fish (Palmer & Fowler, 1975; MacKenzie, 1992; Carlson et al., 1997; NOAA, 2008). All three species are sit-and-wait predators. However, windowpane may be more active ambush predators and may be able to obtain larger prey (NOAA, 2008) that have accumulated higher levels of Hg and Se, and they eat a higher proportion of mysid shrimp than the other two species (Link et al., 2002). Further, winter flounder have a relatively smaller mouth than the other two species (Bigelow & Schroeder, 1953; Carlson et al., 1997; ASMFC, 2006), which may result in their consumption of smaller prey that had lower levels of Hg. Another species difference may relate to the length of time they spend in bays and estuaries, where they would be exposed to higher levels of contaminants from coastal sources. Winter flounder are in the New Jersey estuaries for a few months, while fluke are present for over 6 months.

There are few studies that examine Hg or Se levels in any of the three species from the east coast of North America, although different flatfish species are used as bioindicators in Europe (Nakhle et al., 2007). The New York and New Jersey Harbor Estuary Program determined Hg in tissue of selected finfish and reported that levels in all three species of flatfish averaged below 0.2 ppm (NY/NJ HEP, 2002). Hammerschmidt and Fitzgerald (2009) found that levels of MeHg in winter flounder from Long Island Sound averaged 0.021 (± 0.081) ppm, which is lower than the flatfish from New Jersey.

Human Consumption of Flatfish

Many people fish along the New Jersey shore, both recreationally and commercially, and fishing is important to New Jersey's economy. In the late 1880s clubs were formed that were devoted to fishing, held fishing tournaments, and even built weekend clubhouses

(MacKenzie, 1992). Many of these clubs, such as the Jersey Coast Angler's Association, still exist and hold contests, such as their annual flounder tournament, which attract hundreds of anglers. Fluke are the most popular coastal fish for anglers along the Jersey shore during the warmer months until mid-October (Mac Kenzie, 1992; Bologna, 2002), and winter flounder are fished extensively in late winter, making it important to understand Hg levels and the possible exposure of anglers and their families. The present study of fluke was based mainly on fish caught by anglers (and thus reflects angler exposure).

Flounder are an important recreational and commercial fish. Further, flounder (both locally caught and imported flatfish) can be bought in nearly 90% of the fish markets and grocery stores in New Jersey, in both upscale and downscale markets (Burger et al., 2004, 2005). Although fish labeled "flounder" in stores were not genetically tested to see whether these were fluke (= summer flounder) or winter flounder, both were likely represented, since "flounder" were available much of the year. Further, a survey of anglers in the lower Hudson River area indicated that over 60% ingested flounder and 78% consumed fluke (Gobeille et al., 2005).

People fish for relaxation, to be outdoors or commune with nature, and to be with family and friends, as well as for food (Burger, 2004). While anglers do eat the fish they catch, they are fishing primarily for recreation. Given the desire to fish, and the palatability of flatfish (MacKenzie, 1992), it is important for anglers to have information on the fish that are safe to eat, as well as those that are not (the latter information is provided by the FDA and state advisories). One of the main objectives of this study was to examine the hypothesis that flatfish, which are low on the food chain, do not accumulate Hg levels that might pose a risk to people eating them. By taking samples from fish caught by anglers we were able to ensure that the Hg levels reflected exposure of the anglers and their families who consumed these fish.

For all 3 flatfish, Hg levels averaged below 0.20 ppm ($\mu\text{g/g}$), which is below the advisory levels for most states. Further, no samples were above 0.5 ppm, although 5% of fluke, and 15% of windowpane, were above 0.3 ppm Hg. The U.S. FDA action level for MeHg in fish is 1.0 ppm ($\mu\text{g/g}$, wet weight). This is a regulatory action level, rather than a risk-based concentration (FDA, 2001, 2003, 2005), relating to interstate commerce. The results from this study are higher than the mean of 0.045 ppm Hg posted for 23 flatfish on the FDA web site (FDA, 2006a), or the 0.027 ppm MeHg in 11 unspecified flounder (FDA, 2006b).

In 1982, the European Commission set an Environmental Quality Standard for Hg: The mean concentration of Hg in a representative sample of fish shall not exceed 0.3 ppm (wet weight). The established criterion for Hg in fish muscle in the United Kingdom and the European Union is now 0.5 ppm in edible fish (with up to 1 ppm allowed for certain exempt predatory fish species). China has set a standard for MeHg in canned fish (ppm wet weight) of 0.5 ppm (except 1 ppm is allowed for shark, sailfish, tuna, pike, and other high-Hg fish). The U.S. EPA (2001) promulgated 0.3 ppm as an ambient freshwater quality standard for Hg in 2001, and this value was developed using consumption levels of 7 $\mu\text{g/d}$ ($0.1 \times 70\text{-kg}$ person) that are far less than those of many subsistence anglers and hunters, of avid

recreational anglers, or of many Native Americans (Harris & Harper, 1997; Burger et al., 2007).

The U.S. EPA oral reference dose for MeHg is 0.1 $\mu\text{g/kg}$ body weight/d (U.S. EPA IRIS database), meaning that consumption of more than 7 $\mu\text{g/d}$ of MeHg would exceed this level for a 70 kg person. Eating an 8-oz (= 228 g) meal of fish containing 0.2 ppm MeHg (= about 0.18 μg MeHg) would result in a weekly intake of 40.8 μg of total Hg, or 5.8 μg MeHg/d, which is less than 0.1 $\mu\text{g/kg/d}$ for a 70-kg person, but would exceed the reference dose for a 50-kg adult or child (Mariën, 2002). The Agency for Toxic Substances and Disease Research (ATSDR) of the Centers for Disease Control and Prevention established a minimal risk level (MRL) of 0.3 $\mu\text{g/kg/d}$, which would allow three 8-oz meals of fish averaging 0.2 ppm MeHg to be consumed in a week (ATSDR, 1999).

The mean levels of Hg in the three species sampled fall below the criteria presented earlier, suggesting that most human consumers are not at risk from Hg when they consume flatfish from New Jersey coastal waters, although consuming such fish frequently would exceed the various guidelines. Winter flounder had substantially lower levels than the other two species. Further, the variance in Hg levels for all three species was low, and the maximum values did not exceed 0.5 ppm for any individual fish examined. Thus, it is unlikely that a pregnant woman would be unduly exposed by eating meals of these fish over several consecutive weeks. Therefore, these data provide assurance to anglers, to their spouses and children, and to others whom they may provide with flounder from the Jersey shore. This is the first study to examine such a large sample size of fish hypothesized to be low in Hg, and to demonstrate that they are indeed relatively low in Hg, regardless of season or fishing location. Nonetheless, high-end consumers, who eat fish several times per week, would be less at risk selecting winter flounder, or other fish that have Hg levels below 0.1 ppm, than predatory fish that are high on the food chain.

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Fig. 1.
Map showing the sampling locations for flatfish collected in New Jersey 2005 through 2008.

Fig. 2.

Relationship of mercury (ppm, wet weight) and selenium (ppm) in flatfish of New Jersey to fish length. Species presented are fluke or summer flounder (*Paralichthys dentatus*), winter flounder (*Pseudopleuronectes americanus*), and windowpane (*Scophthalmus aquosus*) collected from 2005 through 2008. Shown are means $\pm$ standard error.

Table 1

Size, Selenium, and Total Mercury Levels (ppm wet weight) for All Flatfish Analyzed From New Jersey Anglers and Trawls, 2005 Through 2008 (Kruskal-Wallis Chi Square Test with *p* Values in Parenthesis)

Species	N	Total length (cm) Mean ± SE	Weight (g) Mean ± SE	Selenium (ppm-ww) Mean ± SE	Mercury (ppm-ww) Mean ± SE	Mercury	
						Percent above 0.30 ppm	Percent above 0.50 ppm
Fluke (<i>Paralichthys dentatus</i>)	258	52.0 ± 0.47	1491 ± 49.2	0.35 ± 0.01	0.14 ± 0.01	5	0
Windowpane (<i>Scophthalmus aquosus</i>)	48	28.2 ± 0.34	271 ± 10.2	0.36 ± 0.02	0.18 ± 0.02	15	0
Winter flounder (<i>Pseudopleuronectes americanus</i>)	58	36.2 ± 0.45	643 ± 27.5	0.25 ± 0.01	0.06 ± 0.01	0	0
Chi-squared (<i>p</i>)		201 (<.0001)	223 (<.0001)	28.6 (<.0001)	65.3 (<.0001)		

Table 2

Correlation of Size and Contaminant Levels in Flatfish From New Jersey, 2005 Through 2008, With Kendall Tau Correlations (p Values in Parentheses)

Fluke (<i>n</i> = 258)	mercury	selenium	length	weight
mercury	*****	0.09 (.04)	0.12 (.004)	0.14 (.0009)
selenium	*****	*****	NS	NS
length	*****	*****	*****	0.8 (<.0001)
weight	*****	*****	*****	*****
Windowpane (<i>n</i> = 48)	mercury	selenium	length	weight
mercury	*****	-0.22 (.03)	0.60 (<.0001)	0.4 (.0001)
selenium	*****	*****	-0.26 (.01)	-0.29 (.005)
length	*****	*****	*****	0.70 (<.0001)
weight	*****	*****	*****	*****
Winter flounder (<i>n</i> = 58)	mercury	selenium	length	weight
mercury	*****	NS	NS	NS
selenium	*****	*****	NS	NS
length	*****	*****	*****	0.73 (<.0001)
weight	*****	*****	*****	*****

Table 3

Mean Mercury and Selenium Levels by Season

Species	Year (n)				Selenium (ppm)		Mercury (ppm)		Total length (cm)		Weight (grams)	
	2005	2006	2007	2008	Total by Season	Mean $\pm$ SE	Mean $\pm$ SE	Mean $\pm$ SE	Mean $\pm$ SE	Mean $\pm$ SE	Mean $\pm$ SE	Mean $\pm$ SE
Fluke												
Spring	94	1	20	9	124	0.32 $\pm$ 0.01	0.13 $\pm$ 0.01		52.5 $\pm$ 0.68		1565 $\pm$ 74	
Summer	20	82	11	21	134	0.38 $\pm$ 0.01	0.15 $\pm$ 0.00		51.6 $\pm$ 0.66		1420 $\pm$ 65	
Chi-squared (p)						13.4 (.0002)	1.3 (NS)		0.1 (NS)		3.2 (NS)	
Windowpane												
Summer			30		30	0.38 $\pm$ 0.03	0.16 $\pm$ 0.02		27.4 $\pm$ 0.40		254 $\pm$ 13	
Autumn			18		18	0.32 $\pm$ 0.01	0.21 $\pm$ 0.02		29.4 $\pm$ 0.48		299 $\pm$ 15	
Chi-squared (p)						3.8 (.05)	3.3 (NS)		9.2 (.003)		5.3 (.02)	
Winter flounder												
Spring				30	30	0.26 $\pm$ 0.02	0.05 $\pm$ 0.01		37.6 $\pm$ 0.65		754 $\pm$ 39	
Autumn			28		28	0.25 $\pm$ 0.02	0.06 $\pm$ 0.01		34.7 $\pm$ 0.49		524 $\pm$ 22	
Chi-squared (p)						0.001 (NS)	0.14 (NS)		10.3 (.001)		21.5 (<.0001)	

Note. Spring fish were caught 14 April through 13 June, summer fish were caught 1 July through 15 August, and all autumn fish were caught in October. Analysis by Kruskal–Wallis nonparametric one way analysis of variance. NS = not significant.

Table 4

Mean Mercury and Selenium Levels by Region

Species	n	Selenium (ppm)		Mercury (ppm)		Total length (cm)		Weight (g)	
		Mean ± SE		Mean ± SE		Mean ± SE		Mean ± SE	
Fluke									
North	107	0.34 ± 0.01		0.14 ± 0.01		51 ± 1		1501 ± 72	
Central	42	0.34 ± 0.02		0.11 ± 0.02		56 ± 2		2062 ± 167	
South	109	0.36 ± 0.01		0.15 ± 0.01		52 ± 1		1260 ± 53	
Chi-squared (<i>p</i>)		1.54 (NS)		14.9 (.0006)		10.6 (.005)		17.6 (.0001)	
Windowpane									
Central	16	0.27 ± 0.02		0.22 ± 0.02		30 ± 1		328 ± 9	
South	32	0.40 ± 0.02		0.17 ± 0.02		28 ± 0		243 ± 12	
Chi-squared (<i>p</i>)		12.9 (.0003)		3.9 (.05)		8.9 (.003)		16.9 (<.0001)	

Note. The North region includes fish from Jersey City, Raritan Bay, and Sandy Hook. The Central region includes fish caught between Point Pleasant and Atlantic City, and the South region includes all locations south of Atlantic City. Winter flounder were obtained only in the North region. NS = not significant.

TABLE 5

Models Explaining the Variation in Mercury and Selenium Levels in Flatfish Caught in New Jersey, 2005 Through 2008

Model	Fluke		Winter flounder		Windowpane	
	Mercury	Selenium	Mercury	Selenium	Mercury	Selenium
<i>F</i>	5.22	3.5	1	0.2	15.8	6.0
df	7	7	4	4	6	6
<i>p</i>	<.0001	0.002	NS	NS	<.0001	0.0001
<i>r</i> ²	0.13	0.09	0.07	0.01	0.70	0.47
Factors entering <i>F</i> (<i>p</i>)						
Season	15.1 (.0001)	7.4 (.007)	NS	NS	NS	NS
Location	5.8 (.004)	NS	a.	a.	NS	7.8 (.008)
Length (cm)	NS	NS	NS	NS	5.7 (0.02)	NS
Weight	NS	NS	NS	NS	NS	5.1 (.03)
Length × Weight	NS	NS	NS	NS	NS	4.9 (.03)
Location × Season	15.3 (.0001)	NS	a.	a.	NS	15.5 (0.0003)

Note. NS = not significant. All winter flounder were from the North region.