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Contaminant levels in Herring (*Larus argentatus*) and Great Black-backed Gull (*Larus marinus*) eggs from colonies in the New York harbor complex between 2012 and 2013

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Abstract

Birds living in coastal areas are exposed to severe storms and tidal flooding during the nesting season, but also to contaminants that move up the food chain from the water column and sediment to their prey items. We examine metals in Herring Gull (*Larus argentatus*) and Great Black-backed Gull (*Larus marinus*) eggs collected from the New York/New Jersey harbor estuary in 2012 and in 2013 to determine if there were significant yearly differences in metal levels. We test the null hypothesis that there were no significant yearly differences in metal levels. We investigate whether there were consistent differences in metals from 2012 to 2013 that might suggest a storm-related effect because Superstorm *Sandy* landed in New Jersey in October 2012 with high winds and extensive flooding, and view this research as exploratory. Except for arsenic, there were significant inter-year variations in the mean levels for all colonies combined for Herring Gull, and for lead, mercury and selenium for Great Black-backed Gulls. All metal levels in 2013 were less than in 2012, except for lead. These differences were present for individual colonies as well. Metal levels varied significantly among islands for Herring Gulls in both years (except for cadmium in 2013). No one colony had the highest levels of all metals for Herring Gulls. A long term data set on mercury levels in Herring Gulls indicated that the differences between 2012 and 2013 were greater than usual. Several different factors could account for these differences, and these are discussed.

Keywords

Storm effects; Sediment redistribution; Mercury; Lead; *Larus argentatus*; *Larus marinus*

Introduction

Coastal birds are exposed to a range of environmental stressors during the nesting season, including human disturbance, predators and competitors, severe storms, and tidal flooding. These factors, alone or in combination, can reduce survival and reproduction. Storms and sea level rise are likely to continue (NPCC2 2013). Coastal storms, however, can exert an effect on foraging behavior and success during the breeding season by influencing prey abundance and availability. Storms can include both inland storms that increase run-off and coastal storms that may produce flooding and storm surges. Longer-term effects can occur if nesting habitats are no longer suitable or lead to decreased reproductive success, or contaminant levels are changed in their prey as a secondary effect of changes in prey availability (species, sizes, abundance), in contaminant levels in their prey, or both. Changes in contaminant levels with storms could come about through mobilization and redistribution of contaminants in sediments and the water column, which ultimately leads to changes in contaminants in the food chain. In general, contaminant levels in some organisms are more related to sediment (and sediment pore water) levels than to water column levels (Balls 1985), partly because biomethylation occurs in the sediment (Jernelov 1969). Methylmercury is the form generally found in birds, including eggs.

In this paper we examine the levels of arsenic, cadmium, chromium, lead, mercury and selenium in the eggs of Herring Gulls (*Larus argentatus*) and Great Black-backed Gull (*Larus marinus*) nesting on islands in the New York/New Jersey harbor estuary and associated rivers in 2012 and 2013. We were especially interested in whether there were consistent differences across metals levels for both species and for all colonies combined between the 2 years, whether there were differences among islands, and whether the same islands had the highest levels of most metals. Normally the differences in metals levels among years and colonies are small (Burgess et al. 2013).

While there are several potential hypotheses for significant metal differences between years, this region experienced a severe storm that caused more flooding and damage than any other storm in the region for decades. Superstorm *Sandy* made landfall in the New York/New Jersey (NY/NJ) harbor estuary on 29–31 October 2012; the storm stalled over the region, causing severe storm surges and flooding (BBB 2012; USGS 2013). Over the past several decades, coastal development has continued at a rapid rate, particularly in urban areas such as New York and New Jersey. This build-out has resulted in management of natural beach, dune, and saltmarsh habitats, along with building extensive bulk-heads, piers and boardwalks, marinas, and other coastal developments. The important role and dynamic nature of coastal beaches, dunes, and salt marshes has not been recognized by the public, managers, and planners (Nordstrom and Mitteager 2001; Psuty and Ofiara 2002). Yet, beaches and marshes serve as barriers to damages from the forces of wind, waves, currents, and surges, potentially reducing sediment movement, and ultimately providing resiliency to ecological communities (USGS 2010; Plant et al. 2010). Physical damage to nesting islands, however, was less, as the storm surge washed over some of the nesting islands without resulting in major loss of habitat.

Gulls are excellent bioindicators of environmental change and contaminants because they have been extensively studied in the northeast and elsewhere, temporal and spatial patterns of contaminants are known, and gulls exhibit different trophic patterns (e.g. Thompson et al. 1993; Weseloh et al. 2011; Burgess et al. 2013). Black-backed Gulls are twice as large as Herring Gulls, and can thus eat larger food items, and are more voracious and aggressive predators. Both species are abundant in the NY/NJ harbor estuary. Since they nest on the ground, eggs are easy to collect, and eggs reflect local exposure since they arrive on nesting sites well before egg-laying, foraging in the vicinity of the colonies. Eggs are used as indicators of metal contamination because: (1) females sequester metals in their eggs (Burger and Gochfeld 1996; Lam et al. 2005), (2) the concentrations of metals in eggs represent local exposure (Sanpera et al. 2000; Becker et al. 2002), (3) there is a high correlation between contaminant levels in seabird diets and eggs, and (4) removal of one egg from species with clutches of three does not adversely affect reproductive potential (since gulls rarely raise more than two chicks). Since the order of egg-laying can affect metal levels (Brasso et al. 2010, Akearok et al. 2010), including gulls (Becker 1992). It is thus prudent to collect either the first or last-laid egg. The harbor itself is home to over 4,000 colonial waterbirds of 12 species with nesting colonies on 17 of the harbor's 19 undeveloped islands (Craig 2013).

Materials and methods

Eggs were collected from colonies in the NY/NJ harbor, including South Brother, Mill Rock, Hoffman, Swinburne, and Little Egg (Fig. 1). Contaminated sediments are a problem in the Hudson River and the estuary (USACE and PA NY/NJ 2009), especially mercury. Great Black-backed and Herring Gull eggs were collected in late April through mid-May in 2012 and 2013, under appropriate federal and state permits. Eggs were not always collected from the same colonies in 2012 and 2013 due to colony numbers, shifts in colony sites, logistics, temporal differences in egg-laying (Herring Gulls lay later), and inclement weather. Only one freshly-laid egg, usually the last egg to be laid, was collected from widely-separated locations within each colony. Eggs were labeled with a number, placed in a cooler, immediately taken back to the laboratory, and stored in a refrigerator for immediate analysis. Some eggs were frozen for archival purposes. All procedures were approved by the Rutgers University Animal Protocol Review Board.

All samples were analyzed in the Elemental Laboratory of the Environmental and Occupational Health Sciences Institute of Rutgers University, in Piscataway, New Jersey. In the laboratory, egg contents were emptied into acid-washed weigh boats, weighed, and dried and re-weighed. Whole egg contents were homogenized and digested individually in 70 % nitric acid within microwave vessels for 10 min at 150 pounds per square inch (1–6 kg/sq cm) and subsequently diluted with deionized water.

Mercury was analyzed by cold vapor atomic absorption spectrophotometry and other metals were analyzed by graphite furnace (flameless) atomic absorption. Mercury was analyzed as total mercury; about 90 % is assumed to be methylmercury (Thompson et al. 1991). All concentrations are expressed in nanograms per gram (parts per billion) on a dry weight basis. Instrument detection limits were 0.02 ppb for arsenic and cadmium, 0.08 ppb for

chromium, 0.15 ppb for lead, 0.09 ppm for manganese, 0.02 ppb for mercury, and 0.7 ppm for selenium, but matrix detection limits were an order of magnitude higher. All specimens were run in batches that included a standard calibration curve and spikes specimens. The accepted recoveries on spiked specimens ranged from 90 to 115 %. The CV on replicate samples was always less than 10 %.

Data were analyzed by Kruskal–Wallis to determine differences among metals (SAS 2005), and the Duncan multiple range option (SAS 2005) was used as a post hoc test of the significance of the differences among metals. We also used multiple regression models to examine the dependent factors that contributed to variations in metal levels (SAS 2005). We accept a significance level of 5 %.

Results

Overall, the best models explained 32–58 % of the variation in metals levels by location and year (except for arsenic), species (except for arsenic and lead), and a combination of location $\times$ year (Table 1). Except for cadmium and lead, Great Black-backed Gulls had significantly higher levels than Herring Gulls (Table 2). There was a significant yearly difference in mean metals levels in eggs of Herring Gulls for all metals (except arsenic) and for lead, mercury and selenium for Great Black-backed Gulls (Table 3). For Herring Gulls, cadmium, chromium, mercury and selenium were lower in 2013 compared to 2012, and only lead levels in eggs were higher in 2013. Cadmium levels were 10 $\times$ higher in 2012 than 2013, and all the others were within an order of magnitude of each other. For Great Black-backed gulls, mercury and selenium were lower, and lead was higher in 2013 compared to 2012 (Table 3).

Models explaining variation in metal levels for the two species differed, partly due to smaller sample sizes for Great Black-backed Gull (Table 4): (1) all models for metals were significant for Herring Gull, but only lead and mercury were for Great Black-backed Gull, (2) between 32 and 67 % of the variation was explained by the models for Herring Gull, but only 18 and 34 % were explained for Great Black-backed Gull, and (3) in general, year explained most of the variation (Table 4). All of the variation was explained by year for Great Black-backed Gull.

Colony site comparisons were made only for Herring Gulls because the collection of eggs was more balanced. There were significant variations in metal levels in Herring Gull eggs collected from the different islands (Table 5). Overall, of the 30 possible combinations (number of islands $\times$ number of metals), metal levels decreased for 19 ($X^2 = 12.6$, $P < 0.002$). Thus, the differences between metal levels in 2012 and 2013 for all colonies combined, also occurred for each colony individually.

Discussion

The major findings of this study were: (1) Great Black-backed Gulls had higher levels of arsenic, chromium, mercury and selenium than Herring Gulls, (2) levels of mercury and selenium were lower in 2013, and higher for lead in 2013 for both species, (3) decreases in

metal levels for Herring Gulls were consistent among nesting islands. These data suggest both trophic level and yearly variations.

Metals sequestered in eggs of gulls come from their foods, obtained locally. The crabs, fish and other prey they eat obtained metals through the food chain, and ultimately from bacterial biomethylation in the sediment (Jernelov 1969). There are a number of possible hypotheses for what might account for yearly variations, including exposure differences because of differences in contaminants in their prey, changes in prey use, changes in water flow down the rivers, other weather variables (excess rain during egg formation, wind differences that affected levels in prey), severe storms, and random variation. We reject that these differences were random because they were generally in the same direction, and the differences were greater than usually occurs from year to year (see below). Further it is unlikely due to changes in prey as opportunistic observations indicated the same number of crab shells, fish parts, and garbage at their nests. It may be that the differences were due to differences in prey IF levels in prey were also influenced by variations due to the severe storm. That is, changes in contaminant levels in sediment might well affect levels in bottom-dwelling invertebrates, which are then reflected up the food chain.

Possible explanations for variations in contaminant levels following a severe storm with major storm surge include: (1) mobilization of metals from sediments, with subsequent increase in uptake of contaminants, and bio-accumulation in the food chain, (2) downstream movement (and input from land surfaces) of sediment low in contaminants that buries the sediment in the harbor and adjacent rivers, burying contaminants and making them less available to the food chain, (3) downstream movement (and input from land surfaces) of sediment high in contaminants that overlays the pre-existing sediments, increasing the availability of contaminants to the food chain, and (4) surge-induced scouring of the pre-existing sediments in bays that either uncovers more contaminated sediments (4a), or entirely removes contaminated sediment (4b). All rely on movement of sediment within the system, which clearly occurs in the NY/NJ harbor estuary (Benoff et al. 1999). Further, metal levels could have shifted in their prey because of shifting sediments and changes in levels in sediments. Possibilities 1, 3, and 4a predict an increase in metals following a severe storm, while possibilities 2 and 4b predict a decrease in metals following a severe storm. Although these are speculative, we argue that severe storms can affect metal levels in both prey and higher trophic levels due to shifting sediments. Further, although these observations involve only one severe storm, they suggest avenues for further research. With increasing sea level rise and increases in either the frequency or the severity of storms, there will be more opportunities to examine differential movement of sediment and contaminants in coastal ecosystems.

The major finding of this study was that levels of cadmium, chromium, mercury and selenium in eggs of Herring Gulls were significantly higher in 2012 (pre-Sandy) than in 2013 (post-Sandy), and that this pattern held for individual colonies as well. Similarly, mercury and selenium levels were higher in Great Black-backed Gull eggs in 2012 than in 2013. At first glance, it appears that the data are consistent with either possibility 2 or 4b. That is, storm surge from Sandy either brought down sediments that covered the pre-existing sediments (which had higher levels of contaminants than those coming downstream), or the

pre-existing contaminated sediments in the estuary were washed out to sea. These hypotheses require additional study over a longer time period, and can only be examined concurrently with levels of contaminants in both sediment and prey. We present these hypotheses to encourage future research on weather-related, yearly differences in metal levels, which requires long term data sets.

However, Sandy did not occur in isolation, but followed almost to the year Hurricane Irene that did not have a large storm surge, but did produce heavy rains over the Hudson and Raritan River drainage systems. Major flooding occurred in the streams and rivers throughout the northeast. Streams and rivers overflowed, and carried dirt, silt, trees, debris, personal property, and undoubtedly contaminants down-river via the Hudson River and Raritan Rivers into the NY/NJ harbor estuary system. Such a severe storm, with a heavy sediment load, might have the following effects: (1) contaminants in the harbor would increase if the sediment from upriver had higher levels of metals than currently in the harbor sediments, or (2) contaminants in the harbor would decrease if the sediment from upriver had lower levels of metals than currently in the harbor sediments. In some cases, heavy metal levels are higher upstream in this system (Benoff et al. 1999).

Light can be shed on these hypotheses using a longer time series of metals in Herring Gulls eggs (this series is not available for Great Black-backed Gulls). Levels of mercury in Herring Gull eggs from these same colonies are available from 1989 to 1994 (Burger and Gochfeld 1993, 1995). During this period, mean levels of mercury averaged 190 ± 30 ppb (dry weight) to 520 ± 40 ppb (average for colonies examined). Further, the highest colony mean for Herring Gull eggs was 870 ppb. In 2012, following Hurricane Irene, the overall average mercury for all colonies combined was 707 ppb, and the highest mean for any colony was 1,420 ppb (compared to 870 ppb for 1989–1994). Thus, mercury levels in eggs of Herring Gulls in 2012 appear to have been higher than previously, and then they were in 2013. While only suggestive, it appears that Hurricane Irene may have had the effect of increasing levels of mercury, while Sandy decreased levels. It further suggests that ornithologists should examine long-term metals data sets for possible effects of severe storms.

Cadmium was especially interesting because levels were $10 \times$ lower in 2013 than in 2012 in Herring Gull eggs, but there was no significant difference for Great Black-backed Gulls. This is unusual given that the data are from several colonies, and 99 Herring Gull eggs. Cadmium levels in Herring Gull eggs from 1989 to 1994 from these same colonies had a combined mean of 4.5 to 62.2 ppb (Burger and Gochfeld 1995), compared to 5.3 ppb in 2012 and 0.5 ppb in 2013. Cadmium has clearly declined over the years, both in Herring Gull eggs in this study, and generally in the environment (Boutron et al. 1991). However, the data for every year from 1989 to 1994 were within the same order of magnitude, and did not change by a factor of 10. This bears further examination in the future.

The only metal that increased significantly in Gull eggs from 2012 to 2013 was lead. We might suggest that lead, which is ubiquitous in soil from legacy lead in gasoline and paint (Schwartz 1994), might have been washed off the urban and suburban environments during Sandy into the estuary, where it was available for bioaccumulation up the food chain.

Further, lead has generally been decreasing in the environment, particularly in colonial waterbird eggs in this region (Burger and Gochfeld 2004).

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Fig. 1.
Map of the New York/New Jersey harbor estuary study area, with the colony locations

Table 1

Models explaining variations contaminant levels in Gull eggs collected in 2012 and 2013 from the New York/New Jersey harbor estuary

Model	Arsenic	Cadmium	Chromium	Lead	Mercury	Selenium
F	9.1	8.0	11.2	5.3	15.8	11.9
df	10	10	10	10	10	10
P	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
r ²	0.44	0.42	0.51	0.32	0.58	0.51
Factors entering						
F (p)						
Species	1.9 (NS)	7.0 (0.009)	14.2 (0.0003)	0.6 (NS)	12.3 (0.0006)	20.2 (<0.0001)
Location	3.8 (0.007)	2.9 (0.03)	5.7 (0.0003)	3.2 (0.02)	5.1 (0.0009)	4.9 (0.001)
Year	3.2 (0.08)	63.2 (<0.0001)	67.9 (<0.0001)	24.3 (<0.0001)	73.5 (<0.0001)	58.3 (<0.0001)
Location × (year)	15.0 (<0.0001)	2.3 (0.06)	3.8 (0.006)	2.0 (NS)	8.2 (<0.0001)	3.9 (0.005)

Metals data was log transformed for normality
NS not significant

Table 2

Concentrations of metals in Gull eggs overall

	Herring Gull	Great Black backed gull	χ^2
Number	99	25	
Arsenic	53.5 $\pm$ 7.5	125 $\pm$ 21.6	16.4 (<0.0001)
Cadmium	2.9 $\pm$ 0.4	3.8 $\pm$ 1.0	0.1 (NS)
Chromium	49.7 $\pm$ 7.4	78.3 $\pm$ 17.2	5.4 (0.02)
Lead	192 $\pm$ 28.1	173 $\pm$ 37.8	0.2 (NS)
Mercury	465 $\pm$ 50.9	743 $\pm$ 99.1	11.3 (0.0008)
Selenium	1,570 $\pm$ 47.0	1,996 $\pm$ 67.7	18.1 (<0.0001)

Given are mean $\pm$ SE. Comparisons are made with Kruskal–Wallis one-way analysis of variance, yielding a χ^2 statistic
 All values are in ng/g (ppb dry weight.)
 NS not significant

Table 3

Concentrations of metals in Gull eggs by year

Herring Gull	2012	2013	χ^2
Number	49	50	
Arsenic	57.4 ± 13.4	49.7 ± 7.3	0.7 (NS)
Cadmium	5.3 ± 0.7	0.5 ± 0.1	44.1 (<0.0001)
Chromium	85.2 ± 12.8	16.4 ± 3.7	47.9 (<0.0001)
Lead	138 ± 43.8	244 ± 34.0	17.6 (<0.0001)
Mercury	706 ± 83.5	229 ± 35.8	32.8 (<0.0001)
Selenium	1822 ± 63.0	1323 ± 49.1	30.2 (<0.0001)
Great Black backed gull	2012	2013	χ^2
Number	11	14	
Arsenic	159 ± 42.8	98.2 ± 17.6	1.5 (NS)
Cadmium	4.51 ± 1.7	3.16 ± 1.1	0.9 (NS)
Chromium	55.3 ± 16.0	96.3 ± 27.7	1.0 (NS)
Lead	62.7 ± 22.5	260 ± 55.6	10.3 (0.001)
Mercury	1049 ± 172	504 ± 66.2	10.1 (0.002)
Selenium	2164 ± 112	1864 ± 66.8	3.7 (0.05)

Given are mean ± SE. Comparisons are made with Kruskal–Wallis one-way analysis of variance, yielding a χ^2 statistic
 All values are in ng/g (ppb dry weight.)

NS not significant

Table 4

Models explaining variations in contaminant levels in Gull eggs collected in 2012 and 2013 from the New York/New Jersey harbor estuary

Herring Gull	Arsenic	Cadmium	Chromium	Lead	Mercury	Selenium
Model						
F	7.0	11.5	19.6	4.6	14.1	8.9
df	9	9	9	9	9	9
P	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
r ²	0.42	0.54	0.67	0.32	0.59	0.47
Factors entering						
F (p)						
Location	2.9 (0.03)	2.9 (0.03)	11.2 (<0.0001)	2.9 (0.03)	5.7 (0.0004)	4.6 (0.002)
Year	NS	83.7 (<0.0001)	117 (<0.0001)	22.7 (<0.0001)	73.6 (<0.0001)	47.7 (<0.0001)
Location × (year)	12.0 (<0.0001)	NS	3.3 (0.01)	NS	7.9 (<0.0001)	3.4 (0.01)
Great Black backed gull						
Model						
F	0.3	0.6	0.3	5.9	6.6	2.5
df	2	2	2	2	2	2
P	NS	NS	NS	0.009	0.01	NS
r ²	0.02	0.05	0.03	0.35	0.34	0.18
Factors entering						
F (p)						
Location	NS	NS	NS	NS	NS	NS
Year	NS	NS	NS	11.7 (0.003)	11.2 (0.003)	5.0 (0.04)
Location × (year)	NS	NS	NS	NS	NS	NS

Metals data was log transformed for normality

NS not significant

Table 5

Concentrations of metals in Herring Gull eggs collected in 2012 and 2013 from New York

Location	2012 Mean $\pm$ SE	2013 Mean $\pm$ SE	χ^2	Increase/decrease/no change
South Brother				
Arsenic	81.1 $\pm$ 17.3	0.2 $\pm$ 0.0	13.2 (0.0003)	Decrease
Cadmium	3.8 $\pm$ 1.3	0.7 $\pm$ 0.3	3.0 (0.08)	No change
Chromium	67.4 $\pm$ 15.3	15.4 $\pm$ 4.1	9.1 (0.003)	Decrease
Lead	50 $\pm$ 39.0	225 $\pm$ 92.6	5.1 (0.02)	Increase
Mercury	794 $\pm$ 74.9	364 $\pm$ 149	5.6 (0.02)	Decrease
Selenium	1742 $\pm$ 132	1377 $\pm$ 134	4.1 (0.04)	Decrease
Mill Rock				
Arsenic	20.7 $\pm$ 12.0	56.3 $\pm$ 14.6	3.7 (0.06)	No change
Cadmium	5.5 $\pm$ 1.9	0.3 $\pm$ 0.3	8.9 (0.003)	Decrease
Chromium	113 $\pm$ 35.7	5.4 $\pm$ 1.4	14.3 (0.0002)	Decrease
Lead	40.3 $\pm$ 23.9	451 $\pm$ 95.4	12.7 (0.0004)	Increase
Mercury	1420 $\pm$ 236	218 $\pm$ 62.8	14.3 (0.0002)	Decrease
Selenium	2360 $\pm$ 124	1374 $\pm$ 130	12.7 (0.0004)	Decrease
Hoffman				
Arsenic	143 $\pm$ 50.1	57.4 $\pm$ 18.4	NS	No change
Cadmium	7.3 $\pm$ 1.6	0.4 $\pm$ 0.4	13.2 (0.0003)	Decrease
Chromium	95.6 $\pm$ 34.9	40.5 $\pm$ 15.4	4.0 (0.05)	Decrease
Lead	162 $\pm$ 57.5	244 $\pm$ 62.1	NS	No change
Mercury	474 $\pm$ 80.7	140 $\pm$ 18.6	11.1 (0.0009)	Decrease
Selenium	1720 $\pm$ 97.5	1257 $\pm$ 85.6	7.0 (0.008)	Decrease
Swinburne				
Arsenic	20.0 $\pm$ 13.3	60.6 $\pm$ 15.1	4.4 (0.04)	Increase
Cadmium	2.1 $\pm$ 0.6	0.0 $\pm$ 0.0	9.6 (0.002)	Decrease
Chromium	26.0 $\pm$ 4.3	5.1 $\pm$ 1.9	11.1 (0.0009)	Decrease
Lead	245 $\pm$ 152	236 $\pm$ 36.8	4.2 (0.04)	Decrease
Mercury	237 $\pm$ 38.6	299 $\pm$ 59.9	NS	No change
Selenium	1630 $\pm$ 84.4	1540 $\pm$ 71.8	NS	No change
Litte Egg				
Arsenic	24.2 $\pm$ 16.7	74.1 $\pm$ 17.1	5.7 (0.02)	Increase
Cadmium	7.8 $\pm$ 1.6	0.8 $\pm$ 0.4	12.6 (0.0004)	Decrease
Chromium	122 $\pm$ 24.6	15.6 $\pm$ 3.4	12.9 (0.0003)	Decrease
Lead	186 $\pm$ 136.1	66.1 $\pm$ 17.7	NS	No change
Mercury	615 $\pm$ 159.1	124 $\pm$ 15.0	9.1 (0.003)	Decrease
Selenium	1652 $\pm$ 128.0	1068 $\pm$ 69.6	8.8 (0.003)	Decrease

Given are mean $\pm$ SE. Comparisons are made with Kruskal–Wallis one-way analysis of variance, yielding an χ^2 statistic. All values are in ng/g (ppb dry weight.)

NS not significant