Influence of Diet on Selenium Contamination in Recovered Fish Populations in Belews Lake, North Carolina

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Abstract: Food of bluegills *(Lepomis macrochirus),* redear sunfish *(L. microlophus),* and largemouth bass *(Micropterus salmoides)* from Belews Lake was examined during their recovery from selenium (Se) contamination to evaluate the influence of diet on the continued bioaccumulation of Se in their skeletal muscle tissue. The redear sunfish and largemouth bass consumed food items that originated primarily from Belews Lake while bluegills consumed mostly terrestrial insects. Food items originating from the lake generally exhibited higher concentrations of Se and resulted in higher concentrations of Se in the skeletal muscle tissue of the redear sunfish and largemouth bass when compared to bluegills.

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Selenium contamination of aquatic ecosystems and its devastating impact on fish populations are well known (e.g., Cumbie and Van Horn 1978, Garrett and Inman 1984, Gillespie and Baumann 1986, Crane et al. 1992, Lemly 1993, and Saiki and Ogle 1995). However, there are natural processes present in most aquatic ecosystems that can result in nearly 90% of the aqueous Se being deposited in the sediments after waterborne inputs are eliminated (Lemly and Smith 1987, Lemly 1997*a*). This reduction in Se provides fish populations in contaminated ecosystems with an opportunity for recovery (Barwick and Harrell 1997). But, aquatic ecosystems rarely recover completely from Se contamination and subtle reminders of contamination often remain (Lemly 1997*b*).

Following recovery of fish populations in Belews Lake, Se concentrations in some fish taxa remained elevated while concentrations in other taxa had declined considerably (Duke Power Co. unpubl. data). In 1995, redear sunfish continued to exhibit skeletal muscle Se concentrations (>5 μg/g) that exceeded that noted in the fish consumption advisory established for this lake by the North Carolina Department of

Environment, Health, and Natural Resources, while Se concentrations in bluegills were <3.0 μg/g. We hypothesized that elevated Se concentrations in redear sunfish were related to their dietary exposure resulting from their propensity to feed on snails and clams which may be mobilizing Se from the sediments of this reservoir. The objective of this study was to evaluate the influence of diet on the bioaccumulation of Se in skeletal muscle tissue of bluegills, redear sunfish, and largemouth bass in Belews Lake.

Methods

Belews Lake, a 1,560-ha Duke Power Company reservoir located in north central North Carolina, was contaminated in 1975–1985 when water containing up to 224 μg/liter of Se was discharged into this cooling reservoir from the ash basin at the 2,240-MW Belews Creek Steam Station (Duke Power Co. unpubl. data). This resulted in an increase in the incidence of developmental abnormalities in fish (Lemly 1993, 1997*b*) and a significant decline in fish diversity and biomass (Cumbie and Van Horn 1978). Inputs of Se into Belews Lake were eliminated in 1985 and by late 1986 concentrations of soluble Se in Belews Lake were <1 μg/liter (Duke Power Co. 1996). However, Se concentrations in the sediments of Belews Lake remained elevated (Duke Power Co. 1996, Lemly 1997*b*).

To evaluate the influence of diet on the continued bioaccumulation of Se in fish, we selected 3 fish taxa with different feeding strategies for study. Bluegills, redear sunfish, and largemouth bass were electrofished for diet analyses from areas of Belews Lake that historically received the highest Se burden. Generally, 10 fish of each species were collected in May, July, and October 1997 (Table 1) and placed on ice until their stomachs could be removed and preserved in 70% isopropyl alcohol. The stomach contents of all fish were microscopically examined. All food items were identified and enumerated, and percent composition by number calculated for all major food items consumed by these fish. Concentrations of Se in fish tissue and invertebrates reported in this study were obtained from ongoing studies that utilized neutron activation analysis conducted by personnel in the Department of Nuclear Engineering, North Carolina State University, as described by Finley (1985) and Barwick and Harrell (1997). All Se concentrations reported are for wet weights.

Table 1. Numbers, mean total length (mm), and range in lengths for fish collected from Belews Lake.

	Bluegill			Redear Sunfish			Largemouth Bass		
Month	*N*	Mean	Range	*N*	Mean	Range	*N*	Mean	Range
May	10	152	136–193	9	137	103–212	10	317	252–443
Jul	10	159	145–194	10	173	155–208	10	325	281–371
Oct	10	166	152–184	10	170	136–235	10	319	246–370

Results and Discussion

Diets of bluegills, redear sunfish, and largemouth bass varied during this study (Table 2). Bluegills consumed primarily zooplankton and midges (larvae) in May and terrestrial insects (mostly winged ants) in July and October. The diet of redear sunfish consisted mostly of midges (larvae) in May and some snails and small clams *(Corbicula fluminea).* In July and October, redear sunfish consumed mostly clams along with some midges (mostly larvae) and terrestrial insects. Largemouth bass consumed mostly fish during the study. Crayfish and dragonfly nymphs were the only other food items found in their stomachs. Threadfin shad *(Dorosoma petenense)* composed mostly of the largemouth bass diet, followed by redbreast sunfish *(L. auritus),* bluegill, and catfish *(Ameiurus* spp. and *Ictalurus punctatus).*

Overall, redear sunfish and largemouth bass consumed items originating from Belews Lake, while bluegills consumed mostly terrestrial insects. Redear sunfish consumed mostly midges and clams that in 1997 had mean whole-body Se concentrations of 2.8 and 1.8 µg/g, respectively (Table 3). Thus, it seems entirely possible that the midges and clams eaten by the redear sunfish were mobilizing Se from the sediments of this reservoir. Malloy et al. (1999) reported that Se concentrations were consistently

Table 2. Percentage composition (by number) of food items in the diet of fish collected from Belews Lake.

Month	Food item	Bluegill	Redear Sunfish	Largemouth Bass
May	Zooplankton	36		
	Mayflies	1	<1	
	Dragonflies		<1	
	Aquatic bugs	<1		
	Caddisflies	1	4	
	Aquatic beetles	<1		
	Midges	61	72	
	Snails	<1	8	
	Clams		15	
	Terrestrial insects		<1	
	Fish			100
Jul	Crayfish			17
	Mayflies	<1	1	
	Dragonflies	<1	<1	33
	Aquatic bugs	<1		
	Caddisflies	<1	1	
	Midges	8	14	
	Clams		71	
	Terrestrial insects	91	12	
	Fish			50
Oct	Mayflies	<1	<1	
	Dragonflies		<1	
	Aquatic bugs	<1		
	Midges	<1	4	
	Snails		<1	
	Claims		73	
	Terrestrial insects	99	22	
	Fish			100

Table 3. Mean selenium concentrations (μg/g wet weight) in food items consumed by bluegill, redear sunfish, and largemouth bass collected from Belews Lake (Duke Power Co. unpubl. data).

Food Item	Year	Selenium	Range
Plankton	1997	1.5	0.7–3.4
Larval midges	1997	2.8	0.8–7.0
Clams	1997	1.8	0.8–3.5
Winged ants	1997	0.9	0.7–1.1
Threadfin shad	1993	0.4	
Redbreast sunfish	1994	2.4	
Bluegill	1995	2.1	1.3–2.9
Catfish	1996	1.9	0.8–2.9

higher in midge larvae of the family Chironomidae (Order: Diptera) than in any other aquatic invertebrate taxon sampled in Se contaminated Benton Lake (Montana).

Largemouth bass consumed mostly threadfin shad that in 1993 (most recent data available for this species) had a mean whole-body Se concentrations of 0.4 μg/g (Table 3). However, largemouth bass also consumed redbreast sunfish, bluegills, and catfish that had somewhat higher levels of Se in their skeletal muscle (Table 3). Although largemouth bass did not consume large numbers of benthic invertebrates, both redear sunfish and largemouth bass were consuming prey with Se levels that were higher than that of the winged ants that composed most of the annual diet of bluegills. Consequently, redear sunfish and largemouth bass were bioaccumulating more Se from their diets than were bluegills. The limited bioaccumulation of Se by bluegills apparently resulted from their consumption of zooplankton and midge larvae in the spring. Mean Se concentrations in bluegills and largemouth bass from contaminated areas of Belews Lake were 2.1 and 3.5 μg/g, respectively, in 1996 (the last year that Se concentrations were measured in bluegills and largemouth bass) and 4.4 μg/g for redear sunfish in 1997 (Duke Power Co. unpubl. data). All 3 fish taxa from Belews Lake exhibited somewhat elevated skeletal muscle Se concentrations when compared to normal concentrations (0.2–0.6 μg/g) reported by Sorensen (1991).

Management Implications

A major concern regarding mobilization of Se from sediments into the food chain is its continued bioaccumulation in fish in Belews Lake. If sufficient Se were bioaccumulated, then affected taxa could be subjected to significant long-term effects of Se and this could alter the structure of the fish community in this lake. While all 3 fish taxa in this study were apparently bioaccumulating some Se, it did not appear to have had an overall detrimental impact on their populations. Lemly (1997*b*) did report some teratogenic deformities in larval fish in Belews Lake during 1996 that may have been related to Se, but mean concentrations of Se in fish muscle tissue from Belews lake in 1998 remained <5 μg/g (Duke Power Co. unpubl. data). Therefore, the

concern that some fish taxa might continue to bioaccumulate toxic levels of Se from the sediments through the food chain was apparently unfounded. A possible reason for the lack of toxic Se concentrations in fish from Belews Lake might be related to sediment focusing (Davis and Ford 1982) where sediment (containing Se) is naturally transported from shallow-water areas of high biological productivity to deep-water areas of low productivity. Presently, the highest concentrations of Se (26.4–31.6 µg/g) in Belews Lake are consistently found in sediments from deep (>14 m) water (Duke Power Co. 1996). As more Se-containing sediment is moved to deeper areas of Belews Lake, Se concentrations in fish taxa should continue to decline and fish recruitment should remain adequate to support fish populations that are expected for the trophic status of this reservoir.

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