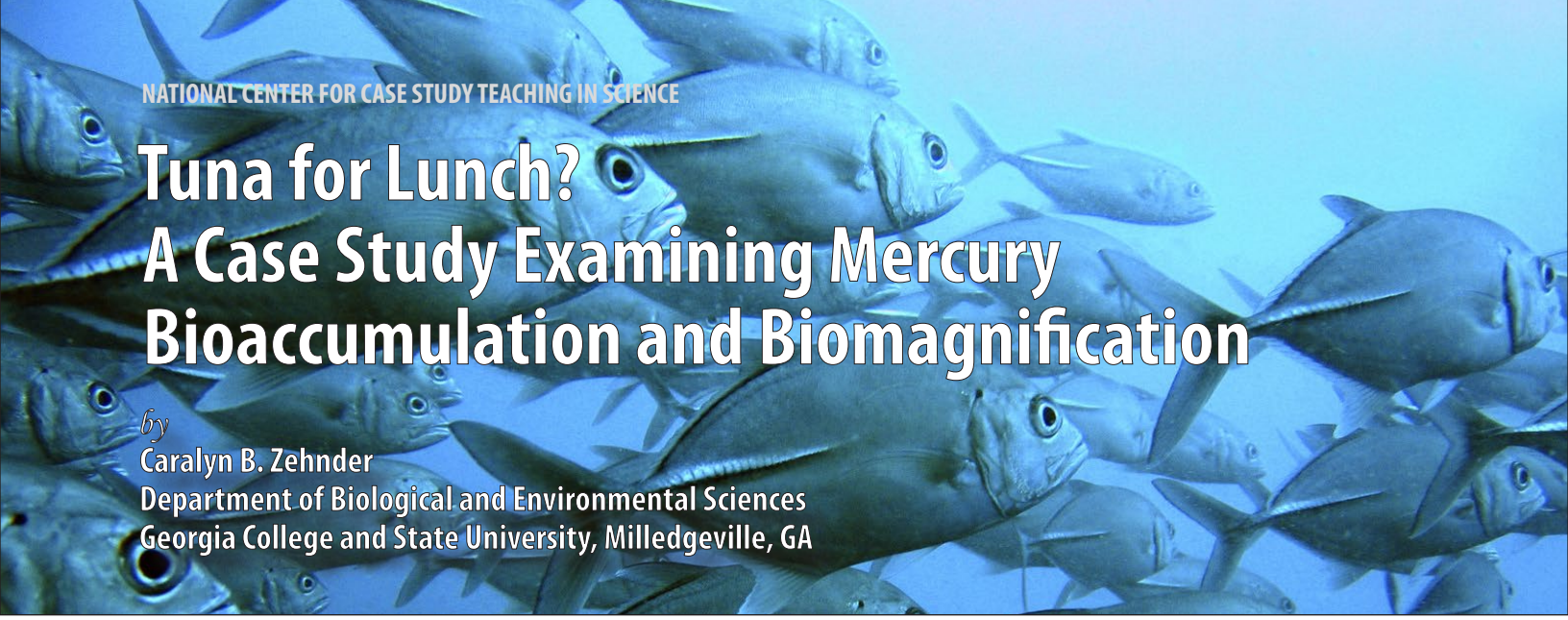

NATIONAL CENTER FOR CASE STUDY TEACHING IN SCIENCE

Tuna for Lunch? A Case Study Examining Mercury Bioaccumulation and Biomagnification

by
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Part I – The Problem

Amanda and Tara had been friends since the eighth grade. They kept in touch through college and Tara was Amanda's maid-of-honor at her wedding. Now with careers and hectic schedules, they didn't get to see each other as often as they would like but they still tried to get together every so often. This afternoon was one of those lucky occasions when they were meeting for lunch at The Garden, a restaurant they regularly visited.

Amanda was sitting at a table near the window when Tara walked into the restaurant. Amanda jumped up and the two friends hugged.

"How have you been? You look great!" Tara exclaimed to her friend.

"I'm well. How are you?"

"I'm fine. Why are you grinning like that? What secret are you hiding?" said Tara as the two friends sat down.

"I wanted to wait to tell you in person—I'm pregnant!"

"Congratulations, Amanda! You and Chad must be so excited. When are you due? Do you have morning sickness? Do you know if it's a boy or girl? What about names?

Just then their waitress came over and asked them if they were ready to order.

"I'll have what I always have," said Tara. "Pan-seared tuna with lime pepper crust and a garden salad, please."

"That sounds great," said Amanda. "But I don't think I am going to order tuna like I usually do. My doctor said that I shouldn't eat certain types of fish more than once or twice per week and I think tuna is one of those fish. I'll have the Fettuccini Alfredo instead."

The waitress wrote down their orders and walked away.

"I knew I would have to cut back on coffee and not drink alcohol because of the baby, but I didn't know about this fish restriction," said Amanda. "I'm not sure why I can regularly eat some fish but not others. I thought fish was healthy and good for you. You have a degree in biology; do you know why my doctor doesn't want me to eat tuna?"

"I'm not sure," said Tara. "It's been a few years since my last biology class, but I'll try to track down some information about fish and pregnancy and see what I can find."

Part II – Why Would Some Fish Be Restricted?

That evening, Tara decided to do a little online investigation for her friend. She Googled "pregnancy" and "fish restriction" and came up with a list of articles, blogs, and websites. She scrolled through the list and settled on the following website from the U.S. Food and Drug Administration.

2004 EPA and FDA Advice for: Women Who Might Become Pregnant, Women Who are Pregnant, Nursing Mothers, Young Children

Fish and shellfish are an important part of a healthy diet. Fish and shellfish contain high-quality protein and other essential nutrients, are low in saturated fat, and contain omega-3 fatty acids. A well-balanced diet that includes a variety of fish and shellfish can contribute to heart health and children's proper growth and development. So, women and young children in particular should include fish or shellfish in their diets due to the many nutritional benefits.

However, nearly all fish and shellfish contain traces of mercury. For most people, the risk from mercury by eating fish and shellfish is not a health concern. Yet, some fish and shellfish contain higher levels of mercury that may harm an unborn baby or young child's developing nervous system. The risks from mercury in fish and shellfish depend on the amount of fish and shellfish eaten and the levels of mercury in the fish and shellfish. Therefore, the Food and Drug Administration (FDA) and the Environmental Protection Agency (EPA) are advising women who may become pregnant, pregnant women, nursing mothers, and young children to avoid some types of fish and eat fish and shellfish that are lower in mercury.

By following these 3 recommendations for selecting and eating fish or shellfish, women and young children will receive the benefits of eating fish and shellfish and be confident that they have reduced their exposure to the harmful effects of mercury.

1. Do not eat Shark, Swordfish, King Mackerel, or Tilefish because they contain high levels of mercury.
2. Eat up to 12 ounces (2 average meals) a week of a variety of fish and shellfish that are lower in mercury.
   - Five of the most commonly eaten fish that are low in mercury are shrimp, canned light tuna, salmon, pollock, and catfish.
   - Another commonly eaten fish, albacore ("white") tuna has more mercury than canned light tuna. So, when choosing your two meals of fish and shellfish, you may eat up to 6 ounces (one average meal) of albacore tuna per week.
3. Check local advisories about the safety of fish caught by family and friends in your local lakes, rivers, and coastal areas. If no advice is available, eat up to 6 ounces (one average meal) per week of fish you catch from local waters, but don't consume any other fish during that week.

Questions

1. What is in some fish and shellfish that has caused the EPA and FDA to issue the restriction?
2. Why is there a restriction for pregnant women and young children, but not the rest of the population?
3. Do pregnant women have to avoid all fish? Explain your answer.
4. Should Amanda have avoided the pan-seared tuna for lunch?

Part III – How Does Mercury Get into Fish?

Tara decided to share this information with her friend. She picked up her cell phone and texted Amanda: "Some fish have mercury in them which is bad for your baby. I'm emailing you a brochure." A few minutes later she had a new message from Amanda: "How does mercury get into fish and why are some fish high in mercury and others low?"

Since these questions were a little more complicated, Tara decided to e-mail her friend Michelle, who was a scientist working for EPA. The next day there was a reply from Michelle in her inbox.

From: Michelle Lapensa [mlapensa44@epa.gov]
To: Tara Trepanski [ttfortwo@hotmail.com]
CC:
Subject: re: question for you about mercury
Attachments:

Hi Tara,

Mercury can be highly toxic – it can cause nerve damage in young children and developing fetuses, which is why your friend's doctor recommended that she limit her fish intake. The fetus's developing nervous system is more vulnerable to mercury than an adult nervous system. Mercury is a naturally occurring element, and volcanoes and rock weathering can introduce mercury into the environment. However, human activities have been increasing mercury concentrations globally. Coal-burning power plants are the most common source of mercury pollution. Coal is naturally contaminated with mercury and, when it is burned, the mercury simply goes up the smokestack and into the air. Then the mercury is deposited in rain (wet deposition) or it falls from the sky (dry deposition) onto the ground and, more importantly, in water. I've attached a map showing mercury wet deposition across the U.S. Aquatic bacteria convert inorganic mercury (Hg) to the organic form methylmercury (MeHg), which is highly toxic. So it's the methylmercury in fish that is of concern. The U.S. Geological Survey recently completed a mercury survey of freshwater environments and I've attached a summary of their report.

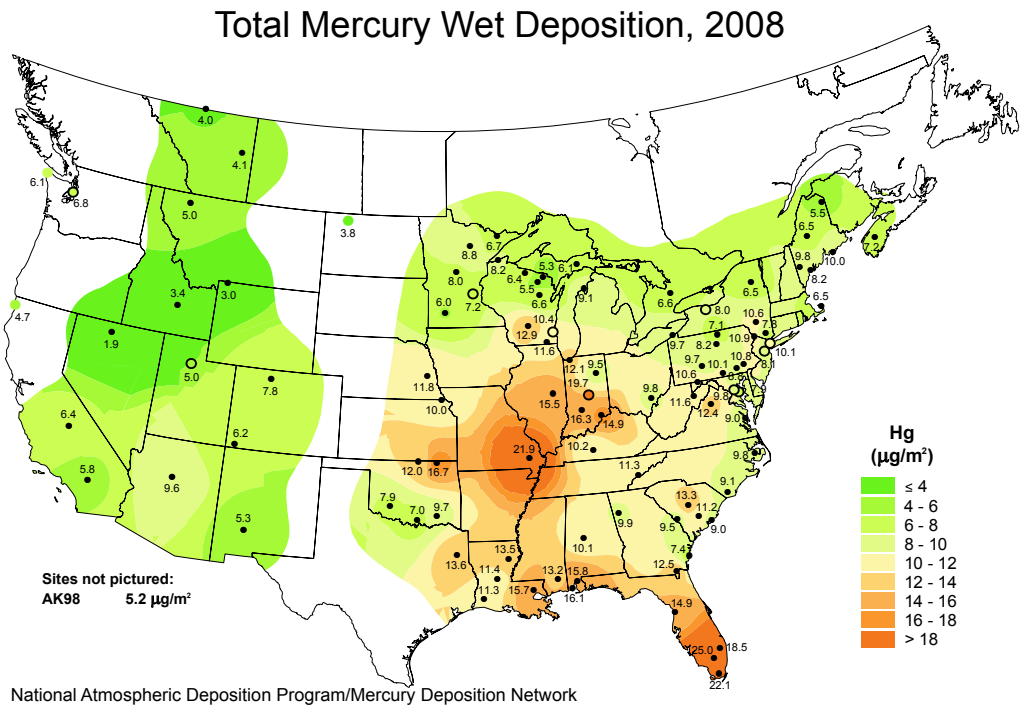
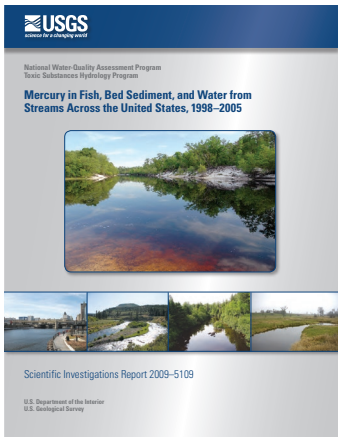


Figure 1: Mercury deposition map. Colors indicate mercury deposition levels (green = lowest and orange = highest). Points indicate monitoring stations. White areas were not monitored.

Below are the data from a 2009 USGS report, *Mercury in fish, bed sediment, and water from streams across the United States*. The objectives of this report were to describe the nationwide occurrence and distribution of mercury in fish tissue and evaluate mercury in streambed (bed) sediment and stream water.



Methods

- Fish: 291 fish from streams nationwide. Largemouth bass were targeted for collection, but 34 different fish species were collected. Fish were caught by electrofishing, rod & reel, and gill nets. Fish fillets were analyzed for mercury.
- Sediment: A plastic scoop was used to remove the upper 2 to 4 cm of bed sediment from 5 to 10 depositional areas; samples were composited into a single sample for each site. Each sample was homogenized and mercury levels were measured.
- Stream-water samples were collected by dipping Teflon® or PETG (Nalgene) bottles in the center of streamflow by use of trace-metal clean techniques. Samples were analyzed for mercury.

Figure 2: Mercury concentrations (ug/g) found in fish tissues of commonly sampled fish species. Bars are means + one standard error. Fish were sampled from 291 locations around the U.S.

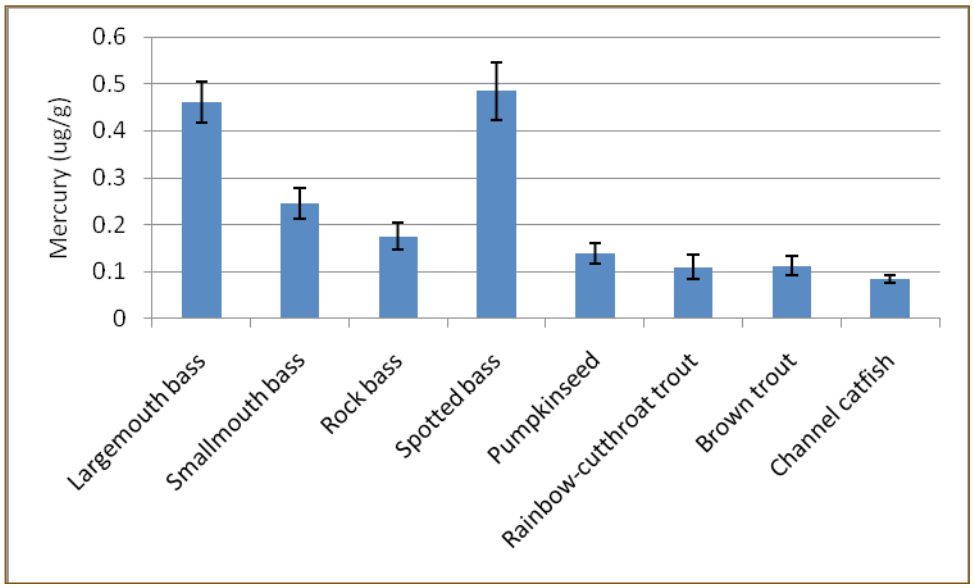


Table 1: Conversion factors.		
Mass Units	*is equal to*	*Factor*
Kilogram (kg)	1000 grams	103
Milligram (mg)	0.001 grams	10-3
Microgram (ug)	0.000001 grams	10-6
Nanogram (ng)	0.000000001 grams	10-9

Table 2: Mean, median, standard deviation (Std Dev), minimum values and maximum values from fish tissue, sediment samples and water samples analyzed for methylmercury. n = the number of total samples collected.

	Mean	*Median*	*Std Dev*	*Minimum*	*Maximum*	*n*	*Units*
Fish	0.261	0.169	0.278	0.014	1.95	291	ug/g
Sediment	1.65	0.51	2.54	0.01	15.6	344	ng/g
Water	0.19	0.11	0.35	<0.010	4.11	337	ng/L

Questions

1. What human actions lead to increased mercury levels in the environment?
2. How does the mercury end up in fish? Draw a flow chart following the mercury path.
3. Where in the United States are mercury wet deposition levels highest? What do you think explains this pattern?
4. The EPA criterion for human health is 0.3 ug/g. Which fish species have average mercury concentrations that exceed the EPA limits?
5. The concern level for piscivorous (fish-eating) mammals is 0.1 Hg ug/g. Which fish species have average mercury concentrations that exceed this limit? Why is the mercury level for piscivorous mammals lower than the level for human health?
6. Should you be concerned about mercury toxicity if you catch and eat a largemouth bass in a local lake? Why or why not?
7. In which samples were mercury concentrations the highest (fish, streams, or sediment)? Why do you think this is?

Part IV – Mercury in Aquatic Food Chains

Tara spent the next evening looking over the information that Michelle had sent her. She was getting ready to send Amanda a follow-up e-mail when she received another message from Michelle.

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From:       Michelle Lapensa [mlapensa44@epa.gov]
To:         Tara Trepanski [ttfortwo@hotmail.com]
CC:
Subject:  re: question for you about mercury
Attachments:

Hi Tara,

I've been thinking about the questions you asked last night and I realized that I
didn't help you much with the second part of your questions. I've included a table
from a recent paper about the relationship between trophic position (where an animal is
along the food chain) and mercury in the food web of Lake Washington. For this paper,
the scientists collected fish, crustaceans, and zooplankton and measured methylmercury
levels in these organisms.

Hope this helps!

Cheers,

Michelle
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Table 3: Animal species, feeding preference, and methylmercury concentrations of organisms collected from Lake Washington.

	Species	*Food*	*Methylmercury (ug/kg)*
Fish	Northern pikeminnow	Other fish	413 ± 45
	Cutthroat trout	Other fish	194 ± 32
	Smallmouth bass	Other fish	261 ± 13
	Juvenile sockeye	Zooplankton and arthropods	46 ± 2
	Stickleback	Zooplankton and arthropods	39 ± 1.3
*Arthropods**	Mysids (small shrimp)	Phytoplankton	15 ± 2
	Signal crayfish	Phytoplankton	23 ± 4
	Caddisfly larvae	Phytoplankton	6 ± 0.6
Zooplankton	Bulk zooplankton	Phytoplankton	4 ± 0.4

*Arthropods are organisms with segmented bodies, hard exoskeletons, and multiple pairs of jointed legs. Aquatic examples include shrimp, crayfish, crabs, and insect larvae including caddisflies.

Questions

1. Draw a food web for Lake Washington using the species and food preferences given in Table 3. Start with phytoplankton (algae) as the base of your web and then build up the food chain.

2. Label the species in your food chain as either high (>100 ug/kg), medium (20-100 ug/kg), or low (below20 ug/kg) mercury concentrations. Which types of animals have the highest levels of mercury? Which types of animals have the lowest? Why do you think this is?

Final Activity

1. Imagine you are Tara. Write an email to your friend Amanda explaining what you have learned about mercury. Be sure to convey the aspects of your learning that will be most useful to Amanda.
2. Find two other examples of compounds that biomagnify. Explain how each compound and/or toxin enters the biosphere and what impacts it has on living organisms in general and humans in particular.
3. Distinguish between bioaccumulation and biomagnification and design a mnemonic device for the distinction.

References / Resources

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Image credits: Photo of tuna in title block ©Tommy Schultz | Fotolia.com. Figure 1 courtesy of National Atmospheric Deposition Program, (NRSP-3). 2007. NADP Program Office, Illinois State Water Survey, 2204 Griffith Dr., Champaign, IL 61820. http://nadp.sws.uiuc.edu/maps/Default.aspx. Figure 2 by author based on data from B.C. Scudder et al., 2009, *Mercury in fish, bed sediment, and water from streams across the United States, 1998–2005*, U.S. Geological Survey Scientific Investigations Report 2009-5109.