Exposure to Toxic Algal Blooms: The vulnerability of Martin County's subsistence fishing communities

Ocean Research and Conservation Association (ORCA)

Background and Research Focus

An excess of nutrients introduced into freshwater ecosystems has resulted in blooms of cyanobacteria, also referred to as blue-green algae, across the state of Florida. Some species of cyanobacteria produce toxins (cyanotoxins) that can damage the nervous system (neurotoxins) or the liver (hepatotoxins). Routes of exposure to cyanotoxins include skin contact, inhalation, and ingestion. Microcystin, a hepatotoxin, is the most toxic form produced by cyanobacteria and the most common. Our research is focused on how – and to what extent – microcystin form our local waters is impacting the health of humans and animals.

The World Health Organization (WHO) has set a provisional total daily intake (TDI) for chronic microcystin exposure (40 ng/kg of body weight) and set acceptable drinking water levels (less than 1 μg/L). Several studies have demonstrated the accumulation of microcystin and other cyanotoxins in species of plants, bivalves, crustaceans, and fish destined for human consumption (Poste et al. 2011; Gutiérrez-Praena et al. 2013; Gurbuz et al. 2016). Given these findings, a case has been made for including fish consumption in estimates of microcystin exposure. However, the inclusion of fish consumption standards alone is not enough. In the case of several other pollutants, fish consumption standards have underestimated the risk of some vulnerable communities. For example, a study following the BP Oil Spill determined that the Food and Drug Administration's (FDA) procedures for determining the safety of seafood from environmental hazards underestimates exposure risk by communities who consume above average amounts of seafood (Rotkin-Ellman, Wong, & Solomon, 2012). Ceccatto et al. 2016 found similar limitations in the Food and Agricultural Organization (FAO) and World Health Organizations' (WHO) standards for mercury, regarding fishing communities in Pantanal, Brazil.

Subsistence or 'artisanal' fishers are those who fish primarily to feed their family and relatives. In contrast to sport and commercial fishers, subsistence fishers utilize traditional fishing gear (e.g. reels, small boats, etc.) rather than large vessels with sophisticated technologies for finding and catching fish. This distinction is important due to subsistence fishers increased contact with water and consumption of fish containing microcystins. Additionally, subsistence fishing communities are often impoverished and, in the U.S., socioeconomic disparities in "healthy" food consumption have increased over time (Darmon & Drewnowski, 2008). These communities are likely already experiencing disparities in the accessibility of healthy foods and therefore fishing is a crucial resource of healthy foods.

Martin County, Florida, which contains part of Lake Okeechobee and the St. Lucie Canal (C-44) that connects Lake Okeechobee to the Indian River Lagoon and the Atlantic Ocean, hosts a large subsistence fishing community and has experienced several critical cyanobacterial blooms. Due to increased concerns about the transfer of toxins from algae to humans, ORCA completed this study to estimate the exposure of a subsistence fishing community in Martin County to microcystins.

Method

Subsistence fishers were interviewed and fish samples collected from August 2018 through May 2019. Prior to beginning the project Institutional Review Board approval for research including human subjects was obtained through Solutions IRB (www.solutionsirb.com). ORCA researchers approached anglers as they were fishing – primarily at the Port Mayaca Locks where the C-44 enters Lake Okeechobee, but also in adjacent waterways. After obtaining informed consent, face-to-face interviews were conducted. Interviewees were questioned about the locations and frequency of their fishing, species caught, species eaten, frequency of eating the fish, and how they prepare and cook the fish. Additionally, they were asked questions to assess who consumed the fish caught. A visual aid was used to estimate serving size (suggested by the EPA guidance for fish and wildlife surveys).

Based on interview results identifying fish species eaten, ORCA researches collected the same species of fish – caught at the same locations – for microcystin analysis. Fish were collected by angling, and through donations of fish from the fishers. Samples of skin, fillet, and liver were collected from each fish. Each sample was homogenized and microcystin was extracted following a methanol extraction protocol. Microcystin was measured using the Abraxis Microcystins/Nodularins-DM ELISA kits (www.abraxiskits.com). Water samples were also collected from the areas were fish were caught throughout the study period. Water samples were collected throughout the water column using a Snap Sampler (www.snapsampler.com) and composited into one representative sample.

Results

Fisher Surveys

The demographics of the 50 fishers surveyed is show in Table 1. On average the fishers fished 2.7 times per week. The 50 fishers surveyed shared their fish with a minimum of 199 other people (note: fishers provided a range, and total was calculated using the low end of the range). Of these, 24% were children and 30% were above the age of 65. Eleven pregnant women ate the fish caught by the fishers surveyed.

Table 1

Demographics		Number	Percent
Gender	Male	45	90%
	Female	5	10%
Age	18-65	29	58%
	>65	14	28%
	Unknown	7	14%
Race/ ethnicity	Black	41	82%
	Hispanic/Latino	5	10%
	White	2	4%
	Asian/Pacific Islander	1	2%
	Unknown	1	2%

Fishers reported eating fish they caught an average of 1.5 times per week (range = .025 – 7 times per week), with an average serving size of 6 ounces (range = 4 – 12 ounces). Crappie is by far the most frequently eaten fish, followed in frequency by bass, catfish and bluegill. Table 2 lists the number of fishers that reported eating each species of fish, as well as the number of fishers that reported eating each species most frequently.

Table 2

Species	Number of fishers that reported eating species	Number of fishers that eat this species most frequently
Crappie	50	42
Bass	20	2
Catfish	18	3
Bluegill	14	5
Mullet	2	0
Gar	2	0
Tilapia	2	0
Saltwater fish/fish from other regions	3	1

One hundred percent of fisher surveyed reported eating the filet, while 60% eat skins. None of the fishers reported eating organs, but 6% did eat other parts of fish including eggs, head (no eyes), and tail meat. The majority of fishers fry their fish (96%). Fifty-four percent bake their fish, and 22% used additional methods of preparation including broil, boil, steam and grill.

Fish Analysis

A total of 73 fish were tested for microcystin. Fillet samples of all 77 fish were tested. Sixty-eight liver samples, 46 skin samples, and 15 egg samples were also tested. The concentrations of all fish samples tested are shown in Table 3.

Table 3

	Concentration of Microcystin (ng/g)			
	Fillet	Liver	Skin	Eggs
Mean ± SD	2.3 ± 5.8	71.7 ± 154.2	1.3 ± 1.6	1.5 ± 1.2
Range	0-43.9	0-500.0	0.3-11.5	0.2-4.0
5th percentile	0.0	0.0	0.3	0.2
25th percentile	0.7	3.0	0.7	0.5
50th percentile	0.9	15.0	1.1	1.2
75th percentile	1.2	47.0	1.4	1.6
95th percentile	7.0	500.0	1.9	3.9

Table 4 lists the concentration of microcystin in the individual species tested.

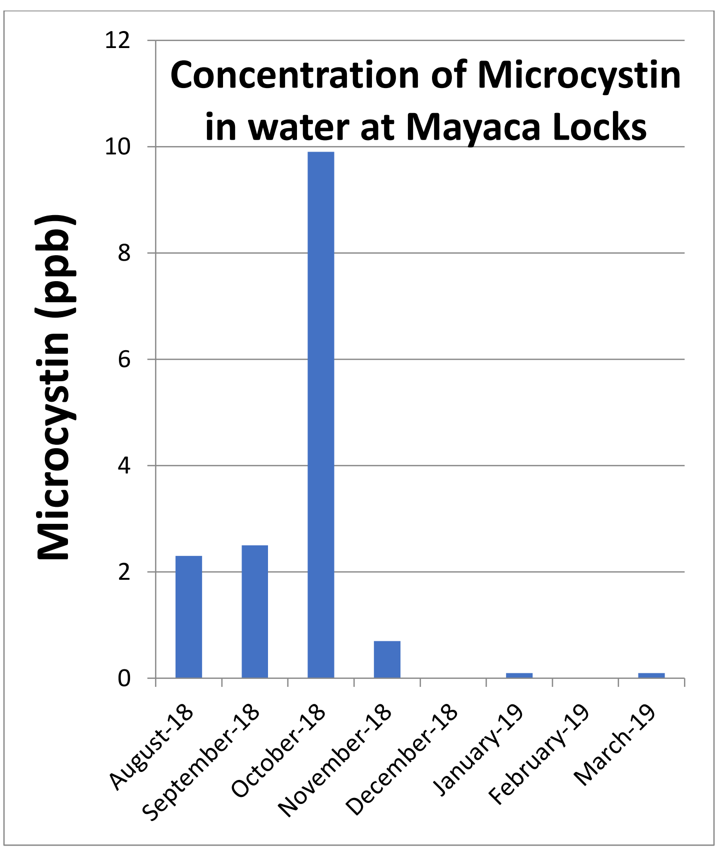
Table 4

	Concentration of Microcystin (ng/g)		
Species (number of fish tested)	Fillet	Liver	Skin
Crappie (n=23)	1.2 ± 1.4	41.6 ± 59.5	1.1 ± 0.3
Bass (n=3)	0.6 ± 0.5	3.1 ± 4.4	0.9
Channel catfish (n=9)	0.7 ± 0.3	10.6 ± 9.6	0.8 ± 0.5
Bluegill (n=2)	0.5 ± 0.7	3.1 ± 4.4	0.36
Mullet (n=10)	1.0 ± 0.3	91.5 ± 158.7	2.2 ± 3.3
Gar (n=2)	2.4 ± 4.1	9.8 ± 16.1	no samples
Tilapia (n=6)	3.4 ± 3.7	430.2 ± 156.2	1.9 ± 1.2
Armored Catfish (n=5)	17.2 ± 22.3	30.5 ± 35.5	1.2
Other* (n=13)	0.9 ± 0.3	62.5 ± 132.3	1.0 ± 0.6

* Bowfin, American shad, Redear sunfish, Mayan cichlid

Water Analysis

The following figure depicts composite water samples collected at Mayaca Locks monthly from August 2018 through March 2019.



Estimates of exposure

Based on the average serving size of six ounces, table 5 shows estimated levels of microcystin per meal for all fish tested and for each species. Exposures are estimated for fish eaten without and with skin.

Microcystin per serving (ng)

	Average serving size without skin (6 oz fillet)	Average serving size with skin (6 oz fillet + 1 oz skin)
All fish	391	428
Crappie	204	235
Bass	102	127
Channel catfish	119	142
Bluegill	85	95
Mullet	170	232
Tilapia	578	632
Armored catfish	2924	2958

Discussion

Based on the WHO's tolerable daily intake for microcystin exposure of 40 ng/kg of body weight, a 155 pound (70 kg) person should consume less than 2800ng of microcystin per day. Taken together, the data collected in this study do not indicate exposure levels approaching this tolerable daily intake among subsistence fishers in Martin County. The one exception is armored catfish. This species has consistently been found to have very high levels of microcystin. While none of the fishers surveyed in this study reported eating armored catfish, it is important that all fishers are aware of the risk of eating this species. The fact that the fishers surveyed shared the fish they caught with a significant number of children (n=47) is potentially cause for concern. While still below the WHO's limit, the concentrations of microcystin found in average servings of fish approaches that limit for young children (e.g. average weight of a two year old is 10 kg, so the TDI for microcystin would be 400 ng/day). Likewise, the implications of people over 65 years of age, and pregnant woman, consuming fish containing microcystin should be considered by public health professionals.

It is is important to recognize that this study only estimates exposure to microcystin through the consumption of fish. Fishers also have the potential for exposure through inhalation of aerosolized microcystin, and physical exposure while fishing. At Mayaca Locks, fishers target times of high water flow (i.e. when the locks are open)for the best fishing. This increases the aerosolization of any toxins found in the water. In several instances algae blooms were present as ORCA researchers were completing surveys and talking with fishers. It also only measured one cyanotoxin. While the exposure to this toxin was well below the WHO's TDI, cyanobacteria produce a number of different toxins and the rate, or impact, of cumulative exposure to several cyanotoxins is not known. Finally, the TDI for microcystin set by the WHO is provisional. The tolerable intake is generally referred to as "provisional" if there is a scarcity of data on the consequences of human exposure at low levels, and new data may result in a change to the tolerable level.

ORCA's One Health program is focused on studying the transfer of toxins and toxicants from water ecosystems to humans and animals. We are focused on upstream solutions – identifying the root cause of a problem so it can be solved. Upstream solutions are focused on prevention, while downstream solutions are focused on intervention. When it comes to ecosystem health, downstream solutions nearly always have unintended consequences and never result in permanent solutions. Ultimately, the upstream solution of reducing the nutrient load to our local waters to reduce the frequency, size and duration of algae blooms is urgently needed to prevent the public risks associated with the blooms. In the meantime understanding and addressing human health concerns associated with the transfer of cyanotoxins is warrented.

References

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