



Subsistence Fish Consumption on the Lower Cape Fear River

SUMMARY OF RESEARCH 2016 – 2022



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SUMMARY OF RESEARCH 2016 – 2022

JUNE 2022

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ACKNOWLEDGEMENTS

We would like to acknowledge all the many partner organizations and individuals, and their vital role in making this work possible. A special thanks to Cape Fear River Watch, New Hanover County NAACP, New Hanover County Department of Health, the Wake Forest School of Medicine, and the Duke University Environmental Law & Policy Clinic who initiated this work, and to those who have joined and sustained it, including the North Carolina Coastal Federation, Veronica Carter, Deborah Dicks-Maxwell, Dean Neff, Keith Rhodes, Madi Polera, Catherine Kastleman, and Bryan Luukinen. We are also deeply indebted to all those from the North Carolina Wildlife Resources Commission and Department of Marine Fisheries who offered their time and expertise in collecting fish tissue samples and at the North Carolina Department of Health and Human Services who conducted the health risk assessment that led to the setting of new consumption advisories on the lower Cape Fear River.

Funding

The Duke University Superfund Research Center's Community Engagement Core is supported through the National Institute of Environmental Health Sciences Superfund Research Program P42 Multiproject Center Grant program, grant number [P42ES010356](#). The 2016-2017 household survey was supported through the U.S. Environmental Protection Agency's [Environmental Justice Collaborative Problem-Solving Cooperative Agreement Program](#) under assistance agreement 00D49616.

Attribution

Please cite this work as follows:

Shapiro-Garza, Elizabeth, Mozhgon Rajaei, Samuel Cohen, Chiara Klein, and Abigail Joyce. 2022. *Subsistence Fish Consumption on the Lower Cape Fear River: Summary of Research 2016 – 2022*. Duke University Superfund Research Center and Oakland University.

Cover photos: screenshots from the 'Eating safe fish from the Cape Fear River, NC – Stop, Check, and Enjoy!' YouTube [video](#), created by Hendy Street Productions.

Executive Summary

While written and published by the Duke University Superfund Research Center and the School of Health Sciences at Oakland University, the research on subsistence fish consumption described in this report was generated from and has been sustained by the deep interest and dedication of a coalition of individuals and organizations from throughout the lower Cape Fear River basin who are passionate about protecting the health of its people and its waterways. The questions addressed were informed by the observations and concerns of this group and they were directly involved in conducting the research and in deciding how best to apply the results. The ultimate vision of this coalition is that fewer people—particularly those who are most vulnerable to harm, such as children and pregnant people—eat unhealthy amounts of contaminated fish from the lower Cape Fear River.

Subsistence fish consumers and consumption

Two separate studies, a household survey (2016-2017) and a bankside survey combined with key actor interviews (2019-2020) were conducted to assess wild caught fish consumption practices in the lower Cape Fear River. While the number of respondents for each survey were not sufficient to conduct complex statistical analyses, together they paint a fairly detailed picture of who is consuming what types of fish, from where, and why. The results indicate that those eating fish from the river tend to be low-income and/or food insecure individuals and families. Key actor interviews and publicly available data for the region indicate that those groups are in turn more likely to be Latinx and African American.

These studies also suggest that some people who eat fish from the lower Cape Fear River are consuming types and quantities of fish that likely pose health risks, especially for children and pregnant people. Preferred species include larger, saltwater fish: red drum, black drum, and trout. Catfish is by far the most popular freshwater species. Bass (freshwater/anadromous) was also popular across both surveys. This research also suggests that fishers are sharing their catch widely with family and friends. Frying, which can trap fat-loving contaminants, was the most popular cooking method across both surveys by a significant margin, followed by baking and grilling.

The results of these studies also indicated that while many people are aware of the official fish consumption advisories, the majority, while they would be open to changing a number of practices to reduce exposure to chemical contaminants in fish, would not be willing to stop consuming wild caught fish altogether. This is likely tied to the dietary and economic importance of wild caught fish, but also to the expressed cultural identity embedded within the practice of fishing for both native North Carolinians and immigrant communities.

Health risks from chemical contaminants found in popular fish species

Based on the results of these previous studies and community concern that existing fish consumption health advisories were inadequate, additional research was conducted to understand the types and quantities of chemical contaminants present in the most commonly consumed fish species from the locations where they are most commonly caught. In conjunction with the North Carolina Wildlife Resources Commission and North Carolina Department of Marine Fisheries, tissue was collected at five different locations from over 130 individual fish and shellfish representing seven species: catfish (flathead, blue, channel), bowfin, red drum, bluegill, and blue crab. The fish tissue was analyzed for heavy metals (arsenic, mercury, chromium) and a small sample was analyzed for PCBs and dioxins. This data was submitted to the North Carolina Department of Health and Human Services who used it to conduct a health risk assessment. This assessment resulted in new site-specific fish consumption advisories issued in October 2021 (see table below).

Lower Cape Fear basin fish consumption advisories issued in October 2021, listed by contaminant of concern

Species	Meals per week limit	Locations				
		Brunswick River (Belville)	Burnt Mill Creek (Wilmington)	Cape Fear River (Riegelwood)	Davis Creek (Navassa)	NE Cape Fear (Castle Hayne)
Red drum	0	Cr(VI)				
Bowfin	0		Hg, Cr(VI)	Hg, Cr(VI)	Hg, Cr(VI)	Hg, Cr(VI)
Bluegill	1		Cr(VI)	Cr(VI)	Cr(VI)	Cr(VI)
Flathead catfish	1		Cr(VI)			
Channel catfish	0			Hg, Cr(VI)		

Hg = mercury, Cr(VI) = hexavalent chromium. Blank cells indicate no new advisory.

Conclusions

- People are eating fish from the lower Cape Fear River. Many do so out of need and consume species and quantities deemed to pose health risks according to current state advisories.
- Existing fish consumption advisories for this region are based on very limited data. More frequent testing for a broader range of contaminants, species and sites is needed to better understand the health risks of consuming wild caught fish.
- The current scope and methods for communicating fish consumption advisories on the lower Cape Fear River do not adequately reach or protect subsistence fish consumers. More resources and new approaches are needed to reach target groups and to communicate potential risks in ways that acknowledge the dietary, economic, and cultural importance of wild caught fish and that provide viable alternatives.
- In North Carolina, the process for setting fish consumption advisories does not capture the full health risks posed, particularly for subsistence fish consumers. The risk assessments used to set advisories do not account for the health impacts of multiple or emerging contaminants that may be found in fish, do not always provide specific recommendations for more vulnerable populations, and often fail to address the species and locations favored by subsistence consumers.

The results of our research and the new advisories provide more information about safely eating fish from the lower Cape Fear River. Additional funding and support for state agencies and local health departments is needed to better understand and address risks from eating contaminated fish in the region and across the state. In a state with nearly 3,000 miles of impaired streams and rivers (Sorg 2022), where catching and eating fish is a culturally vital activity and primary source of food for so many, this is an issue that deserves greater recognition and support.

Table of Contents

Tables and Figures	8
I. Introduction and Goals of the Project	9
Background and history of the project	9
II. Fish Consumption Advisories in the Lower Cape Fear Region	11
Limitations	11
Current advisories in the lower Cape Fear River basin	12
III. Eating Fish from the Lower Cape Fear River	15
Household survey (2016-2017)	15
Bankside/Intercept Survey and Key Actor Interviews (2019-2020)	17
Summary	22
IV. 2020-2021 Fish Tissue Analysis	24
Sample Collection and Testing Process	24
Fish Tissue Testing Results	28
V. Risk Assessment and Fish Consumption Advisory Setting	34
Calculating Meal Limits and Setting Advisories	34
Limitations of New Advisories	38
VI. Conclusions	40
VII. References	42
VII. Appendix	43
Fish Tissue Testing and Risk Assessment Process Flow Diagram	43

Tables and Figures

Tables

1. [Summary of statewide fish consumption advisory for mercury](#)
2. [New fish consumption advisories in the lower Cape Fear River basin, October 2021](#)
3. [Number of respondents for household survey who reported eating the following fish species from the lower Cape Fear River basin \(n=36\)](#)
4. [Relationship between indicators of food insecurity and consumption of catfish from the household survey](#)
5. [Likelihood of Behavior Changes \(Bankside Survey\)](#)
6. [Fish tissue samples collected for metal testing for each site and fish species](#)
7. [Average contaminant concentrations at each site](#)
8. [Meal limit calculations and final consumption advisories for each site](#)

Figures

1. [Timeline of fish consumption research on the lower Cape Fear River](#)
2. [Portion and frequency results from bankside survey](#)
3. [Fish preparation results from bankside survey](#)
4. [Fish cooking results from bankside survey](#)
5. [Wilmington area map and corresponding heat map of fishing locations](#)
6. [Map of the five sampling locations](#)
7. [Sources and health effects of target pollutants](#)
8. [Average mercury \(Hg\) concentrations by fish species across all sites](#)
9. [Average inorganic arsenic \(As\) concentrations by fish species across all sites](#)
10. [Average total chromium \(Cr\) concentrations by fish species across all sites](#)

I. Introduction and Goals of the Project

The research on subsistence fish consumption described in this report was generated from and has been sustained by the interest and dedication of a coalition of individuals and organizations from throughout the lower Cape Fear River basin who are passionate about protecting the health of its people and its waterways. The questions addressed were informed by the observations and concerns of this group and they were directly involved in conducting the research and in deciding how best to apply the results. The ultimate vision of this coalition is that fewer people—particularly those who are most vulnerable to harm, such as children and pregnant women—eat unhealthy amounts of contaminated fish from the lower Cape Fear River.

Background and History of the Project

Starting in 2008, a coalition of community-based organizations, businesses and individuals started a legislative, outreach and legal campaign to oppose the proposed construction of a cement plant and strip mine along the lower Cape Fear River. In the process of gathering information for the campaign, the members of the coalition became aware of the high existing levels of chemical and biological contaminants in the river. In trips along the lower Cape Fear River to document potential impacts, they also observed many people and families fishing bankside who, because they knew their own communities, they suspected were taking those fish home to eat out of need.

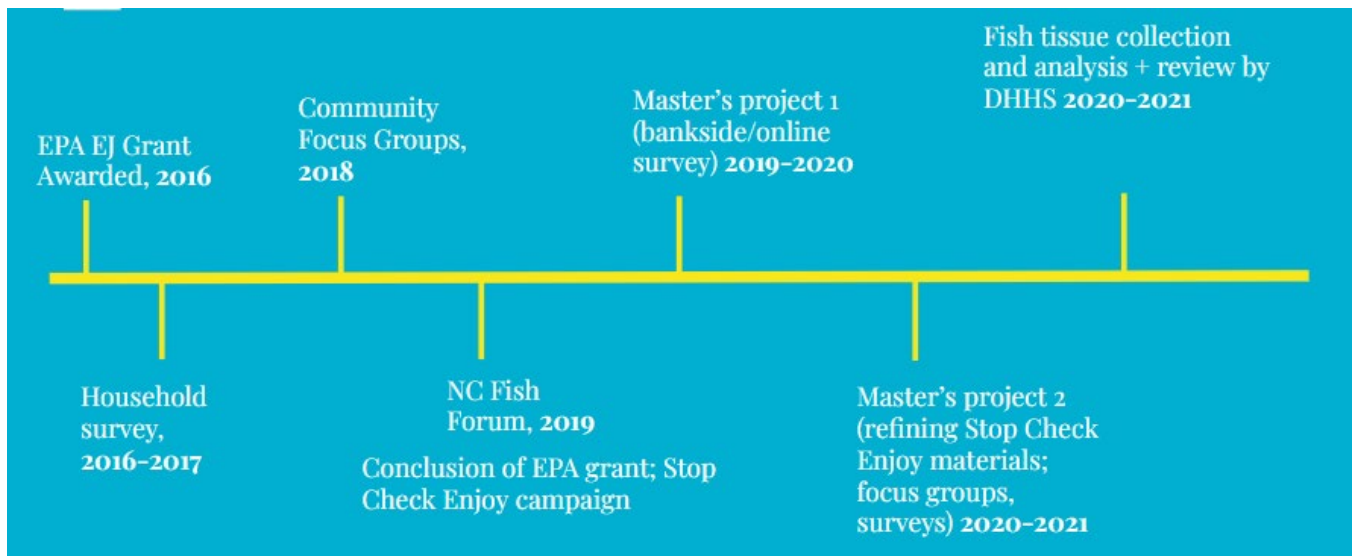
A number of the organizational partners in the coalition applied for an Environmental Justice Collaborative Problem-Solving grant from the United States Environmental Protection Agency to educate subsistence fishers living along the river on the health risks associated with mercury and other contaminants found in fish tissue. In 2016, the group, which included Cape Fear River Watch, the New Hanover NAACP, the New Hanover County Department of Health and Wake Forest School of Medicine, received the reward. The collaborative, joined by Community Engagement Core of the Duke University Superfund Research Center, then employed community data collectors to carry out a household survey in low-income neighborhoods in the lower Cape Fear River basin to learn more about who was eating fish from the river and their motivations for doing so. Based on the results, and further community focus groups in 2017-18 to help inform culturally appropriate messaging, the group designed a public health outreach campaign entitled, Stop, Check, Enjoy! The goal of the [campaign](#) is to limit exposure to chemical contaminants found in fish from the lower Cape Fear River by encouraging people to select safer fish and preparation and cooking methods that reduce contaminant levels.

The 2019 North Carolina [Fish Forum](#) was organized by the Duke University Superfund Research Center, the Institute for the Environment and the Center for Environmental Health and Susceptibility at University of North Carolina at Chapel Hill, and the Center for Human Health & the Environment at North Carolina State University. The forum brought together stakeholders,

including Stop, Check, Enjoy! coalition partners, to discuss challenges and opportunities to create a more effective fish consumption advisory process in the state. Duke University also worked with community partners to build on the results of the previous research to design and conduct bankside surveys, focus groups and key actor interviews. This research aimed to improve understanding of who was fishing from the river, and where and what they were eating as well as the most effective messaging about the risks involved. Beginning in 2020, in conjunction with the community coalition and state agencies, Duke University collected and analyzed the most commonly consumed fish species from popular fishing spots, with the goal of improving understanding of the health risks faced by people eating fish from the lower Cape Fear River and updating existing fish consumption advisories. The results of the fish tissue sampling were then shared with the NC Department of Health and Human Services to inform and potentially update the local fish consumption advisories. They were also combined with the results of our research on subsistence fish consumers to update the Stop, Check, Enjoy! campaign materials and messaging.

While the work of this coalition of community and university partners is ongoing, with a secondary [large-scale roll out](#) of the Stop, Check, Enjoy! campaign in March of 2022, this report is intended to summarize our results and observations to date on the issue of subsistence fish consumption on the lower Cape Fear River.

Figure 1. Timeline of fish consumption research on the lower Cape Fear River



II. Fish Consumption Advisories in the Lower Cape Fear Region

The NC Department of Health and Human Services, and specifically their Division of Public Health, is tasked with issuing [fish consumption advisories](#) throughout the state (NC DHHS 2019). These advisories are based on fish tissue collection done by the NC Department of Environmental Quality (NC DEQ 2018) or other groups that collect and submit samples adhering to DHHS's fish consumption advisory standard operating procedure. After this tissue is tested for contaminants, the Division of Public Health performs a risk assessment and decides whether to issue an advisory based on the elevated presence of a chemical of concern such as mercury or PCBs. Advisories are normally for specific fish species and locations.

Limitations

The 2019 North Carolina [Fish Forum](#) brought together relevant stakeholders to discuss challenges and opportunities to create a more effective fish consumption advisory process. One major takeaway from the forum was that resource constraints limit all phases (tissue collection, testing, data analysis, and outreach) of the fish consumption advisory process (Gray et al. 2019).

Compared to many other states, North Carolina invests relatively little in the setting and communication of fish consumption health advisories. Fish tissue collection and testing is resource intensive, and the NC Department of Environmental Quality and NC DHHS have had to conduct this work with limited funds and personnel. As a result, fish consumption advisories are often based on limited and older data.

According to the NC DEQ's [own record of their fish sampling work](#) from 1990 to December 2018, no fish tissue samples have been collected from the lower Cape Fear River since 2013 (NC DEQ 2018).¹ The responsible state agencies were open and willing to work with us on the fish tissue sampling project, but the overall process was not originally conceived to involve outside groups. So, it was difficult to grasp the standards for and then navigate the process of collecting, analyzing, and submitting our own fish tissue samples to inform the setting of fish consumption advisories. The fish tissue collection and analysis were also complex and costly, and thus would be prohibitive for many community-based organizations or local health departments who might be interested in collecting more up-to-date data on fish in their region.

NC DHHS is also tasked with notifying local health departments about the results of fish tissue risk assessments and new advisories for their coverage area. Although the Department offers

¹ This includes records for the Cape Fear Basin that are located in either Brunswick, Columbus, New Hanover, or Pender County.

assistance in developing language for fish advisories, the responsibility for posting local notifications for the public falls to the local health departments (NC DHHS 2019). We have observed disparities in the funds available to local health departments to carry out this work, with lower resourced counties typically having less ability to devote attention to communicating risks associated with fish consumption.

We present these observations not as a critique of the capable and dedicated state and local government employees who went out of their way to assist our group, but to point to crucial weaknesses in the system itself that limit our collective ability to protect vulnerable populations from chemical contaminants in wild caught fish.

Current Advisories in the Lower Cape Fear River Basin

Statewide mercury advisory

Instead of relying on mercury data from specific water bodies to inform fish advisories for those locations, the Division of Public Health has issued a statewide mercury advisory for [fish designated](#) as HIGH in mercury. This list includes some fish that are regularly caught and consumed in and around the lower Cape Fear River, including: catfish, largemouth bass, bowfin, and black crappie.²

The state has issued separate fish consumption recommendations for more vulnerable populations and the wider public. For more vulnerable populations, which include “women of childbearing age (15 to 44 years), pregnant women, nursing mothers and children under age 15”, the state recommends that **no** fish HIGH in mercury be consumed, and only 2 meals per week of [fish designated](#) LOW in mercury. For everyone else, the state recommends up to 1 meal per week for fish HIGH in mercury, and 4 meals per week for fish LOW in mercury.³

Table 1. Summary of statewide fish consumption advisory for mercury

	Meal limits per week	
	vulnerable populations	other populations
Fish HIGH in mercury	0	1
Fish LOW in mercury	2	4

² This applies to catfish and bowfin caught south and east of Interstate 85, and black crappie caught south and east of Interstate 95, of which the lower Cape Fear is included.

³ Meals are defined as 6 ounces of uncooked fish for adults, and 2 ounces of uncooked fish for children under 15.

It should be noted that the statewide mercury advisory does not preclude more specific guidance. If a fish thought to be low in mercury is found with elevated levels, then a mercury advisory for that location could be issued.

2017 Kerr-McGee superfund site fish advisories

The Kerr-McGee Chemical Corporation site in Navassa, NC was placed on the US EPA's Superfund National Priorities List in 2010. In 2011 and 2013, NC DEQ and the EPA collected and analyzed fish and shellfish from the waters near the site: Sturgeon Creek, the Brunswick River, and the Cape Fear River. The NC Division of Public Health [reviewed these data](#) and issued additional fish consumption advisories in 2017 (NC DHHS 2018).

The current statewide mercury advisory was deemed protective for people eating fish and shellfish from these waters, except for three species (striped bass, striped mullet, and blue crab). The Division of Public Health recommends that for these sites⁴, all populations should:

- Eat up to 2 meals per week of striped bass due to high levels of mercury
- Eat up to 3 meals per week of striped mullet due to high levels of hexavalent chromium
- Eat up to 3 meals per week of blue crab due to high levels of arsenic, hexavalent chromium, and mercury

Notably, NC DEQ has had a [moratorium](#) on harvesting striped bass from these waterbodies since 2015 due to species conservation concerns (NC DEQ, n.d). Also, for both striped mullet and blue crab, the statewide mercury advisory for more vulnerable populations recommends no more than 2 meals per week of fish low in mercury, which is fewer than recommended for the 2017 Kerr McGee advisories.

2020-2021 Duke and Oakland University-led lower Cape Fear sampling and resulting fish advisories

The Duke University Superfund Research Center, Oakland University, and our partners collected 62 fish samples (representing 136 individual fish or crab) for testing in 2020-2021. Sections IV and V will go into greater detail on the particular limitations and caveats of our recent sampling work. Here, the finalized fish consumption advisories (weekly meal limits) are summarized.

⁴ These advisories apply to these specific locations only:

- [Brunswick River](#): from its confluence with the Cape Fear River downstream to the US-17 bridge
- [Cape Fear River](#): just upstream of the confluence with the Brunswick River downstream to the US-17 bridge
- [Sturgeon Creek](#): just upstream of the confluence with the Brunswick River downstream to the US-17 bridge

The new advisories apply to five specific locations:

- Brunswick River (Belville): near US Hwy. 74 / US Hwy. 17 bridge
- Burnt Mill Creek (Wilmington): near the Archie Blue Community Park, upstream of the confluence of Burnt Mill Creek with Smith Creek
- Cape Fear River (Riegelwood): between Riegelwood Landing and the confluence of Livingston Creek and Cape Fear River
- Northeast Cape Fear River (Castle Hayne): near Riverside Park Community Building, upstream of the I-40 bridge, at Castle Hayne Boat Ramp
- Davis Creek (Navassa): downstream of Cartwheel branch, upstream of the confluence of Davis Creek and Cape Fear River in Navassa, NC

Table 2: New 2021 fish consumption advisories in the lower Cape Fear River basin by contaminant of concern

Species	Meals per week limit	Locations				
		Brunswick River (Belville)	Burnt Mill Creek (Wilmington)	Cape Fear River (Riegelwood)	Davis Creek (Navassa)	NE Cape Fear (Castle Hayne)
Red drum	0	Cr(VI)				
Bowfin	0		Hg, Cr(VI)	Hg, Cr(VI)	Hg, Cr(VI)	Hg, Cr(VI)
Bluegill	1		Cr(VI)	Cr(VI)	Cr(VI)	Cr(VI)
Flathead catfish	1		Cr(VI)			
Channel catfish	0			Hg, Cr(VI)		

Hg = mercury, Cr(VI) = hexavalent chromium. Blank cells indicate no new advisory

III. Eating Fish from the Lower Cape Fear River

Two separate studies were conducted to determine fish consumption practices in the lower Cape Fear River. The first was based on a household survey in low-income neighborhoods, and the second on a survey of fishers intercepted along banksides combined with key actor interviews.

Household Survey (2016-2017)

The 2016-2017 household survey was funded through an Environmental Justice Collaborative Problem-Solving grant from the US Environmental Protection Agency that was awarded to a coalition of community organizations on the lower Cape Fear River. Researchers from the Wake Forest University School of Medicine led the research process, with Duke University researchers serving in an advisory capacity. The aim of the study was to increase understanding of if, and to what extent, households eat fish caught from the Northeast Cape Fear River. The survey also collected demographic and socio-economic information from these households.

Results

The survey was conducted in the communities of Castle Hayne, Love Grove, and Rocky Point, selected for the predominance of low-income households and their proximity to the northeastern lower Cape Fear River. Of the 83 individuals approached, 36 responded that they consumed fish from the river at least 10 times in the prior year and were therefore eligible to complete the survey. Demographic results indicated a significant level of food insecurity among those consuming wild caught fish, as determined by respondents' children receiving free/reduced lunch in school, the respondents receiving SNAP and/or WIC benefits, and respondents earning \$12,000 or less annually, pre-tax (US EPA 2016).

Respondents were given labeled images of eight species known to be commonly consumed (catfish, bass, carp, shad, crappie, sunfish, bowfin, warmouth) and asked if they had eaten each in the past year and, if so, how often. By far the most popular fish to eat was catfish, followed by bass, shad, and bowfin (see table 3).

Table 3. Number of respondents for household survey who reported eating the following fish species from the lower Cape Fear River basin (n=36)

Fish species consumed	Number of respondents who indicated consumption in the last year
Catfish	25
Bass	12
Shad	10
Bowfin	10
Crappie	7
Sunfish	6
Carp	3
Warmouth	2

EPA 2016.

Although it is important to keep in mind the relatively small sample size, respondents, particularly those who also had indicators of food insecurity, did consume the types and quantities of fish that state advisories warn pose health risks. Respondents also were widely sharing the fish caught, including with children, women who are of childbearing age and pregnant people. Based on the statewide mercury advisory alone, these populations are particularly vulnerable to mercury and so are advised not to consume any catfish, largemouth bass, bowfin, or black crappie and only limited amounts of other wild caught fish.

Table 4. Relationship between indicators of food insecurity and consumption of catfish from the household survey

Indicators of food insecurity	Number of respondents who consumed catfish in the last year
10 of 36 respondents' children received free/reduced price lunches at school	→ 8 of those 10 caught and ate catfish in the last year
7 of 36 respondents receive SNAP benefits	→ 6 of those 7 caught and ate catfish in the last year
5 of 36 respondents receive WIC benefits	→ 4 of those 5 caught and ate catfish in the last year
4 of 36 respondents earned less than \$12,000 in total income before taxes	→ 3 of those 4 caught and ate catfish in the last year

EPA 2016.

The most common methods of fish preparation and cooking were to remove the head, guts, fins, and tails and then fry the fish, which can trap fat-loving chemical contaminants. Only 3-4 respondents reported steaming, grilling, baking, and/or poaching their fish “most of the time,” which are considered the safest methods of cooking fish to avoid these types of contaminants (EPA 2016).

Only 47% of fish consumers surveyed had seen a state health advisory. Of those that were aware of the advisories, 53% stated that it did not affect the types of fish they ate and 73% that it did not limit their total fish consumption. When asked what sources they would use for information if they had a question about which fish and how much was safe to eat, 61% said internet searches, 50% said family and friends, and only 9% indicated that they would look to the state advisory sign where they go fishing.

Takeaways

The majority of low-income and food insecure populations surveyed also eat fish from the river. The most commonly caught fish are more likely to contain unsafe levels of contaminants (e.g., catfish, bowfin, crappie) and people, particularly the most vulnerable populations, are consuming quantities of these fish that pose health risks according to state advisories. Additionally, respondents often prepare and cook fish in ways that do not serve to reduce contaminant ingestion.

The household survey’s greatest strength was confirming the link between food insecurity and fish consumption. This reinforces the need for targeted and nuanced communication about fish consumption advisories and best practices for preparing and cooking locally caught fish.

Limitations

This survey was limited by relatively low sample size (36 respondents / 83 approached) and reliance on self-reporting.

Bankside/Intercept Survey and Key Actor Interviews (2019-2020)

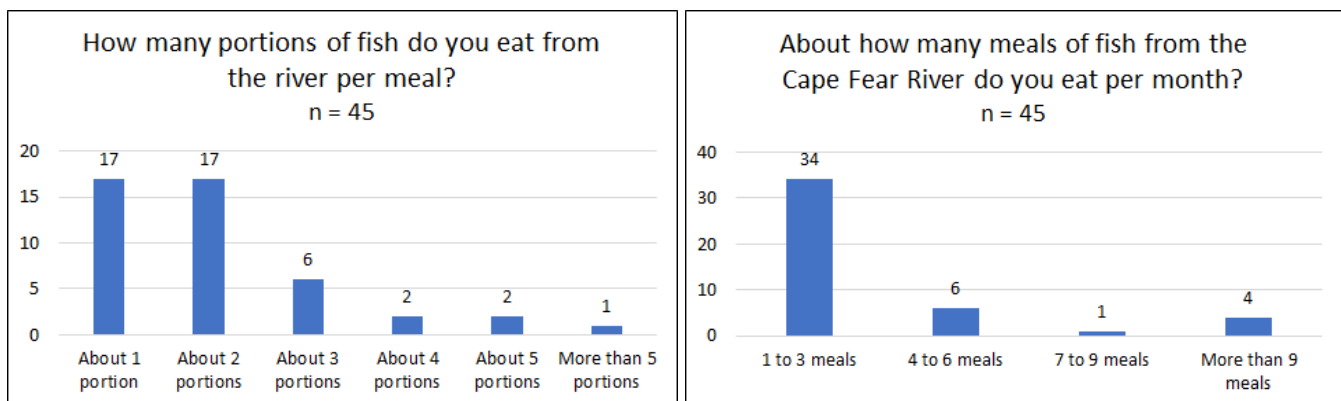
Research, including a bankside survey and extensive key actor interviews, conducted in 2019-2020 by Duke University masters’ students Martin Dietz and Steven Yang, aimed to expand on the results from the previous household survey. People fishing bankside were targeted under the assumption that they were more likely to be low-income and food insecure than those fishing from boats. The survey and interviews were conducted from November 8, 2019 to March 2, 2020 over the course of eight visits to the Wilmington area. The survey contained questions similar to the household survey, with fewer socioeconomic questions and the addition of

questions of about where people fished and their willingness to change certain behaviors related to fish consumption.

Survey Results

The bankside survey had 46 total respondents (7 of which were completed online). Similar to the household survey, respondents were given labeled photos of fish species and asked to indicate which of these species they caught and ate, and how often. Eighteen freshwater species were presented in the bankside survey, with an option to write in additional species. Respondents wrote in responses 67% of the time; and nearly all were saltwater species (Dietz and Yang 2020). The most common species consumed were red drum (saltwater), black drum (saltwater), speckled trout (saltwater), and three types of catfish, blue, channel, and flathead (freshwater). Most respondents indicated that they ate 1-2 portions of fish (6 ounces) per meal and 1-3 meals per month (see Figure 2).

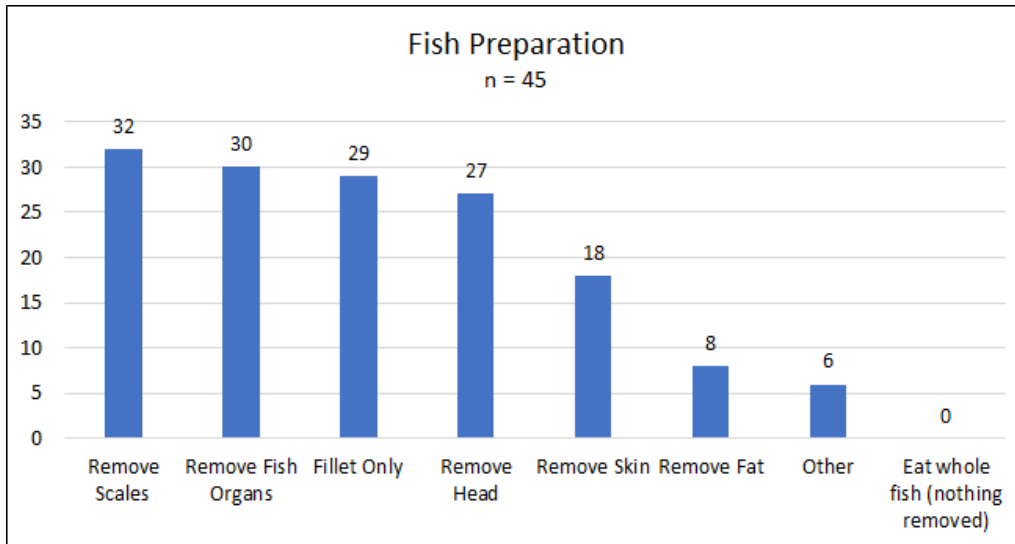
Figure 2. Portion and frequency of fish consumption results from bankside survey



Dietz and Yang 2020.

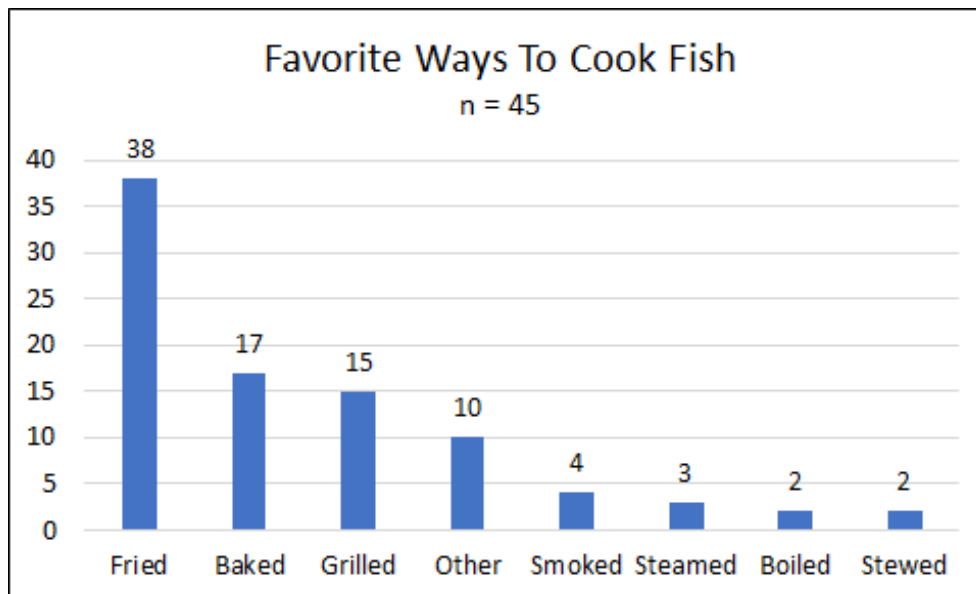
Nearly all respondents indicated that they shared the fish they caught with others: 48% shared with others only, 43% ate the fish themselves and also shared with others, and only 9% exclusively ate the fish themselves. Of those who said they shared, 63% indicated that they shared with at least one woman between the ages of 15-44 and 35% reported sharing with at least one child under the age of 15. Both groups are considered higher risk populations. Similar to the household survey, the most popular cooking method was frying, followed by baking and grilling. Removing scales, organs, and filleting were the most popular preparation methods; skin and fat removal was not as prevalent.

Figure 3. Fish preparation results from bankside survey



Dietz and Yang 2020.

Figure 4. Fish cooking results from bankside survey



Dietz and Yang 2020.

Also, the survey revealed that most respondents get their information about fish consumption guidelines from the news and by word of mouth. While respondents mostly indicated that they had seen posted fish advisory signs (67%) and that the advisories themselves were mostly clear (87%), researchers Dietz and Yang did not observe signs at any of the bankside survey locations.

Table 5. Likelihood of Behavior Changes (Bankside Survey)

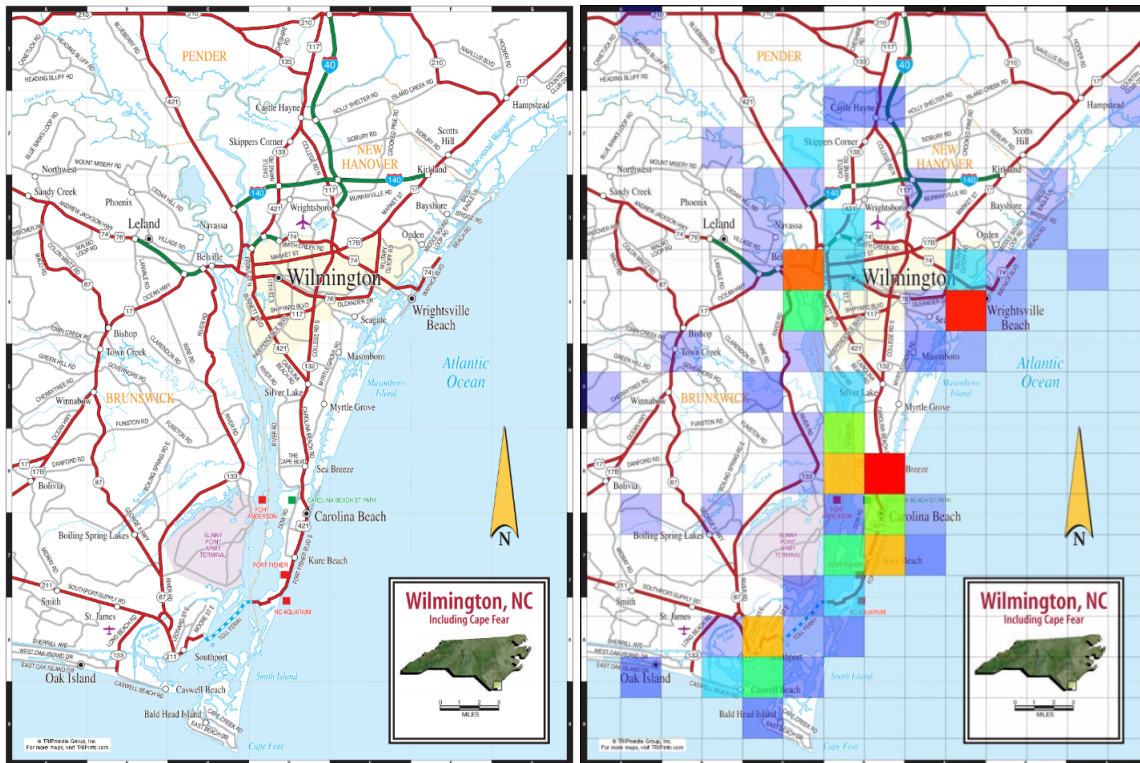
Behavior Change Options	Definitely will not do	Probably will not do	Neutral	Probably will do	Definitely will do
Eat fewer large fish	5	9	4	12	11
Eat more small fish	2	7	1	19	12
Filet fish	0	3	5	16	17
Buy fish at market/store instead	10	6	5	16	4
Try other non-frying cooking methods	2	10	3	15	11
Stop eating fish from the river	19	7	3	8	1

n = 41, Dietz and Yang, 2020

The survey also demonstrated that respondents were receptive to a series of suggested behavior changes that would reduce exposure to chemical contaminants in fish (see table 5), except for not eating any fish from the river. This confirms that fishing from the river is an important aspect of peoples' lives and that it is important to preserve peoples' ability to do so. This finding also reinforces the need to craft messages and guidance that still leaves room for residents to catch and eat fish from the river.

Respondents were asked to identify on a map where they and others most commonly fished from the bankside. Results show that those that do catch and eat fish are primarily fishing along the main stem of the Cape Fear River (see Figure 5), specifically at the Southport Fishing Pier, the Bellville River Walk on the Brunswick River, Smith Creek and Burnt Mill Creek, Carolina Beach State Park, Fort Fisher, and Snow's Cut. As previously noted, the bankside survey was unable to survey those fishing in freshwater locations.

Figure 5. Wilmington area map and corresponding heat map of fishing locations



Dietz and Yang 2020

Key Actor Interviews

Key actor interviews were conducted with individuals who hold specialized knowledge of the issue of subsistence fish consumption on the lower Cape Fear River. These semi-structured interviews were conducted over the phone or in person and provided valuable context that helped interpret and provide depth to survey results. Topics covered included fishing and fish consumption patterns in the area, effective messaging and communication channels for fish consumers, knowledge of existing advisories and barriers to health protective behavior change. Nine interviews were conducted, and key actors included a bait and tackle shop owner, a local city council member, staff at a local non-profit focused on food security, and county health department employees (Dietz and Yang 2020).

These key actors made clear that cultural identity was an important part in explaining the prominence of fishing and practices related to eating fish such as frying. Another key observation was, that while fishing and eating fish is common across the region, those people fishing for food were more likely to be low-income communities and people of color. Wealth inequality was frequently mentioned as a driver for some groups to try and get the “most amount of food for the least amount of money”, which includes fishing for food and frying fish (Dietz and

Yang 2020). The food security non-profit representative mentioned that most communities they work with are Latinx and African American.

The sharing of fish caught was mentioned often. One key actor suggested a common hypothetical of catching a big catfish, frying it at home, and sharing with neighbors and family who couldn't get out to fish because they were busy at work. Key actors mentioned various barriers to reducing exposures from contaminated fish including, lack of fresh food and food deserts, difficulty in changing old habits, and lack of immediate health effects from eating fish in the past (Dietz and Yang 2020).

Takeaways

The majority of respondents who catch and eat fish are also sharing with others. Also, many fish consumers tend to eat higher trophic level species which carry higher contamination risk. Some respondents who eat fish from the river may exceed the fish consumption guideline for a specific species during just a single meal. Dietz and Yang primarily collected in brackish/saltwater fishing spots, since freshwater spots were difficult to identify and access. This added an important context regarding saltwater fish species. The household survey did not allow respondents to indicate if they were consuming saltwater fish.

Limitations

Conclusions drawn from the bankside survey are constrained by a small sample size and self-reporting. In addition, Dietz and Yang primarily sampled in brackish/saltwater fishing locations, due to those being more popular and accessible during the survey time period and only on weekends, meaning they may have missed those fishing during the week.

Summary

The following is a summary of our findings about the people who catch and eat fish from the lower Cape Fear River, keeping in mind the previously noted limitations of this research.

Who eats fish from the river?

Overall, the people eating fish from the river tend to be low-income and/or food insecure individuals and families, as defined by the parameters in the household survey. While there was not a direct correlation between race and income based upon survey answers alone, key actor interviews conducted by Dietz and Yang indicated that most of the food insecure communities that the nonprofit works with are Latinx and African American (Dietz and Yang 2020). There

seem to be a fairly broad range of identities within the subsistence fishing community, making it a tricky population to define and to reach.

Do they do so out of need?

Based on the survey findings, it can be assumed that many are consuming fish from the river out of need. However, there can be no definitive conclusion drawn, as neither survey asked specifically about financial and dietary needs. This can be a sensitive question, making it difficult to gather relevant data. It does seem that based on the frequency with which many bankside survey respondents share the fish they catch, that the fish represent an important protein source for survey respondents' families and their wider network. The majority of respondents to the bankside survey indicated that, while open to adopting a number of other practices, they would not be open to completely stop consuming wild caught fish. This is likely tied to the dietary and economic importance of wild caught fish, but also to the expressed cultural identity embedded within the practice of fishing for both native North Carolinians and immigrant communities.

What do they catch and how do they prepare it?

People fishing from the river are primarily catching larger, saltwater fish: red drum, black drum, and trout. Catfish is by far the most popular freshwater species. Bass (freshwater/anadromous) was also popular across both surveys.

The household survey indicated that many respondents were eating fish whole and/or only removing the head. However, the bankside survey indicated that most respondents were removing scales, fins, and organs, and that a good portion of respondents (64%) were filleting the fish before cooking. Frying was the most popular practice across both surveys by a significant margin, followed by baking and grilling.

What are the most used and most trusted channels of communication?

Based on both surveys, while some people were aware of state issued fish consumption advisories, many did not follow the advice provided. The most used channels of communication for fish consumption guideline information were news (broadly, television, radio, newspaper, etc.), fishing magazines, license vendors, and "other people who are fishing," which can also be defined as word of mouth. The most used and trusted source for health information more broadly were health clinics, followed by the internet. The most common suggestion for where a good place might be to share safe fish information was bait & tackle shops, which indicates that this might be an underutilized channel of communication.

IV. 2020-2021 Fish Tissue Analysis

The Duke University Superfund Center's Community Engagement Core and Analytical Chemistry Core worked with Dr. Mozhgong Rajaei of Oakland University, and officials from the North Carolina Department of Marine Fisheries, the North Carolina Wildlife Resources Commission, and others to collect fish tissue samples at multiple sites within the lower Cape Fear River.

Our goal was to shed more light on the potential health risks faced by people who eat fish from the river. We sought to update the fish tissue data for the region to inform the health risk analysis for subsistence fish consumers specifically by collecting commonly consumed species from popular fishing spots. Ultimately, we aim to contextualize and share these results with our partners in the region and impacted populations.

Sample Collection and Testing Process

All sample collection and transport were conducted following all established NC Department of Environmental Quality protocols. Weights and lengths of these fish were recorded at the time of collection. All samples were collected during one of two periods of time: September 24 – December 11, 2020 or June 25 – July 1, 2021. Samples were stored at -20 degrees Celsius for approximately 1-2 months prior to preparation and digestion.

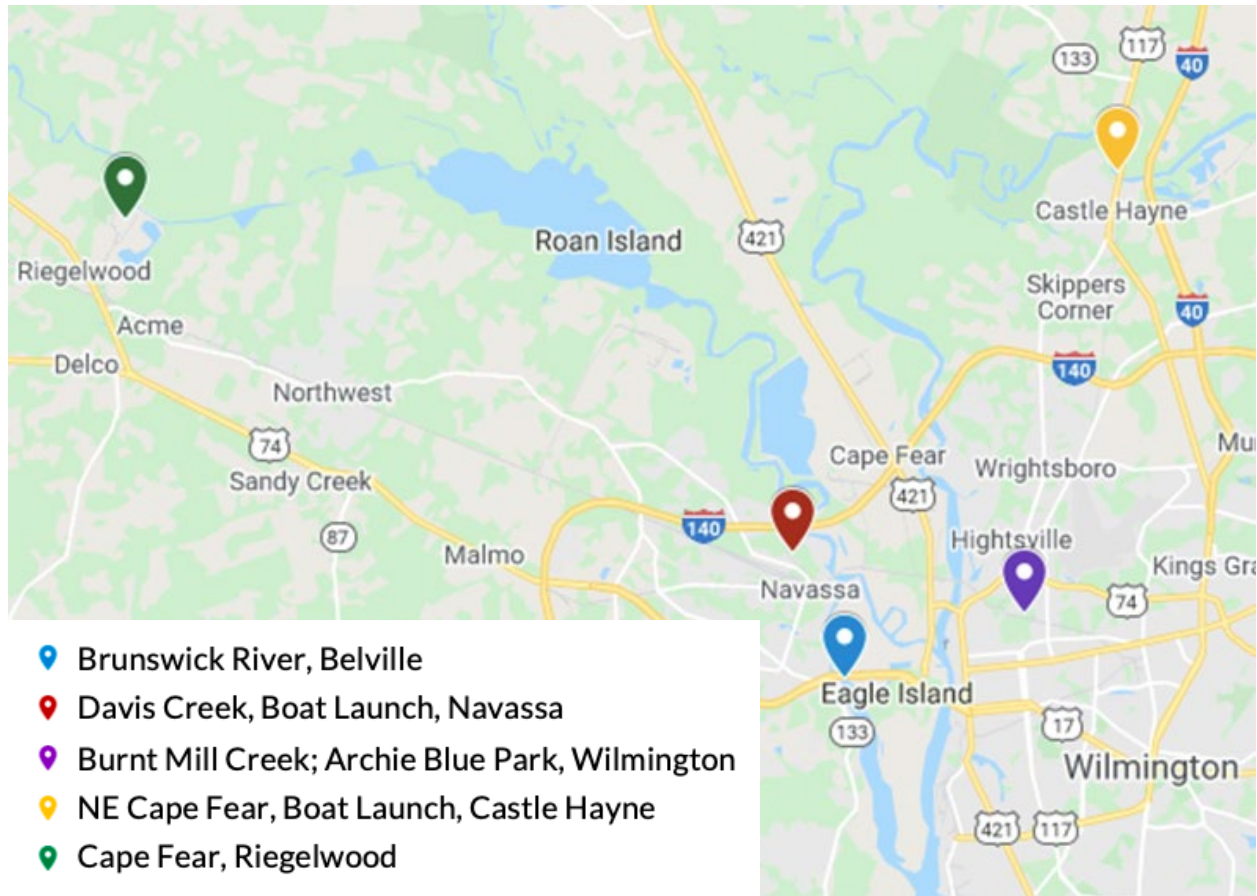
Where did we sample and why?

Our team collected samples from five locations, which are popular fishing spots according to our past surveys.

- Brunswick River (Belville): near US Hwy. 74 / US Hwy. 17 bridge
- Burnt Mill Creek (Wilmington): near the Archie Blue Community Park, upstream of the confluence of Burnt Mill Creek with Smith Creek
- Cape Fear River (Riegelwood): between Riegelwood Landing and the confluence of Livingston Creek and Cape Fear River
- Northeast Cape Fear River (Castle Hayne): near Riverside Park Community Building, upstream of the I-40 bridge, at Castle Hayne Boat Ramp
- Davis Creek (Navassa): downstream of Cartwheel branch, upstream of the confluence of Davis Creek and Cape Fear River in Navassa, NC

Both Davis Creek Boat Launch and Burnt Mill Creek sites have not been sampled before by the NC Department of Environmental Quality. Among the sites, Brunswick River was sampled most recently in 2013.

Figure 6. Map of the five sampling locations



Which species did we test for? How many samples did we collect?

Our team collected and tested tissue from seven different commonly caught fish and shellfish species.

Listed from higher to lower trophic level:

- Flathead catfish
- Bowfin (blackfish)
- Red drum
- Blue catfish
- Channel catfish
- Bluegill
- Blue crab

Bowfin were not tested previously as part of the 2011 & 2013 Kerr-McGee study, and bluegill and red drum were tested in very low numbers (NC DHHS 2018). Fifty-seven samples were tested for metals, representing 131 individual fish and shellfish. Five additional samples were tested for PCBs and dioxins/furans (3 red drum from the Brunswick River and 2 flathead catfish from Burnt Mill Creek).

Table 6. Fish tissue samples collected for metal testing for each site and fish species

Site	Species caught	# of individuals	# of filets	# of composites
Brunswick River (Belville)	<i>Blue Crab</i>	14	-	3
	<i>Blue catfish</i>	1	1	-
	Red drum	7	7	-
Burnt Mill Creek (Wilmington)	Bluegill	14	-	3
	Flathead catfish	5	5	-
	Bowfin	5	5	-
Cape Fear River (Riegelwood)	Bluegill	15	-	4
	Channel catfish	10	-	3
	Bowfin	5	5	-
Northeast Cape Fear River (Castle Hayne)	Bluegill	14	-	3
	<i>Blue catfish</i>	6	1	1
	Bowfin	5	5	-
Davis Creek (Navassa)	Bluegill	21	-	3
	<i>Channel catfish</i>	4	2	1
	Bowfin	5	5	-
Total sampled	All	131	36	21

Composite samples are made up of multiple individuals of the same species. Composites are often used for smaller fish. *Italics* indicates species that were not considered for advisories for that location, either because not enough samples were collected (blue catfish, channel catfish), or because too much time passed between sample collection (blue crab).

Which pollutants did we test for and why?

Metals

The majority of the fish tissue samples were tested for the heavy metals mercury and chromium, and the metalloid arsenic. These three metals are commonly found in fish tissue, and mercury is one of the pollutants most likely to trigger fish consumption advisories due to its widespread use and toxicity at low concentrations. Each of these metals is linked with serious health concerns. These metals also biomagnify as you move up the food chain, meaning that some of the higher trophic level fish that we collected can have very elevated concentrations.

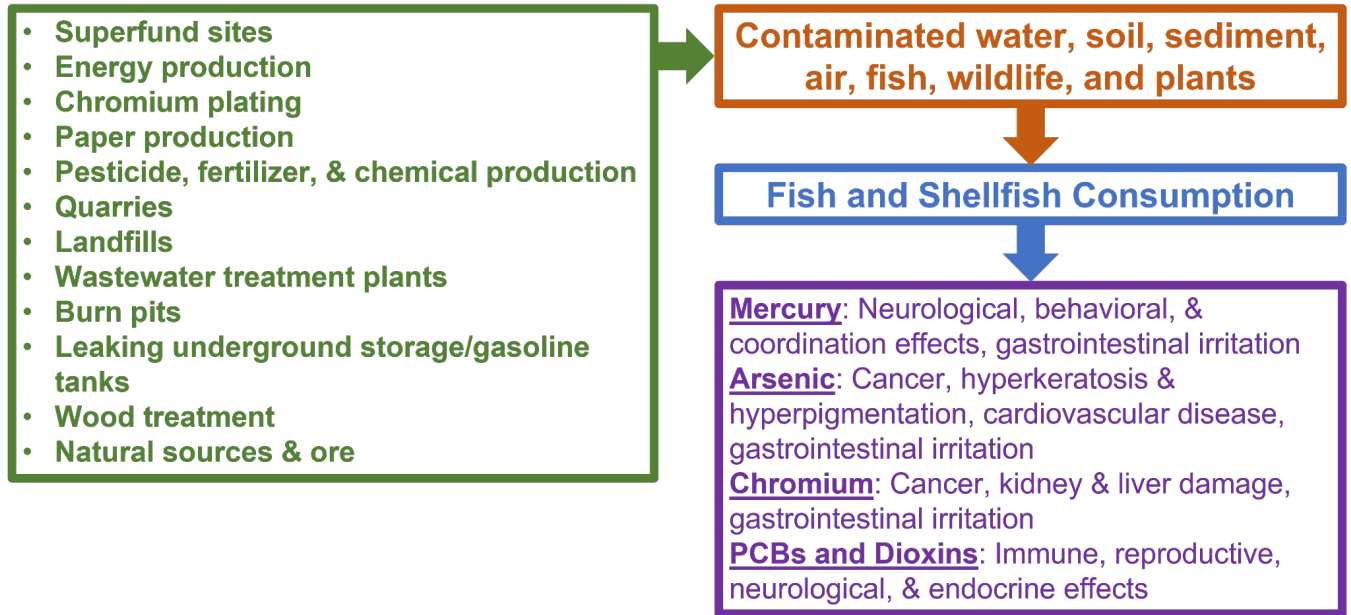
Metal analysis was performed by Element One, Inc., in Wilmington, NC, using EPA method 3050B for analytical preparation, 7470A for total mercury, and 6020B for total arsenic and total chromium. EPA method 360A/7199 for hexavalent chromium was attempted after the measurements were made for total mercury, arsenic, and chromium on the first 40 individual and composite samples, but recovery was unsuccessful, and the use of the method was halted. The detection limit was 1.0 µg/L for arsenic and chromium (including the hexavalent chromium analysis), and 0.004 µg/L for mercury. The majority of the fish analyzed for metals were freshwater fish (n=46; catfish, bowfin, bluegill), and eleven were from brackish water (n= 7 red drum and n=3 blue crabs).

PCBs and dioxins/furans

Polychlorinated biphenyls (PCBs) and dioxins and furans are classes of anthropogenic chemicals. PCBs consist of 209 different chemicals and dioxins and furans consist of 74 different chemicals. These chemicals are known as persistent organic pollutants because of their widespread contamination and resiliency in the environment. In this study we analyzed for the chemicals known to be most toxic and most commonly found in the environment. Guidance for targeted PCBs was taken from the United States Environmental Protection Agency and the World Health Organization for dioxins and furans. Five samples were analyzed by Cape Fear Analytical, LLC, in Wilmington, NC, using EPA method 1668C and HRMS tissue analysis for PCBs, and SW846 Method 8290A for dioxins/furans.

This work was done to determine whether more extensive testing would be necessary. PCBs and dioxins/furans are highly toxic, so even low levels in fish tissue would be concerning. Not only are they highly toxic, these pollutants persist in the environment for a long time, and like metals they also biomagnify.

Figure 7. Example sources, environmental fate, human exposure, and health effects of target pollutants



Fish Tissue Testing Results

Metals

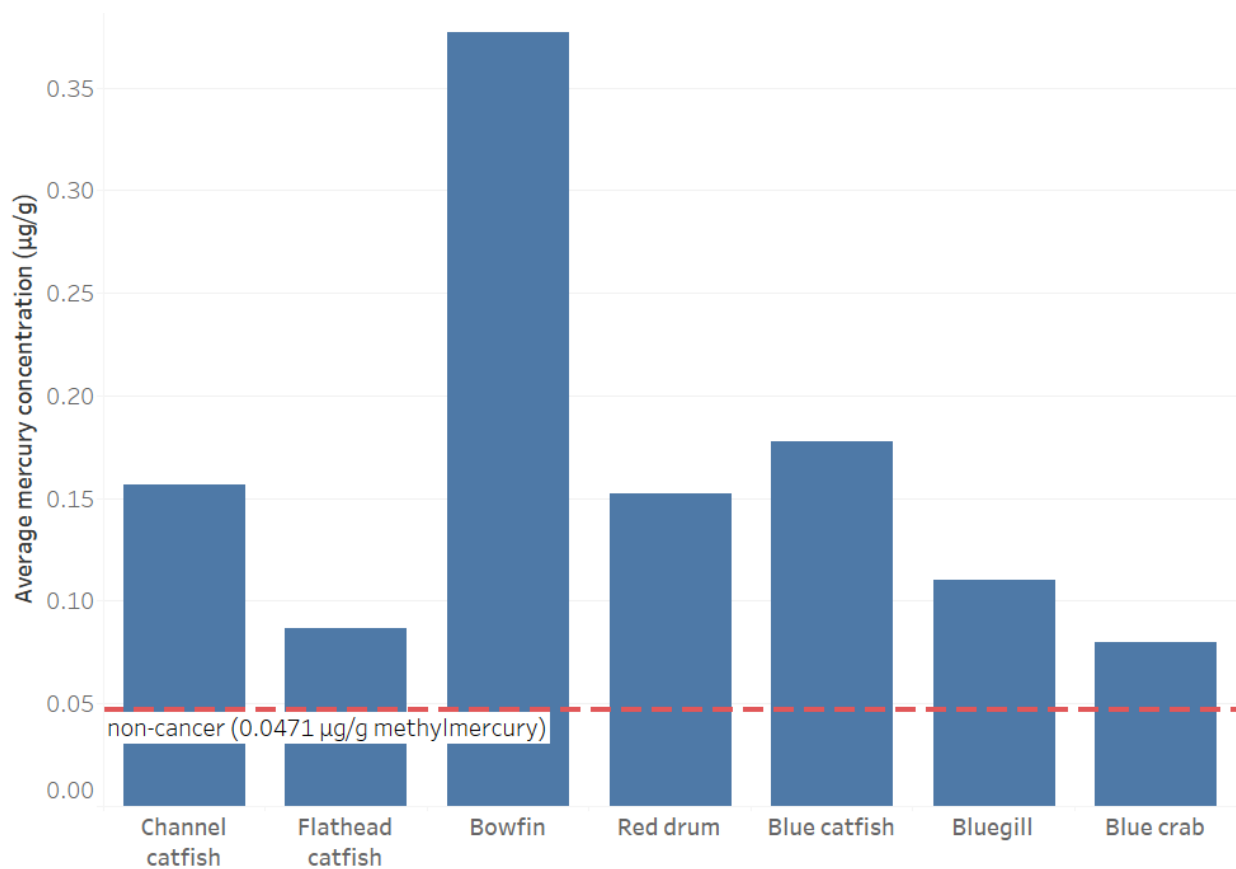
The analysis was done for *total* concentrations of mercury, chromium, and arsenic, not specific forms. When evaluating fish testing results, it is helpful to be aware of the assumptions that the NC Division of Public Health uses when comparing total metal concentrations in fish tissue to health screening levels (NC DPH 2017).

- All mercury measured in fish tissue is assumed to be methylmercury.
- 10% of total arsenic measure in fish tissue is assumed to be inorganic arsenic.
- All chromium measured in fish tissue is assumed to be hexavalent chromium.

Mercury

None of the fish and crab samples exceeded the FDA tolerance level for mercury⁵ (1.0 µg/g), but all but one exceeded the NC Division of Public Health screening level for non-cancer effects (0.0471 µg/g). Fish from the Cape Fear River (Riegelwood), Northeast Cape Fear River (Castle Hayne), and Burnt Mill Creek (Wilmington) had the highest mean levels of mercury (0.2843 µg/g, 0.2655 µg/g, and 0.2286 µg/g, respectively). Bowfin, which has a high trophic level, had the highest mean levels of mercury (0.3768 µg/g).

Figure 8. Average mercury (Hg) concentrations by fish species across all sites



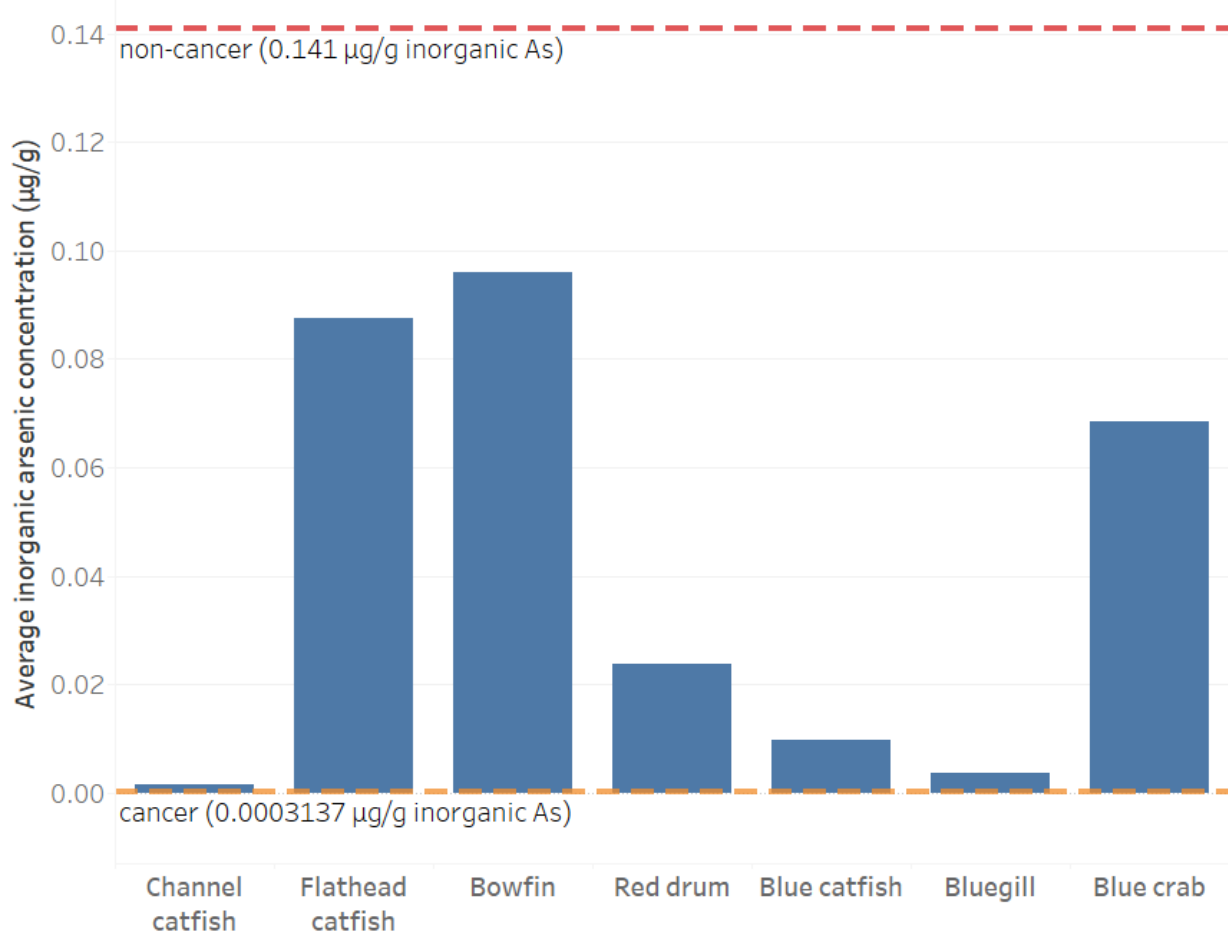
Notes: The dotted line represents the non-cancer effects screening level for methylmercury (0.0471 µg/g).
Neither blue catfish nor blue crab had enough samples to be considered for an advisory.
Only total mercury was quantified. Methylmercury was assumed to be 100% of total mercury concentrations.

⁵ The FDA tolerance level is 1.0 µg/g for methylmercury. FDA (2020). Appendix 5: FDA and EPA safety levels in regulations and guidance. <https://www.fda.gov/media/80400/download>

Arsenic

All samples exceeded the NC Division of Public Health screening level for cancer effects for inorganic arsenic (0.0003137 µg/g). Only five samples (all bowfin from Burnt Mill Creek) exceeded the NC DPH non-cancer effects for inorganic arsenic (0.141 µg/g). The mean inorganic arsenic levels in bowfin were 0.0961 µg/g for all samples and 0.2049 µg/g for bowfin at Burnt Mill Creek (Wilmington).

Figure 9. Average inorganic arsenic (As) concentrations by fish species across all sites



Notes: The dotted lines represent the non-cancer effects screening level for inorganic arsenic (0.141 µg/g) and the cancer effects screening level for inorganic arsenic (0.0003137 µg/g).

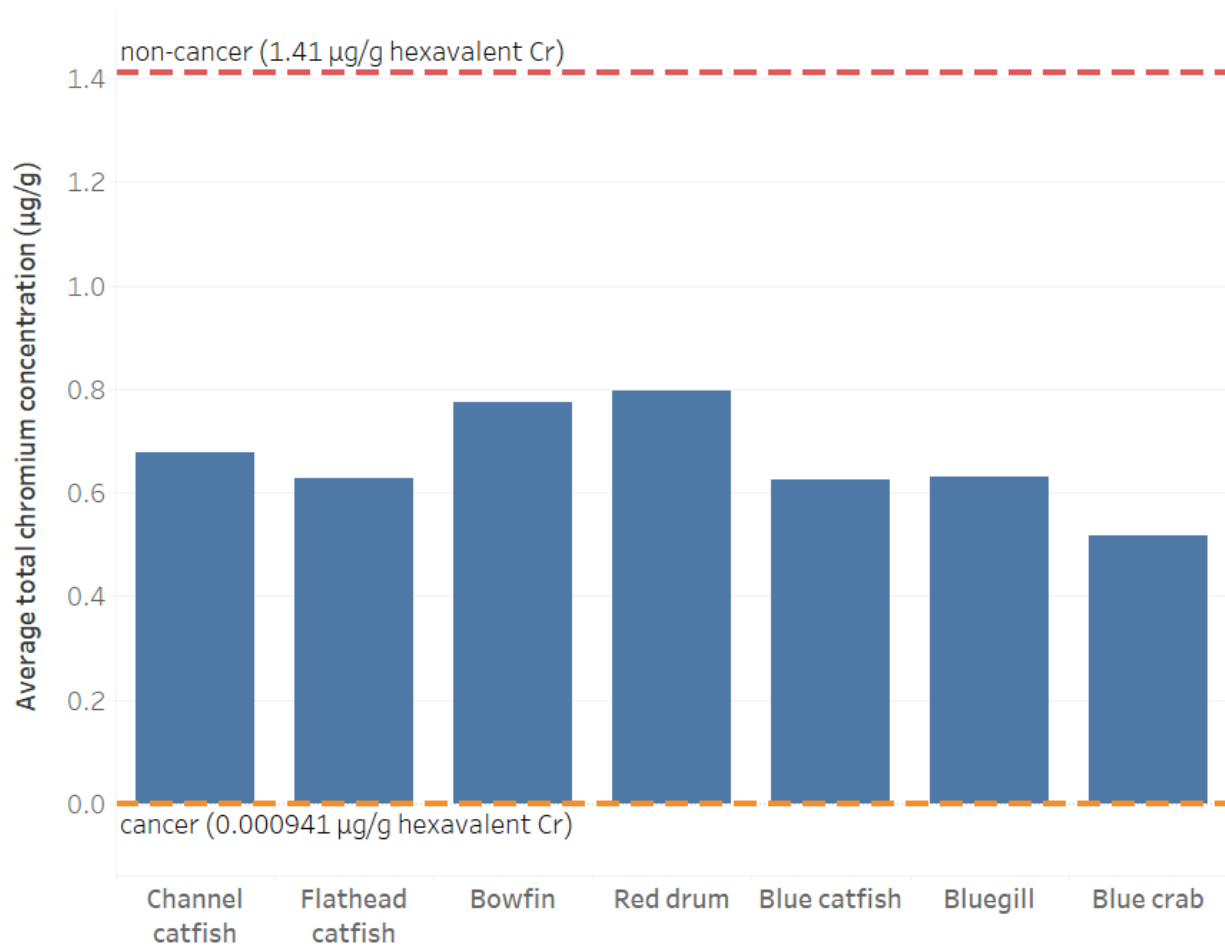
Neither blue catfish nor blue crab had enough samples to be considered for an advisory.

Only total arsenic was quantified. Inorganic arsenic was assumed to be 10% of total arsenic concentrations.

Chromium

All samples exceeded the NC DPH screening level for cancer effects for hexavalent chromium (0.000941 $\mu\text{g/g}$). None of the fish and blue crab samples exceeded the non-cancer screening level (1.41 $\mu\text{g/g}$) for hexavalent chromium. Total chromium levels were highest at Davis Creek (Navassa), Cape Fear River (Riegelwood), and Brunswick River (Belville) (0.7268, 0.7251, and 0.7098 $\mu\text{g/g}$, respectively), and for red drum (0.7969 $\mu\text{g/g}$) and bowfin (0.7738 $\mu\text{g/g}$).

Figure 10. Average total chromium (Cr) concentrations by fish species across all sites



Notes: The dotted lines represent the non-cancer effects screening level for hexavalent chromium (1.41 $\mu\text{g/g}$) and the cancer effects screening level for hexavalent chromium (0.000941 $\mu\text{g/g}$).

Neither blue catfish nor blue crab had enough samples to be considered for an advisory.

All total chromium was assumed to be hexavalent chromium.

Metal results by sampling site

Lab analysis quantified total mercury, arsenic, and chromium concentrations. The tables below display *estimated* methylmercury, inorganic arsenic, and hexavalent chromium concentrations, calculated according to the [standard assumptions](#) for total concentrations of the three metals/metalloid.

Table 7a. Average contaminant concentrations at Brunswick River (Belville)

	Mercury (µg/g)	Arsenic (µg/g)	Chromium (µg/g)
Blue crab	0.0799	0.0684	0.5168
Red drum	0.1525	0.0236	0.7969
Blue catfish	0.1425	0.0212	0.6790

Table 7b. Average contaminant concentrations at Burnt Mill Creek (Wilmington)

	Mercury (µg/g)	Arsenic (µg/g)	Chromium (µg/g)
Bluegill	0.0548	0.0049	0.6247
Flathead catfish	0.0869	0.0874	0.6276
Bowfin	0.4745	0.2049	0.7102

Table 7c. Average contaminant concentrations at Cape Fear River (Riegelwood)

	Mercury (µg/g)	Arsenic (µg/g)	Chromium (µg/g)
Bluegill	0.1299	0.0055	0.6636
Channel catfish	0.1673	0.0010	0.6790
Bowfin	0.4779	0.0364	0.8020

Table 7d. Average contaminant concentrations at Northeast Cape Fear River (Castle Hayne)

	Mercury (µg/g)	Arsenic (µg/g)	Chromium (µg/g)
Bluegill	0.1418	0.0010	0.5953
Blue catfish	0.1950	0.0036	0.5980
Bowfin	0.3679	0.0416	0.7704

Table 7e. Average contaminant concentrations at Davis Creek (Navassa)

	Mercury (µg/g)	Arsenic (µg/g)	Chromium (µg/g)
Bluegill	0.1087	0.0030	0.6337
Channel catfish	0.1460	0.0018	0.6763
Bowfin	0.1869	0.1014	0.8130

PCBs and dioxins/furans

Dioxins and furans were not detected in any fish samples. This result does not mean that dioxins/furans are not present in fish sampled in the lower Cape Fear. This result simply means that dioxin and furan concentrations in these fish samples were smaller than what can be measured with the instrument used in this analysis. These detection limits are on the order of 0.0000001 µg/g. Some PCBs were measured in each fish sample, but concentrations were about 10 times lower than NC Department of Public Health screening levels.

V. Risk Assessment and Fish Consumption Advisory Setting

After fish tissue testing was completed, we worked closely with the NC Department of Health and Human Services to assess potential health risks from eating these fish, and to determine whether any new fish consumption advisories were warranted.

Calculating Meal Limits and Setting Advisories

Meal limits are recommendations for the maximum number of meals of a given fish per week or month, based on the fish tissue toxicity data. As shown in Appendix A, if the calculated meal limit is less than 7 meals/week, then a fish consumption advisory will be issued if a more stringent advisory does not already exist. Appendix C of NC DPH 2017 provides formulae for calculating meal limits for cancer and non-cancer health effects. These calculations were done using the average contaminant concentration for each species per site. Meal limits were calculated based on estimated concentrations of methylmercury, inorganic arsenic, and hexavalent chromium.

Generally, fish consumption advisories corresponding to calculated meal limits are issued for the contaminant that presents the greatest health risk, whether cancer or non-cancer, at a given site. In the following tables, meal limits for mercury were calculated for non-cancer health effects, while meal limits for arsenic and chromium are for cancer health effects (meal limits for non-cancer health effects for arsenic and chromium were not calculated since average concentrations did not exceed non-cancer screening levels). When multiple contaminants are considered, fish consumption advisories are based on the most restrictive, or health protective, meal limit recommendation of the individual contaminants.

These tables represent our own calculated meal limits and the NC Division of Public Health's final fish advisory and recommended meal limits, issued on October 6, 2021. Fish with meal limits greater than 7 (that is, can be eaten daily) have no meal limit advisory. For fish whose calculated meal limits were below 1 meal per week, the Division of Public Health chose to round these down to 0 to be more health protective. Our calculated meal limits for these fish are listed to two decimal places.

Table 8a. Brunswick River (Belville)

	Meals per week			
	Mercury	Arsenic	Chromium	Final Advisory
Blue crab*	4.84	3.37	1.28	3 (2017 advisory)**
Red drum	2.94	no limit	0.83	0
Blue catfish*	2.32	No limit	0.97	1 (statewide Hg advisory)***

Meal limits are for non-cancer health effects for mercury, and cancer health effects for arsenic and chromium.

* Blue crab and blue catfish did not have enough samples collected within one week to be considered for an advisory.

** No update. See [2017 Kerr-McGee advisories](#)

*** No update. See [Table 1](#) for more detail about statewide mercury advisory. Meal limit for the general public is shown, separate guidance for more vulnerable groups.

Location: Brunswick River near US Hwy. 74 / US Hwy. 17 bridge

Notable changes: The statewide advisory classifies red drum as LOW in mercury and recommends 2 meals/week for vulnerable populations and 4 meals/week for others. The new advisory recommends that no one eat any red drum caught from this site.

Table 8b. Burnt Mill Creek (Wilmington)

	Meals per week			
	Mercury	Arsenic	Chromium	Final Advisory
Bluegill	6.23	no limit	1.06	1
Flathead catfish	3.93	no limit	1.05	1 (statewide Hg advisory)*
Bowfin	1.08	1.16	0.93	0

Meal limits are for non-cancer health effects for mercury, and cancer health effects for arsenic and chromium.

* No update. See [Table 1](#) for more detail about statewide mercury advisory. Meal limit for the general public is shown, separate guidance for more vulnerable groups.

Location: near the Archie Blue Community Park, upstream of the confluence of Burnt Mill Creek with Smith Creek

Notable changes:

- The statewide advisory classifies bluegill as LOW in mercury and recommends 2 meals/week for vulnerable populations and 4 meals/week for others. The new advisory recommends that no one eat more than 1 meal/week of bluegill caught from the site.

- Bowfin are classified as HIGH in mercury, so the statewide advisory recommends no meals for vulnerable populations and 1 meal/week for others. The new advisory recommends that no one eat any bowfin caught from this site.

Table 8c. Cape Fear River (Riegelwood)

	Meals per week			
	Mercury	Arsenic	Chromium	Final Advisory
Bluegill	2.59	no limit	1.00	1
Channel catfish	2.15	no limit	0.97	0
Bowfin	0.86	6.23	0.82	0

Meal limits are for non-cancer health effects for mercury, and cancer health effects for arsenic and chromium.

Location: between Riegelwood Landing and the confluence of Livingston Creek and Cape Fear River

Notable changes:

- The statewide advisory classifies bluegill as LOW in mercury and recommends 2 meals/week for vulnerable populations and 4 meals/week for others. The new advisory recommends that no one eat more than 1 meal/week of bluegill caught from the site.
- All catfish and bowfin are classified as HIGH in mercury, so the statewide advisory recommends no meals for vulnerable populations and 1 meal/week for others. The new advisory recommends that no one eat any channel catfish or bowfin caught from this site.

Table 8d. Northeast Cape Fear River (Castle Hayne)

	Meals per week			
	Mercury	Arsenic	Chromium	Final Advisory
Bluegill	2.42	no limit	1.11	1
Blue catfish*	1.74	no limit	1.11	1 (statewide Hg advisory)**
Bowfin	1.43	6.13	0.68	0

Meal limits are for non-cancer health effects for mercury, and cancer health effects for arsenic and chromium.

* Blue catfish did not have enough samples to be considered for an advisory.

** No update. See [Table 1](#) for more detail about statewide mercury advisory. Meal limit for the general public is shown, separate guidance for more vulnerable groups.

Location: near Riverside Park Community Building, upstream of the I-40 bridge, at Castle Hayne Boat Ramp

Notable changes:

- The statewide advisory classifies bluegill as LOW in mercury and recommends 2 meals/week for vulnerable populations and 4 meals/week for others. The new advisory recommends that no one eat more than 1 meal/week of bluegill caught from the site.
- Bowfin are classified as HIGH in mercury, so the statewide advisory recommends no meals for vulnerable populations and 1 meal/week for others. The new advisory recommends that no one eat any bowfin caught from this site.

Table 8e. Davis Creek (Navassa)

	Meals per week			
	Mercury	Arsenic	Chromium	Final Advisory
Bluegill	3.08	no limit	1.04	1
Channel catfish*	2.32	no limit	1.01	1 (statewide Hg advisory)**
Bowfin	1.97	2.19	0.82	0

Meal limits are for non-cancer health effects for mercury, and cancer health effects for arsenic and chromium.

* Channel catfish did not have enough samples to be considered for an advisory.

** No update. See [Table 1](#) for more detail about statewide mercury advisory. Meal limit for the general public is shown, separate guidance for more vulnerable groups.

Location: downstream of Cartwheel branch, upstream of the confluence of Davis Creek and Cape Fear River in Navassa, NC

Notable changes:

- The statewide advisory classifies bluegill as LOW in mercury and recommends 2 meals/week for vulnerable populations and 4 meals/week for others. The new advisory recommends that no one eat more than 1 meal/week of bluegill caught from the site.
- Bowfin are classified as HIGH in mercury, so the statewide advisory recommends no meals for vulnerable populations and 1 meal/week for others. The new advisory recommends that no one eat any bowfin caught from this site.

Limitations of New Advisories

Uncertainty of hexavalent chromium assumptions

In the majority of calculated meal limits for fish species by site, the most restrictive contaminant was hexavalent chromium. Given this, it is important to understand the methods and assumptions in the chromium calculations to clarify the strength behind these recommendations.

The Element One laboratory was only able to quantify total chromium, and not hexavalent chromium. Therefore, we used the standard DHHS assumption that all the detected chromium was in its hexavalent form. Because hexavalent is the most toxic form of chromium, this is a conservative, more protective, assumption. Fish consumption advisories that are based on this assumption will be health protective for chromium, regardless of the actual breakdown of the chromium in the fish.

This assumption may lead to chromium advisories that *overestimate* health risks and meal limits that are too strict. The trivalent form of chromium is common in the environment, though it does not accumulate in fish as easily, and is considerably less toxic (DesMarias and Costa 2019). The assumption about hexavalent chromium was necessary because of our limited data, but quantifying hexavalent chromium concentrations should be a goal for future fish tissue collection and testing in the lower Cape Fear River basin.

Do not consider most vulnerable populations

As we mentioned in [Section II](#), the statewide mercury advisory sets separate guidelines for children under 15 years old, women of childbearing age (15 to 44 years), pregnant women, and nursing mothers to account for the fact that these groups are more vulnerable to mercury exposures. However, the new advisories do not distinguish between risk for these more vulnerable groups and the general public. Despite this, risks are likely to be higher if the person eating a fish is from one of these more vulnerable groups. Therefore, we can assume that the new fish advisories may *underestimate* health risks for children under 15 years old, women of childbearing age (15 to 44 years), pregnant women, and nursing mothers.

Do not consider cumulative exposure

For fish consumption advisories, North Carolina considers each chemical exposure risk in isolation from other chemical exposures. Our data and past data show that fish in the Cape Fear River normally contain multiple chemicals of concern. Some chemicals have similar toxicity endpoints and therefore impact the same organs or systems. Their health impacts can thus be additive or synergistic (that is, greater than just adding the two individual risks together). Since

the State focuses on the individual chemical that poses the highest health risk to set meal limits and advisories, this may *underestimate* the risk posed from the cumulative exposure to multiple chemicals. While this practice of setting advisories based on individual chemicals is common, a Great Lakes study estimated that half of all Ontario-based advisories underestimated risk when they considered contaminants in isolation instead of additively (Gandhi et al. 2017).

Confined geographically

As noted in [Section II](#), the new advisories apply to the specific and limited geographic areas where we collected fish tissue samples. This limits the utility of these advisories and can cause confusion for non-experts who might have difficulty keeping track of the differences in advisories across locations.

Currently, the advisory setting process does not take into account movement and migration of fish to other locations within rivers or other water bodies, but we know that many fish do move beyond the relatively confined sampling locations.

VI. Conclusions

People are eating fish from the lower Cape Fear River basin; many do so out of need and in amounts likely to have health impacts

The combined results of the two surveys, household and bankside, indicate that many of the people who fish from the lower Cape Fear River are eating what they catch or sharing their catch with others. The types and amounts of wild caught fish consumed are often enough to have health impacts, particularly in vulnerable populations such as children under 15 and pregnant people. Some people consuming wild caught fish have low socio-economic status and indicators of food insecurity. A third of participants in the household survey had children who received free or reduced-price lunches at school, a fifth received SNAP benefits, and a tenth earned less than \$12,000 income per year.

Not only is fishing, and cooking and eating fish an important cultural practice in the region, but subsistence fish consumers depend on what they catch from the lower Cape Fear to feed themselves and their families. Survey results indicate that people are unwilling to completely stop consuming wild caught fish, so messaging needs to clearly state health risks while also offering options for safer species, preparation methods and consumption limits.

Our fish tissue testing results and the new advisories provide more information about safely eating fish from the lower Cape Fear

Our recent fish tissue sampling and testing work represents a significant addition in knowledge regarding the health risks associated with various fish and fishing locations in the lower Cape Fear River basin. More restrictive fish consumption advisory limits were deemed necessary primarily based on the levels of hexavalent chromium levels in fish and crab tissue, which, along with arsenic, had previously only triggered an advisory for striped bass in the lower Cape Fear River basin. This makes the need for multi-chemical testing stark, since singular approaches that only test for mercury will miss these risks.

While acknowledging the limited resources afforded to state agencies, the region has seen extremely limited fish tissue sampling over the last decade. At the same time, the interest in the issue has grown since the designation of Kerr-McGee as a Superfund site and amid the ongoing, highly publicized issues with PFAS and other contaminants. The 2020-2021 sampling work and the resulting fish consumption advisories provide additional nuance to our understanding of health risks as well as a foundation for additional monitoring moving forward.

There is still more to learn about the risks of eating fish from the lower Cape Fear River basin

Unfortunately, many knowledge gaps still exist. As mentioned in [Section V](#), our work represents a significant but still limited increase in understanding about the health risks of eating fish from the lower Cape Fear River. Our sampling was limited geographically, in the number of samples we were able to collect, and in the contaminants we were able to analyze. More widespread and consistent sampling in the region will help develop a more holistic and nuanced understanding of health risks.

It also is abundantly clear that current fish consumption advisories, which are determined based only on health risks from individual contaminants, do not align with people's real-life exposures to chemical mixtures nor, in some cases, to differential health risks for more vulnerable populations. Future advisories and guidance should account for these realistic exposure scenarios and the resulting health impacts. In addition, the gap in knowledge of hexavalent chromium concentrations is particularly important. Currently, risk assessments use a necessary but simplistic assumption to estimate hexavalent chromium concentrations. Future sampling and testing work should strive to more specifically and accurately quantify hexavalent chromium concentrations in fish tissue.

More work is needed to communicate health guidance and risks broadly and effectively

Attendees to the 2019 NC [Fish Forum](#) discussed how resource constraints limit all phases (tissue collection, testing, data analysis, risk assessment, and outreach) of the fish consumption advisory process (Gray et al. 2019). This is still a problem today, and the important work of responding to the COVID-19 pandemic has not made it any easier for state and local public health officials to focus on less pressing health concerns such as risks from subsistence fish consumption in the lower Cape Fear River. Nonetheless, the issue still has human health implications that are felt most acutely by already overburdened groups. More work is needed to reach those target groups, and to communicate the information in these advisories more broadly and effectively.

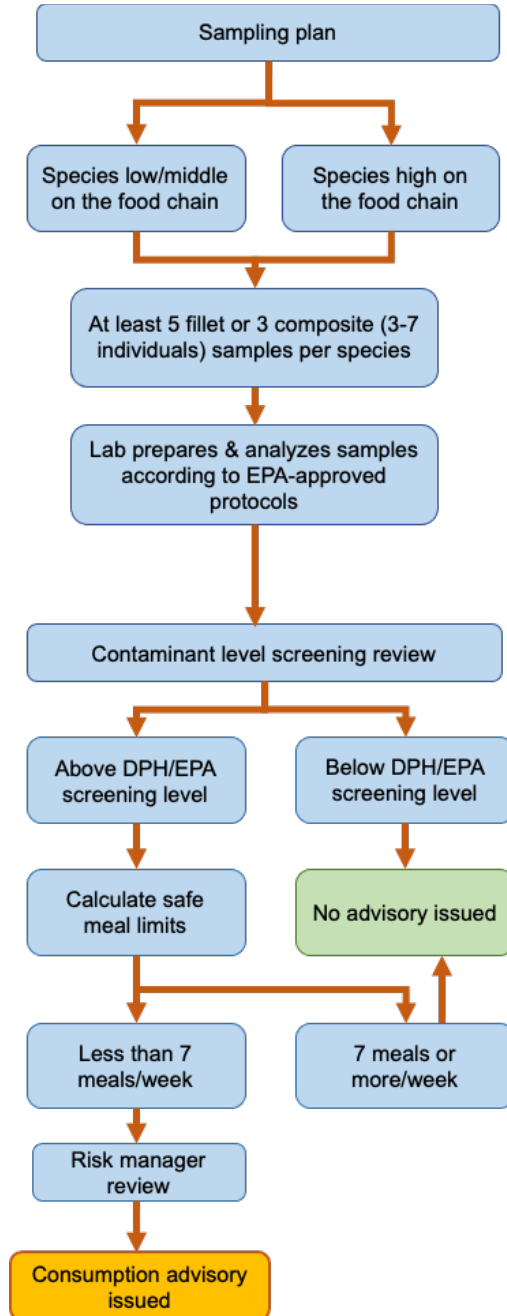
In a state with nearly 3,000 miles of impaired streams and rivers (Sorg 2022), and where catching and eating fish is a culturally vital activity and primary source of food for so many, this is an issue that deserves greater recognition and support.

VII. References

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VIII. Appendix

Fish Tissue Testing and Risk Assessment Process Flow Diagram



Flowchart of sampling, contaminant review, and risk assessment process. Adapted from NC DPH 2017.