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Public Perceptions of PFAS in Dane County Lakes and its Influence on Fish Consumption

Abstract

PFAS are a group of chemicals that have been used in manufacturing and industrial processes for decades. Researching PFAS is essential because these chemicals are still widely misunderstood and can bioaccumulate in people, animals, and the environment over an extended period. The more extensive work of PFAS research reveals exposure pathways and health effects of exposure to PFAS over a long period of time. Unlike the larger scientific body of research on PFAS, this project attempts to reveal the relationship between knowledge of PFAS and fish consumption rates in the greater Dane County region. The core objectives of the study are: (1) to understand public perceptions of PFAS in the context of fish consumption, (2) to understand how PFAS influences consumption decisions, and (3) to quantify data to understand broader trends through visuals such as maps and graphs. The primary method of this research project was a Qualtrics survey distributed to students in the UW-Madison Geography Department, along with various Dane County fishing groups. The main findings of this research project are that there is a direct correlation between age and knowledge of PFAS and that knowledge of PFAS typically influences fish consumption decisions in the Dane County area. This work adds to the current body of knowledge by revealing that knowledge of PFAS influences consumption choices.

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Introduction

Per- and polyfluoroalkyl substances. What are they? Where do they come from? Are they harmful to humans? Per- and polyfluoroalkyl substances, also known as PFAS, are "a group of manufactured chemicals that have been used in industry and consumer products since the 1940s because of their useful properties… One common characteristic of concern of PFAS is that many break down very slowly and can build up in people, animals, and the environment over time" (U.S. EPA, *Our Current Understanding,* March 16 2022). In other words, PFAS are chemicals in many products manufactured for human use, and they leach into the environment through many different lanes. Ultimately, PFAS exposure for humans can have many adverse health effects, such as increased cholesterol levels, hormone interference, decreased fertility among women, and the list goes on and on (EPA). These dangers are why you should be aware of PFAS; they can cause you harm, and there's a chance you've never even heard of them.

Frequently, humans have perceptions about the environment they live in. Which lakes are clean? Which lakes are polluted? Which area of town has the best restaurants? While humans have these perceptions about the environment in which they live, to which degree are these perceptions accurate? Our project sets out to answer the research question: how do perceptions of PFAS in Dane County lakes differ geographically, and how do these perceptions impact consumption decisions? The core objectives of the study are: (1) to understand public perceptions of PFAS in the context of fish consumption, (2) to understand how PFAS influences consumption decisions, and (3) to quantify data to understand broader trends through visuals such as maps and graphs. Answering these questions will allow us to understand how PFAS awareness affects fish consumption rates in the Dane County area.

To answer these questions, we will survey and interview local fishers to find any useful qualitative data they may have to share regarding their attitudes towards fish consumption/PFAS, as well as any personal anecdotes they find helpful or essential. We will then compare our interview/survey results of knowledge of PFAS with individual fish consumption choices, analyzing the results through various demographic factors such as race, age, and zip code. The location of our study area will be focused on the Madison chain of lakes, specifically Lake Mendota, Lake Monona, Lake Waubesa, Lake Kegonsa, Lake Wingra, and the Yahara River.

Geographic Setting

The location of our study area was focused on the Madison chain of lakes, specifically Lake Mendota, Lake Monona, Lake Waubesa, Lake Kegonsa, Lake Wingra, and the Yahara River.

Literature Review

I. What are PFAS?

First and foremost, the most common point of agreement among the gathered sources is the definition of PFAS. After all, the definition is foundational to all other research concerning PFAs. It makes sense to base any scientific research on a commonly accepted definition of PFAS. In a proposal from the Committee on Science, Space, and Technology to The U.S. House of Representatives, researchers defined PFAS as “a group of man-made chemicals that have been used in a wide range of products since the 1940s including firefighting foam, carpeting, packaging, and cookware" (House of Representatives, 2022). One critique of this definition is that it is not very detailed when compared to the other definitions of PFAS in scientific research papers. In a research paper titled "PFAS Exposure Pathways for Humans and Wildlife," PFAs are defined as "a class of thousands of anthropogenic substances containing an aliphatic fluorinated carbon chain. The PFAS family includes 1) perfluoroalkyl substances, mainly perfluoroalkyl acids (PFAA) such as perfluoroalkyl carboxylates (PFCA) and perfluoroalkyl sulfonates (PFSA), as well as perfluoroalkyl sulfonamide substances; and 2) polyfluoroalkyl substances such as fluorotelomer monomers, including fluorotelomer alcohols (FTOH), fluorotelomer olefins, and fluorotelomer iodides, and polyfluoroalkyl ether acids" (De Silva, p. 631). The definition of PFAS in the scientific literature is much more detailed and chemistry focused than the definition of PFAS in the Federal PFAS Research Evaluation Act. At first, this may seem to be a possible critique of the Federal PFAS Research Evaluation Act. However, it is valuable to consider the audience to which this information was being presented. The members of the House of Representatives are not scientists and, therefore, would not understand information about the chemical structure of PFAS. Concerning enacting policy, knowledge of the complicated chemistry of PFAS is not required. Compared to yet another scientific research paper titled "Exposure pathways and bioaccumulation of per- and polyfluoroalkyl substances in freshwater aquatic ecosystems," PFAS is defined as "a diverse set of chemicals that accumulate and transport quite differently in the environment depending on the length of their fluoroalkyl chains and their functional groups" (Lewis et al. 2022). When comparing these three papers, three seemingly different definitions of PFAS are found. However, it is clear that these sources define PFAS in a way that structures the subsequent research and serves the specific purpose of each source.

II. How does PFAS get into the water supply/fish?

After decades of research, scientists and politicians widely accept that “PFAS have been detected in air, water, soil, foods, biosolids, and more” (House of Representatives, 2022). The question is, how do PFAS get into things like the water supply and fish? According to a research paper titled “PFAS Exposure Pathways for Humans and Wildlife,” “Sources of local-scale contamination include fluorochemical manufacturing facilities, other manufacturing facilities where PFAS are used, PFAS-containing AFFF, wastewater-treatment plants, and landfills” (De Silva et al. 2020). In other words, PFAs seem to saturate local populations near PFA-producing activities. Other researchers pose an almost identical assertion in another scientific paper titled “Detection of Poly- and Perfluoroalkyl Substances in U.S. Drinking Water Linked to Industrial Sites, Military Fire Training Areas, and Wastewater Treatment Plants.” The assertion is, "The number of industrial sites that manufacture or use these compounds, the number of military fire training areas, and the number of wastewater treatment plants are all significant predictors of PFAS detection frequencies and concentrations in public water supplies” (Hu et al. 2016). While there are many other uncertainties concerning PFAS, the sources and ways in which PFAS accumulate in drinking water and, therefore, fish are widely accepted. This information is highly relevant to our research because there are industrial sites, firefighting training areas, and a military base within the city limits of Madison. Knowing these sources will help give context to our site setting and determine why we chose to study specific areas.

III. Exposure Pathways to Humans

Since the 1950s, PFAS have been manufactured for consumer products across multiple industries, creating the first wave of exposure to humans. Unsurprisingly, workers involved in the manufacturing process were at the forefront of PFAS exposure. A study titled “PFAS Exposure Pathways for Humans and Wildlife: A Synthesis of Current Knowledge and Key Gaps in Understanding” aimed to discover the primary pathways for PFAS to reach humans. Through plasma and serum sampling, researchers found that people employed at a PFAS manufacturing site had up to a thousand percent more micrograms per liter of PFAS in their samples compared to the general population (De Silva et al. 2020).

Another pathway for human exposure to PFAS is through consumers’ use of products manufactured with PFAS. Though it is unknown exactly how much PFAS companies have manufactured over the years, in 2000, 3M, the prominent manufacturer of PFAS, produced over 6.5 million pounds for use on consumer products (Hites, pg 394). These products range from refrigerants, polymers, pharmaceuticals, lubricants, adhesives, pesticides, corrosion inhibitors, cosmetics, and stain-resistant treatments for leather, paper, and clothing (Hites, pg 393). In the study by De Silva et al., they researched the dermal (through skin) absorption of PFAS. Absorption was not an issue for many products. Still, cosmetics specifically saw high levels of dermal absorption, “Estimated dermal absorption of PFOA in foundation cosmetics, leading to an absorbed dose through dermal exposure of <0.006 to 3.1 ng/kg/d, with the high end exceeding dietary exposure in Sweden” (De Silva et al. 2020).

Another main avenue for PFAS to be absorbed by humans is through drinking contaminated water. During a study titled “Detection of Poly- and Perfluoroalkyl Substances (PFAS) in U.S. Drinking Water Linked to Industrial Sites, Military Fire Training Areas, and Wastewater Treatment Plants,” researchers tested 4064 public water sources across the U.S. that supply water to more than 10,000 people. They found that “Six million people were served by 66 public water supplies that have at least one sample at or above the US EPA’s 2016 health advisory for PFOS and PFOA (70 ng/L individually or combined)" (Hu et al., 2016). This study also compared surface water levels to groundwater levels, finding that the "detection frequency in drinking water sourced from groundwater was more than twice that from surface water" (Hu et al., 2016). These findings disadvantage Wisconsin further since the state relies on groundwater to source drinking water for two-thirds of the state's population (WI DNR).

The next main pathway covered in our literature is the exposure by air, more specifically, the inhalation of dust particles in the air. Although for years, science regarded the air as a non-factor in PFAS exposure, recent studies have found that PFAS can be released into the air by PFAS-treated home goods and personal care products, "Indoor air may represent a dominant direct route for human exposure" (Pfotenhauer et al. 2022). This finding is especially worrisome for our current population because the average North American spends around 90% of their time indoors, and PFAS are commonly used in indoor products like carpeting and furniture (De Silva et al. 2020). Another aspect of exposure to air and dust is which PFAS are most commonly present. Researchers found that PFOS and PFOS are both very common in the dust. Unfortunately, PFOAS and PFOS are both very hazardous kinds of PFAS (De Silva et al., 2020).

The last major pathway for PFAS to be absorbed by humans in our literature is the consumption of contaminated fish, predominantly freshwater. During a study performed in Sweden, researchers set out to find if fish consumption impacted human levels of PFAS, and what factors, if any, were behind it. Through their tests, researchers discovered that freshwater fish were far more likely to have high levels of PFAS than saltwater species (Augustsson et al. 2021). The mean PFOS concentrations in the marine species were between 0.16 and 9.2 μg/kg. In contrast, the mean concentration in freshwater carp was 14.1 μg/kg, which aligned with previous studies which found that mean concentrations in fish muscle from Lake Vättern in

Sweden (where mean concentrations in perch were 11.3 µg/kg) far outweighed the Baltic Sea (mean concentration 2.1 µg/kg) (Berger et al. 2009). Furthermore, researchers found that for male "normal consumers" (eating freshwater fish three times a year), when the consumed fish contains on average 59 µg PFOS per kg fish meat, they reach the maximum dietary intake proposed by EFSA (European Food Safety Authority), which is 0.42 µg per kg bodyweight and year (Augustsson et al. 2021). As well, for "high consumers" (eating freshwater fish once a week), a mean concentration of only 3.4 µg PFOS per kg consumed fish is enough to reach the annual maximum intake (Augustsson et al. 2021). The study concludes that at least 50% of PFOS exposure in their study region relates to the consumption of (commercial) fish (Augustsson et al. 2021).

IV. Health Effects / Outcomes from PFAS

The primary concern of PFAS consumption is public health. Peer-reviewed scientific studies have shown that exposure to PFAS can lead to (1) reproductive effects such as decreased fertility, lower birth weight, reduced response to vaccines, (2) increased risk of cancers including prostate, kidney, and testicular cancers, (3) reduced ability to fight infections and disease, (4) interference with the body's natural hormones, (5) increased cholesterol or risk of obesity, and other outcomes (Augustsson et al. 2021).

A study titled "Perfluoroalkyl substances in older male anglers in Wisconsin" aimed to examine PFAS levels and their determinants, as well as associations between PFAS levels and self-reported health outcomes, in a group of older male anglers in Wisconsin with high fish consumption (Christensen 2016). Researchers conducted the study through biomonitoring by collecting detailed information on fish consumption, demographics, and self-reported health outcomes, along with hair and blood samples for biomarker analysis. Scientists extracted 16 different PFAS from samples, and regression models were used to identify factors, demographic characteristics, and fish consumption habits) associated with PFAS biomarker levels in the blood and associations between PFAS and self-reported health outcomes (Christensen 2016).

The study's results helped draw some essential and concrete conclusions about PFAS and fish consumption, especially in Wisconsin. Scientists found that seven PFAS were detected in at least 30% of participants and then used them in subsequent analyses (PFDA, PFHpS, PFHxS, PFNA, PFOA, PFOS, PFuDA). Of those seven, The PFAS with the highest levels was PFOS. The study also found increasing age was associated with higher PFAS levels while increasing BMI was associated with lower PFAS levels. The study also examined lifestyle choices and their effects: greater alcohol consumption was associated with higher levels of PFHpS, PFHxS, and PFOA, but associations with smoking and employment did not show a consistent pattern (Christensen 2016).

Researchers also examined health outcomes from exposure to the seven PFAS. They found that PFuDA, PFNA, and PFDA were all associated with an increased risk of pre-diabetes or diabetes. In contrast, PFHpS was associated with a significantly increased risk of high cholesterol. The study's most important conclusion is that fish consumption significantly contributes to PFAS consumption and that scientists still need more time and studies to reach broader conclusions.

A study titled “Consumption of freshwater fish: A variable but significant risk factor for PFOS exposure” set out to study PFOS exposure in freshwater fish among “normal” and “high” consumers. They define “normal” consumers as people assumed to eat freshwater fish three times per year and define “high” consumers as people who consume freshwater fish once a week. Researchers conducted the study in Sweden, where they collected three fish species from three different locations. The three species, pike, perch, and pike perch, are the most commonly consumed fish in Sweden. The three locations were (1)~100km off the Swedish coast in the Baltic Sea, (2) a freshwater source near urban Stockholm labeled as “Urban Stockholm,” and (3) a semi-rural freshwater source labeled as “Semi-Rural Kronoberg” (Augustsson et al. 2021).

In fifteen sites of the “Urban Stockholm” dataset, mean concentrations ranged from 2.9 to 44 µg/kg, and the “Semi-Rural Kronoberg” sites had mean PFOS concentrations between 0.9 and 13.0 µg/kg, which means that there were consistently higher concentrations in urban areas than in semi-rural areas. These findings imply that the largest source of variation in fish PFOS concentrations is the fishing location and not which fish species are being caught. The mean PFOS concentrations in the marine species were between 0.16 and 9.2 µg/kg, while the mean concentration in freshwater carp was 14.1 µg/kg (Augustsson et al. 2021). This result confirmed a pre-existing theory that there are higher PFOS concentrations in freshwater fish than in marine fish. Berger et al. (2009), who compared concentrations in fish muscle from Lake Vättern in Sweden (where mean concentrations in perch were 11.3 µg/kg) and the Baltic Sea (mean concentration 2.1 µg/kg), came to the same conclusion. The maximum dietary intake proposed by EFSA (0.42 µg per kg bodyweight and year) is reached for male “normal consumers” when the consumed fish contains, on average, 59 µg PFOS per kg fish meat. This suggests that male “high consumers” with a mean concentration of 3.4 µg PFOS per kg consumed fish is enough to reach the annual maximum intake. The study also found that PFOS intakes per kg body weight are consistently higher (1.26 times) for men than for women. Both Augustsson et al. 2021 and Christensen 2016 concluded that freshwater fish must be considered a critical source of PFOS exposure related to average dietary PFOS intake. Additionally, Augustsson et al. 2021 concluded that more research must be done to understand PFOS concentrations in freshwater fish and the health outcomes that are associated with it.

V. Types of Anglers and their exposure to PFAS

Past research divides angling activity into two main categories, recreational and subsistence (Dietz & Yang, 2020), (Ebbin S.A., 2017). Recreational anglers are those who fish for fun or sport, consuming some fish they catch but not as their primary source of food. Meanwhile, subsistence anglers use fishing as their primary source of protein due to economic or cultural reasons (Dietz & Yang 2020, pg 34). While the behaviors, target species, and consumption patterns of recreational anglers are well documented, little is known about the magnitude, diversity of species harvested, or consumption rates among subsistence anglers (Ebbin, 2017, pg 2). Moreover, because subsistence anglers tend to be from minority and non-English speaking groups, their knowledge of PFAS and consumption advisories is likely more limited than their recreational counterparts. For example, in Dietz & Yang's 2020 survey of subsistence fishers in North Carolina, 67% of individuals had seen fish consumption advisories, compared to 100% of respondents in the Ebbin survey of mainly suburban white males. (Dietz et Yang, 2020 pg 38), (Ebbin, 2017, pg 4). These percentages also align with consumption rates over the recommended guidelines, with only 6 percent of Ebbin's surveyed anglers consuming at rates higher than recommended guidelines, compared to 25% in Dietz and Yang's survey (Ebbin, 2017 pg 5) (Dietz & Yang, 2020, pg 34).

Forty-nine percent of respondents in Dietz and Yang's survey noted that they did not follow the recommended consumption guidelines posted by the state despite being aware of them. Given that the socioeconomic status of many subsistence anglers is below the poverty line, many individuals have no choice but to consume a free accessible protein source when others are far less obtainable. Because of this circumstance, subsistence anglers subject themselves and their families to high levels of PFAS, specifically the dangerous PFOS, which are the predominant PFAS in fish tissue (Ahrens et al. 2014, pg 34).

Due to the inevitability of PFAS exposure in subsistence anglers, a better tactic than reducing consumption is changing how they consume fish. Consuming species in lower trophic levels, fileting a fish, and grilling/baking instead of frying all present well-received ways that subsistence anglers can lower their PFAS consumption without actually removing wild harvest consumption altogether (Dietz & Yang, 2020, pg 39). We agree with Dietz and Yang's discoveries and believe the organizations responsible should display these consumption tactics on fish advisory signage.

VI. How is research relevant to our project?

The literature on PFAS is relevant to Madison for various geographic and demographic reasons. For starters, the legacy of the industrial PFAS deposits into the Madison chain of lakes has left the pertinent chemicals all around our water bodies. Not only are the effects of historical PFAS contamination present in the chain of lakes, current PFAS pollutants from the firefighting site at the Dane County Airport, aqueous film-forming foam (AFFF), continue to drain into the chain through the Starkweather Creek drainage basin. These PFAS have contaminated local wells and bio accumulated into fish many residents consume and rely on for daily protein consumption. The known adverse health effects of PFAS consumption put those who consume fish from the chain of lakes at direct threat of various adverse health effects, many of which are particularly harmful to pregnant women or women in childbearing years. Despite the literature concluding that over 80 percent of surveyed individuals were male, it also uncovered that most anglers share their catches amongst their families, which likely include women and children who are less aware of the consumption advisories than the men gathering the food.

VII. Literature Review Conclusion

While there are multiple definitions of the mysterious group of compounds known as PFAS, the research concludes that many of the thousands of artificial chemicals are hazardous, as they cause several adverse health effects and remain in the systems they contaminate indefinitely. Humans are exposed to these PFAS in various ways, from those manufacturing PFAS, to the air we breathe, the water we drink, and much of the food we consume. Our research focuses on the dietary pathway of PFAS through fish consumption, as angling is essential locally as both a source of recreation and subsistence. Through our surveys, we will compare the existing knowledge we know about PFAS in Dane County lakes with how the public perceives PFAS in Dane County lakes and how this knowledge guides individual fish consumption choices.

Methods

This study surveyed people who fish in Dane County and Madison's chain lakes. There were no qualifications or criteria beyond needing to fish in Dane County lakes. Our sample size ended up being 258 (total number of survey respondents). Data was collected by distributing a survey to various groups of people, such as the UW-Madison Fishing Club, UW-Madison

Geography students, UW-Center for Limnology, and a Facebook group of Dane County area anglers.

Results and Analysis

Figure 1

Q: Do you fish in Dane County Lakes?

We found that 201 respondents answered “Yes” to this question, and 45 respondents answered “No” to this question.

Figure 2

Q: What is your race/ethnicity?

171 of 187 respondents answered “White” as their race/ethnicity (~91.4%), 2 of 187 respondents answered “Black/African American” as their ethnicity (~1%), 0 of 187 respondents answered “American Indian or Alaska Native” as their ethnicity (0%), 3 of 187 respondents answered “East Asian” as their ethnicity (~1.6%), 4 of 187 respondents answered “Southeast Asian/Hmong” (~2%), 0 of 187 respondents answered “Native Hawaiian or Pacific Islander” as their ethnicity (0%), 1 of 187 answered “Hispanic” as their ethnicity (~0.5%), 1 of 187 answered “Latino/Latina/Latinx” as their ethnicity (~0.5%), 4 of 187 respondents answered “Mixed Race” as their ethnicity (~2%), and 1 of 187 respondents answered “Other” as their ethnicity (~0.5%).

Figure 3

Q: What is your age?

42 of 189 respondents selected "18-24" as their age range (~22.2%), 42 of 189 respondents selected "35-45" as their age range (~22.2%), 35 of 189 respondents selected "25-34" as their age range (~18.5%), 28 of 189 respondents selected "55-64" as their age range (~14.8%), 20 of 189 respondents selected "46-55" as their age range (~10.5%), 19 of 189 respondents selected "65+" as their age range (~10%), and only 3 of 189 respondents selected "<18" as their age range (~1.5%).

After that, the range "55-64" was the fourth most selected, with 28 choosing it (~14.8%). Finally, 20 respondents selected "46-55" as their age range (~10.5%). The second least frequently selected age range was "65+", with 19 selecting it (~10%). The least common answer was the range "<18."

Figure 4

Q: How often do you fish in Dane County?

74 of 187 respondents answered, "1-2 times per month" (37.5%), 6 of 187 respondents answered, "3-5 times per month" (3.2%), 1 of 187 respondents answered, "6-8 times per month" (0.5%), 0 of 187 respondents answered "9+ times per month" (0%), and 106 of 187 respondents answered, "No, I do not eat fish caught in Dane County" (56.6%).

Figure 5

Q: Which of the following fish species do you consume?

Our survey found that the most consumed fish species were bluegill, walleye, yellow perch, and crappie. In total, 519 choices were recorded by our survey. Of those 519 choices, 108 were for bluegill (20.81%), 104 were for walleye (20.04%), 88 were for yellow perch (16.96%), and 73 were for crappie (14.07%). None of the other species recorded more than 9% of the total responses.

Figure 6

Q: Have you heard of PFAS chemicals?

150 of 183 respondents answered "Yes" (81.9%), and 33 of 183 respondents answered "No" (18.1%).

Figure 7

Q: Have you seen fish consumption advisory signs?

149 out of 183 respondents answered "Yes" (81.4%), 17 out of 183 respondents answered, "No" (9.2%), and 17 out of 183 respondents answered "Uncertain" (9.2%).

Figure 8

Q: Do fish consumption advisories impact your decision on what/how much fish to eat?

When answering whether or not the consumption advisories impact their decision to eat fish caught from Dane County lakes, 100 of 146 respondents selected "Yes" (~68.5%), and 46 of 146 selected "No" (~31.5%).

Figure 9

Q: Were the fish consumption advisory easy to understand?

Our survey found that the vast majority of respondents found the fish consumption advisory signs easy to understand. In total, 143 of 147 respondents selected “Yes” (97.28%), and 4 of 147 selected “No” (2.72%).

Figure 10

Q: What is your opinion on the water quality in your preferred lake?

When asked to rate the water quality of their preferred lake to fish in, 76 out of 181 rated their lake's water quality as “Neutral” (~41.9%), 48 out of 181 respondents rated water quality as “Favorable” (~26.5%), 43 of 181 respondents rated water quality as “Unfavorable” (~25.4%), 12 of 181 respondents rated water quality to be “Poor” (~6.6%), and 3 of 181 respondents rated water quality as “Excellent” (~1.6%).

Q: Why *don't* you eat fish caught in Dane County lakes?

26 of 86 respondents answered that they do not eat fish caught in Dane County lakes because of water quality/algae concerns, chemicals in water, and pollution in lakes (30.2%), 27 of 86 respondents answered that they do not eat fish caught in Dane County lakes because they only fish for catch & release/fish for sport (31.3%), 3 of 86 respondents answered that they do not eat fish caught in Dane County lakes because they don’t like fish (3.4%), 4 of 86 respondents answered that they do not eat fish caught in Dane County lakes because they do not eat fish under any circumstances (4.6%), 2 of 86 respondents answered that they do not eat fish caught in Dane County lakes because they do not have the time or space to cook fish (2.3%), 4 of 86 respondents answered that they do not eat fish caught in Dane County lakes because of PFAS

concerns (4.6%), and 1 of 86 respondents answered that they do not eat fish caught in Dane County because of fish advisory signs (1.1%).

Figure 11

Relationship between Age and Knowledge about PFAS.

Through our result analysis, we found a statistically significant relationship between a respondent's age and whether or not they have heard of PFAS chemicals. With a large sample size (183) and both variables having over two categories, Qualtrics suggested we run a Chi-Squared test to check for dependence. After running this test with six degrees of freedom, we got a Chi-Squared value of 32.8 and a p-value of 0.0000114. Since a P-Value less than 0.05 is considered significant, our result can be considered highly significant.

Figure 12

Perception of Water Quality in Preferred Fishing Lake

We presented the respondents with a Lickert scale on the perceived water quality in their favorite fishing lake. The choices in the ranking were: excellent, favorable, neutral, unfavorable, and poor. We took the preferred lake and their answer on perceived water quality and assigned a numerical value for each of the Lickert values, five excellent, four favorable, three neutral, two unfavorable, and one poor. We averaged the value for each chain lake and created a water quality index rating where the higher the number, the more favorable the perception of water quality.

Lake Wingra had the highest perceived water quality, with a value of 3.5. Next was Lake Waubesa, with a perceived water quality of 3.19. Lake Mendota had a perfect neutral rating of 3, followed by Lake Kegonsa with 2.8. Lake Monona had the lowest perceived water quality in the chain of lakes, with a value of 2.43

Figure 13

Map of the Distribution of Survey Replies by Zip Code

We asked the respondents what their zip code was to understand better the spatial extent of the use of the Madison Chain Lakes. We had a wide range of zip codes stretching throughout southern Wisconsin.

Figure 14

Map of the Knowledge of PFAS in Zip Codes With at Least Two Replies

Through our analysis, we wanted to see the spatial distribution of PFAS knowledge among Madison Chain Lakes anglers to understand if certain zip codes are under-informed on the issue of PFAS. To do this, we assigned each respondent a value to correlate with their awareness of PFAS, 1 for yes and 0 for no. We then averaged the value for each zip code and presented it in the choropleth map.

Discussion

This study was useful because it helps better understand the geographic and demographic breakdown of PFAS knowledge in Madison's Chain lakes. Results found that the vast majority of people surveyed identify as white (91.3%). Chirstensen 2016 found similar results, as only 2 of 111 (1.3%) of their subjects identified as non-white. This sample pool was a clear limitation to our research as we only received answers from 16 non-white people. The racially homogenous results have held us back from understanding patterns in racial demographics with respect to PFAS in Madison's lakes.

This study found that Bluegill is the most commonly consumed species, Walleye is the second most common, Yellow Perch is the third most common, and Crappie is the fourth most common.

The study also concluded that the public was aware that Lake Monona has the lowest water quality of any of the chain lakes but overestimated the quality concerning PFAS in Lake Waubesa and underestimated it in Lake Mendota. Despite the participants' relative understanding, their knowledge of PFAS and water quality did not impact individual fish consumption choices, as 85.2% of fish consumers knew of PFAS, compared to 79.4% awareness in the group who chose not to eat fish. This is an important finding because it reveals that even though people may be aware of PFAS, such awareness typically is not the main reason why people choose to consume or not consume fish.

Lastly, another one of our significant findings is the correlation between age and knowledge of PFAS. There's nearly a perfect correlation between an increase in age and having been informed about PFAS. Furthermore, this statistically significant relationship shows the correlation between education and knowledge of PFAS. Thus, we can infer between education and healthier fish consumption decisions.

The limited time allotted to complete the study impacted the results of our research. Ideally, we would have had an entire year to gather data and refine our analysis. If we had more time, we could have surveyed more people and possibly gotten more diverse respondents. As a result, our data doesn't necessarily represent the opinions of the entire population of Dane County fishers. More so, it represents the opinions of the mainly white fishing population in Dane County. This was most likely a result of the distribution methods for our survey. We didn't use a random sample to distribute our survey, which is probably why we received responses that don't represent the entire population of Dane County Fishermen. For more effective future research, we could spend more time figuring out who actually makes up the population of Dane County fishermen and then form a random sample from that more accurate population. This change would ideally lead to results that are more descriptive of the entire population of Dane County Fishermen.

Conclusion

In conclusion, our research revealed information about the knowledge of PFAS among Dane County Fishermen and how that knowledge affected their consumption decisions. Overall, most survey respondents were white and knew about PFAS but did not let their knowledge of PFAS affect their consumption decisions. Given one semester, we are happy with our research project and survey results. However, in the future, we would like more time to get a more accurate gauge of the Dane County Fishermen Population. All in all, our research project gave us deeper insight into the knowledge, beliefs, and habits of Fishermen in the Dane County region.

Acknowledgments

We would like to express our deepest gratitude to Professor Gartner. His direction, advice, and practical suggestions were invaluable to our research project. We are also grateful to our fellow students in Geography 565, who provided helpful advice intending to improve our research project. We would like to thank Markia Silverman-Rodriguez for her feedback and time spent helping us better our project. Next, we would like to thank Geography Department Advisor Joel Gruley for distributing our survey to the Geography Department. This was instrumental in garnering responses to our survey, which was used to generate our data and findings. Lastly, many thanks to all who responded to our survey. With their responses, we were able to complete this research project and have meaningful findings.

Figures and Tables / Appendix

((Graphic presentation of data and analyses)

Figure 1. **Q: Do you fish in Dane County Lakes?**

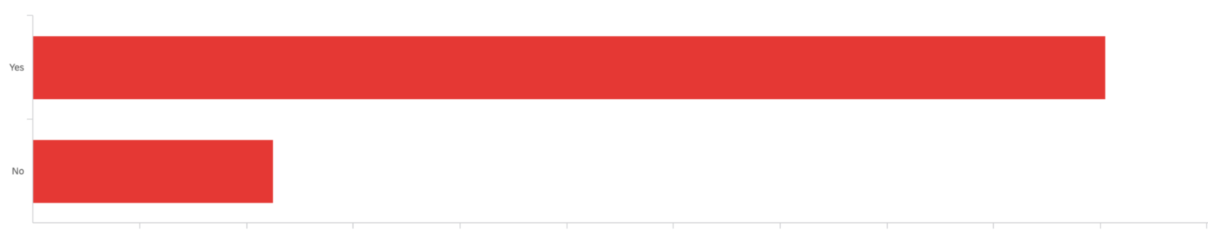


Figure 2. **Q: What is your race/ethnicity?**

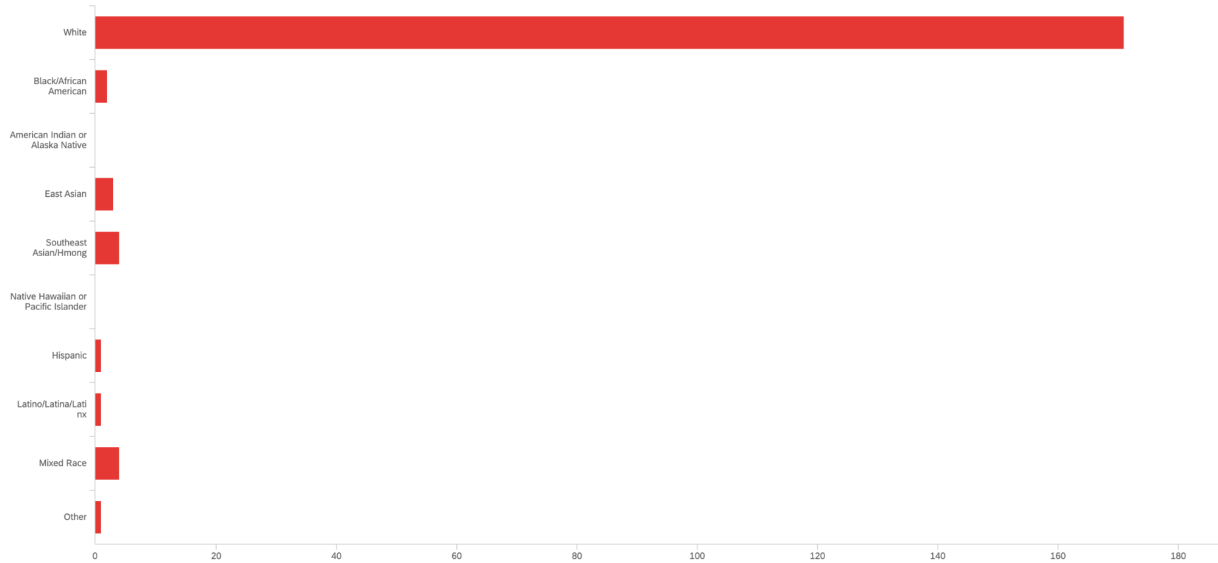


Figure 3. **Q: What is your age?**

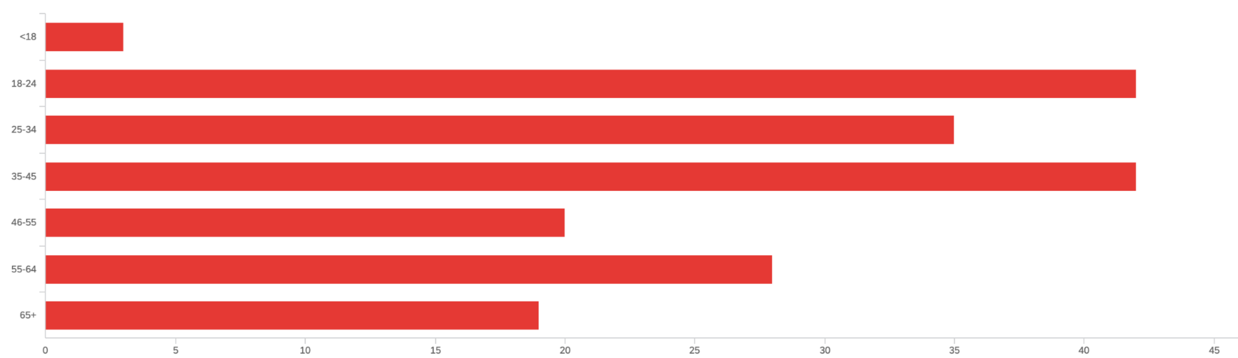


Figure 4. **Q: How often do you fish in Dane County?**

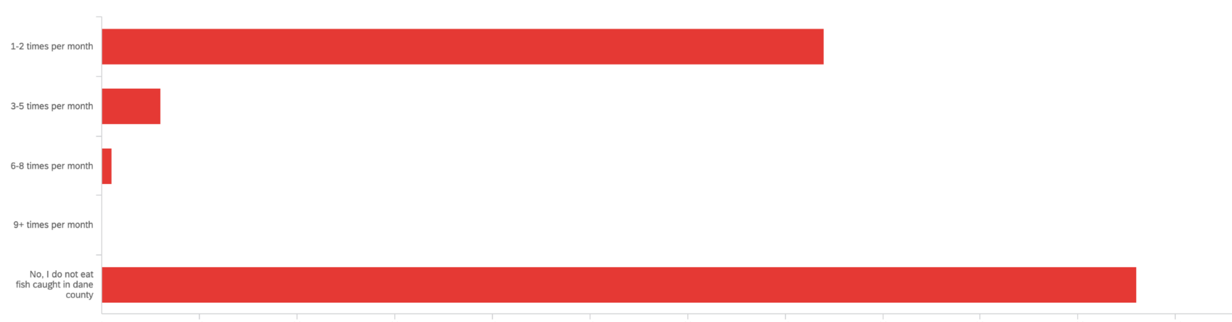


Figure 5. **Q: Which of the following fish species do you consume?**

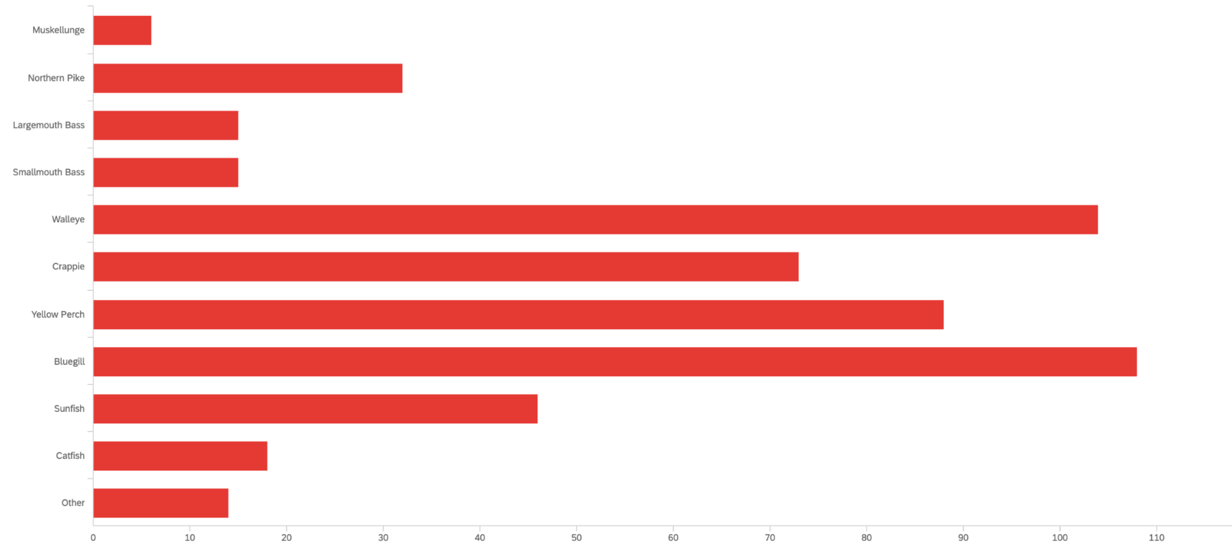


Figure 6. **Q: Have you heard of PFAS chemicals?**

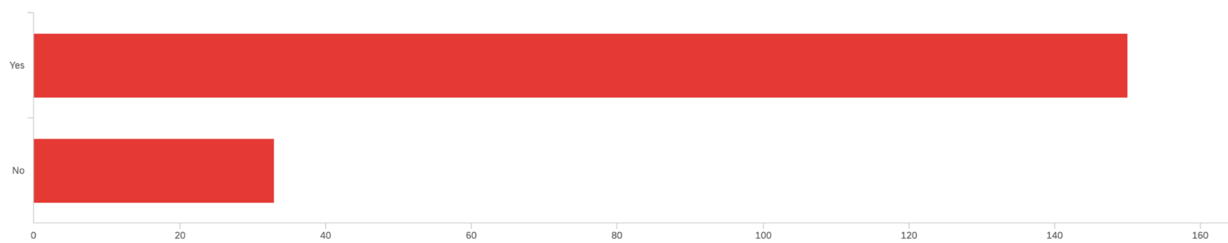


Figure 7. **Q: Have you seen fish consumption advisory signs?**

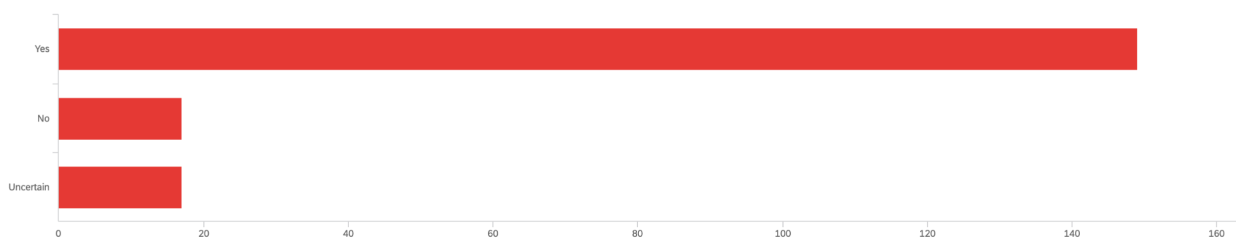


Figure 8. **Q: Do fish consumption advisories impact your decision on what/how much fish to eat?**

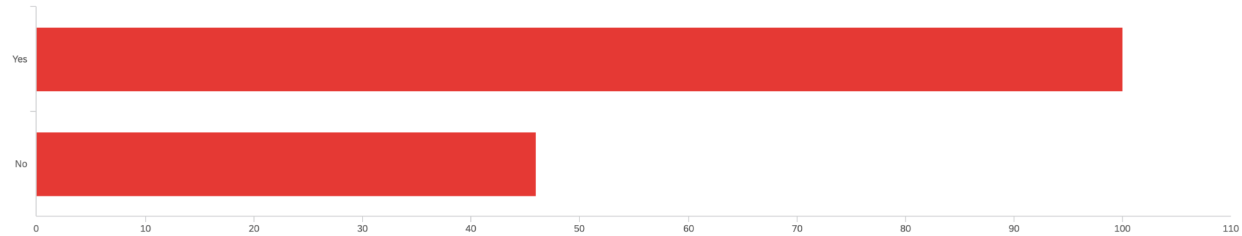


Figure 9. **Q: Were the fish consumption advisory easy to understand?**

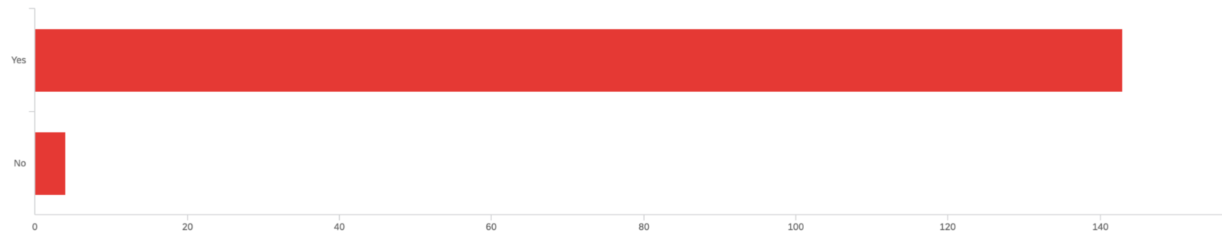


Figure 10. **Q: What is your opinion on the water quality in your preferred lake?**

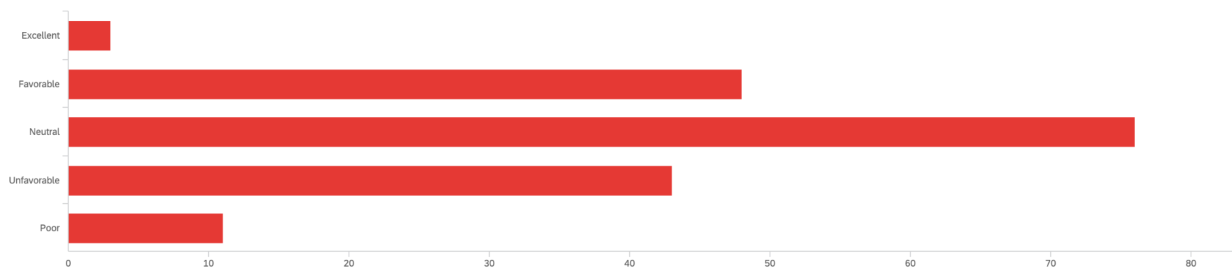


Figure 11. **Relationship between Age and Knowledge about PFAS.**

	Q16: What is your age							
Q7: Have you...s chemicals?	<18	18-24	25-34	35-45	46-55	55-64	65+	Total
Yes	66.7%	52.5%	87.9%	87.8%	90.0%	92.6%	100.0%	
No	33.3%	47.5%	12.1%	12.2%	10.0%	7.4%	0.0%	
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	

Figure 12. **Map of Perceived Water Quality in Madison Chain of Lakes**

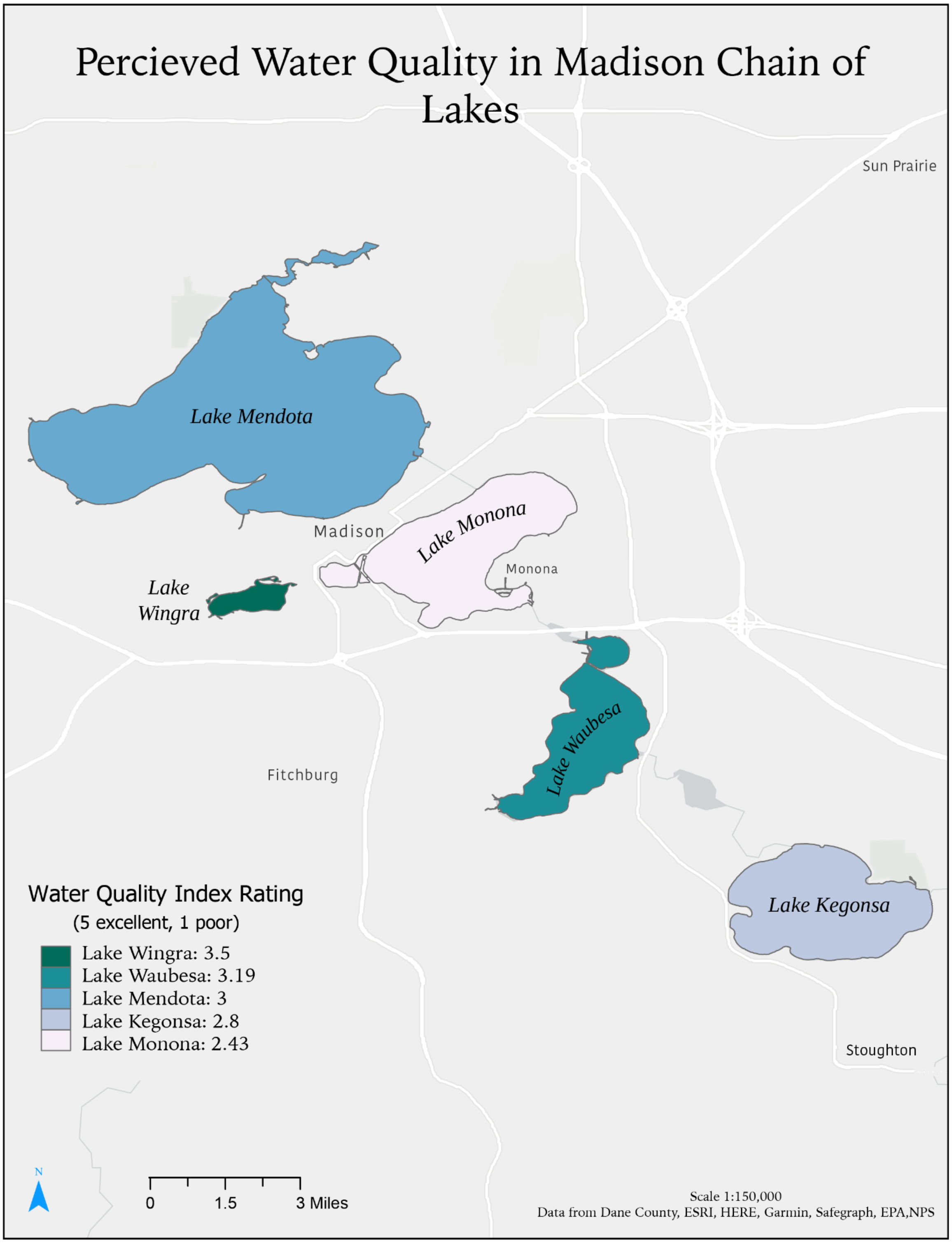

Percieved Water Quality in Madison Chain of Lakes
Sun Prairie
Lake Mendota
Madison
Lake Monona
Monona
Lake Wingra
Lake Waubesa
Fitchburg
Lake Kegonsa
Stoughton
Water Quality Index Rating
(5 excellent, 1 poor)
Lake Wingra: 3.5
Lake Waubesa: 3.19
Lake Mendota: 3
Lake Kegonsa: 2.8
Lake Monona: 2.43
N
0
1.5
3 Miles
Scale 1:150,000
Data from Dane County, ESRI, HERE, Garmin, Safegraph, EPA,NPS

Figure 13. **Map of the Distribution of Survey Replies by Zip Code**

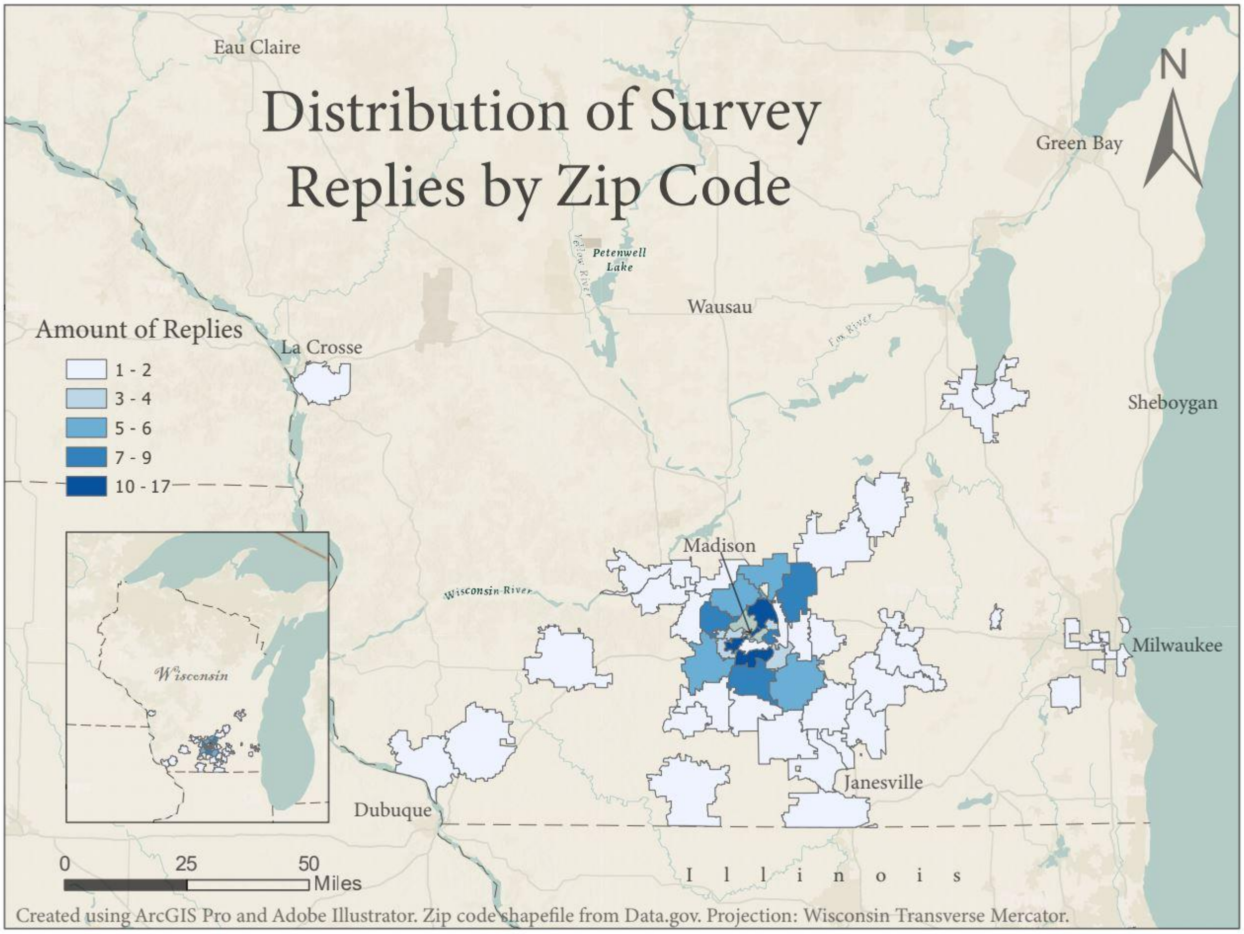
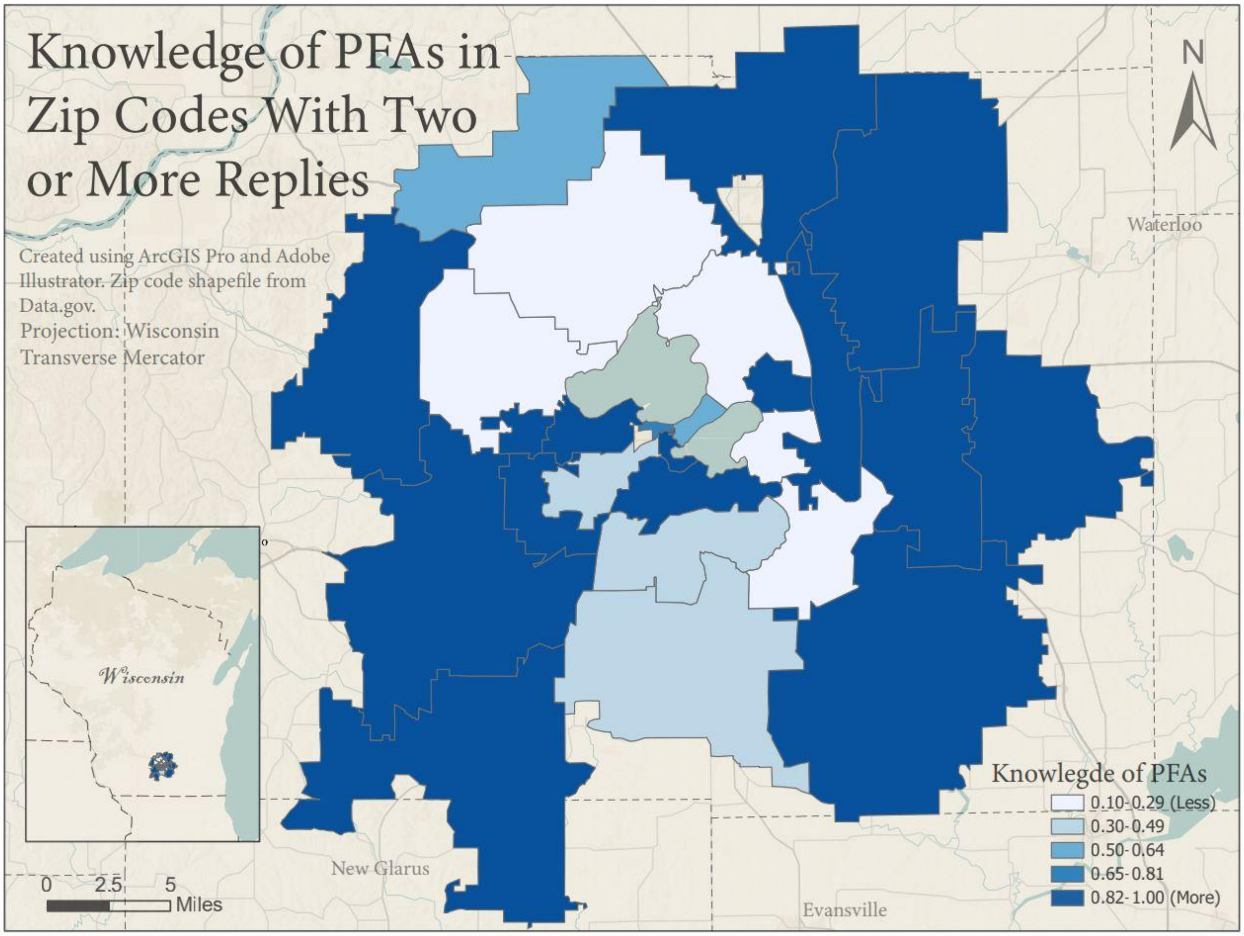


Figure 14. **Map of the Knowledge of PFAS in Zip Codes With at Least Two Replies**



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