

Food Safety and Consumer Choices: The Impact of Lake Victoria's Algal Blooms

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Abstract

Harmful Algal Blooms (HABs) in freshwater ecosystems worldwide are a growing threat to both human health and the health of aquatic ecosystems. In East Africa, HABs threaten the livelihoods and health of the more than 42 million people who live in the Lake Victoria basin. This paper provides an overview of current research around harmful algal blooms and their impacts on human health and the surrounding environment, particularly in the Lake Victoria basin. Since fish is an important food source in this area, understanding how food safety concerns from HABs influence consumer choices is crucial to any policy response. By exploring current literature around discrete choice experiments (DCEs), I detail the possibility of using DCEs to understand how harmful algal blooms impact consumer choices in Lake Victoria, Kenya. As a relatively new approach to choice experiments, with research especially lacking in developing countries, the research for using DCEs to study consumer choices around food safety is scarce. The impact of HABs on consumer choices, especially in the Lake Victoria basin, presents a gap in literature that requires further research.

Keywords: discrete choice experiment, Lake Victoria, harmful algal blooms, food safety

Summary Statement

This paper explores the impact of harmful algal blooms (HABs) on food safety and consumer choices. In particular, I focus on the increasing prevalence of blooms in Lake Victoria, Kenya, as the presence of HABs threatens the livelihoods and health of the more than 42 million people who live in the Lake Victoria basin. By reviewing the impact of HABs on the safety of eating fish and the potential for this to change consumer choices, I explore what current literature can tell us about the impact of HABs in Lake Victoria, Kenya. My findings highlight the severity of the impact of HABs and the danger they pose to human health and food safety, underscoring the need for further research and increased awareness about HABs and their influence on communities.

Figure 1 (right): Map of Lake Victoria and surrounding countries in East Africa

Background

In Africa, high population growth along major river basins has increased land use and pollution, putting pressure on the aquatic ecosystem. Namely, the Lake Victoria basin is home to more than 42 million people and is bordered by three countries, Kenya, Uganda, and Tanzania, serving as an essential resource for food and water in East Africa. As the world's second largest freshwater lake, Lake Victoria has a shoreline of 3,500 km and a surface area of 68,000 km² (Olokotum et al., 2020).



Issues such as a changing fishing dynamic and eutrophication have contributed to the presence of cyanobacteria blooms in the water, primarily due to human population growth and subsequent human activities. Increasing human activities such as farming, housing construction, industrial activities, and solid and liquid waste discharge can result in increased nutrient pollution in the lake, leading to a higher occurrence of cyanobacteria blooms (Olokotum et al., 2020). These cyanobacteria blooms can produce microcystins, inhibiting protein phosphatases and contaminating the water (WHO Guidelines, 2021). This paper will focus on the impact of Lake Victoria's HABs in Kenya, although harmful algal blooms are a pressing public health crisis worldwide. As these blooms become increasingly prevalent, fully understanding their impact on local fish consumers and markets will be pivotal in informing policy responses.

This paper conducts a literature review to assess the state of the art in the impact of HABs, particularly in Lake Victoria, Kenya, on the ecosystem and the surrounding community. Additionally, it covers recent advancements in discrete choice experiments, particularly those around food safety, to explore how discrete choice experiments can be used to understand the influence of HABs on food choices. HABs have the potential to impact human health, especially through fish consumption. There is a notable gap in the literature regarding how algal blooms in Lake Victoria impact human health, especially with food consumption. There was also a deficit in discrete choice experiments conducted in Kenya and developing countries in general. Evidently, the amount of prior research closely related to the project is lacking, leaving room for future exploration.

Methods

This project focused on creating a comprehensive literature review of current research on consumer choices of fish in Lake Victoria, Kenya. From June 5th to August

14th, I conducted a literature update using Google Scholar (<https://scholar.google.com>) and Web of Science (<https://www.webofscience.com/>) to find research papers about discrete choice experiments, particularly those around food safety and based in Lake Victoria, Kenya or nearby locations. My literature review was done as part of an existing project under Dr. Kathryn Fiorella, Dr. Kira Lancker, and Dr. Christopher B. Barrett at Cornell University. I began my review using the past papers used on the project (Table 1) and looked for papers that cited those papers in an attempt to compile recent developments, ideally from the last five to ten years. While I did use papers from further back than five to ten years, my goal with this research was to analyze recent advances in the field. After that, I used the Web of Science to search using different combinations of keywords such as "Harmful Algal Blooms," "algal blooms," "Discrete Choice Experiments," "Food Safety," "Kenya," and "Lake Victoria."

By searching "discrete choice experiments" on the Web of Science, I found 7,325 papers. I then narrowed my search by filtering for papers from Kenya, Tanzania, or Uganda (the countries bordering Lake Victoria, yielding 82 results and eventually down to 38 when further focusing on Kenya. When "discrete choice experiments" was searched with "Lake Victoria," the search yielded two papers, neither relevant to this research project. Table 2 provides a visual for these searches. After repeating this process with other keywords, I found fifteen key papers that provided valuable insight into the current state of discrete choice experiments, especially those around harmful algal blooms and food safety. It is important to note that one potential bias in these papers is that I limited my study to papers written in English, which may exclude other perspectives. However, it is generally rare that this type of literature is not written in English.

Table 1: Papers used as a starting point and the number of citations they had in Google Scholar.

Paper	Citations
Aura, C.M., Nyamweya, C.S., Njiru, J.M., Odoli, C., Musa, S., Ogari, Z., Abila, R., Okeyo, R., Oketch, R., 2019. Using fish landing sites and markets information towards quantification of the blue economy to enhance fisheries management. <i>Fisheries Management and Ecology</i> 26, 141–152. doi: 10.1111/fme.12334.	27
Chen, J., Xie, P., Li, L., Xu, J., 2009. First identification of the hepatotoxic microcystins in the serum of a chronically exposed human population together with indication of hepatocellular damage. <i>Toxicological Sciences</i> 108, 81–89. doi: 10.1093/toxsci/kfp009.	473
Fitzgeorge, R., Clarke, S., Keevil, C., 1994. Routes of intoxication, in: Codd, G.A., Jefferies, T.M., Keevil, C.W., Potter, E. (Eds.), <i>Detection methods for cyanobacterial toxins</i> . The Royal Society of Chemistry, Cambridge, pp. 69–74.	171
Fitzgerald, D.J., Cunliffe, D.A., Burch, M.D., 1999. Development of health alerts for cyanobacteria and related toxins in drinking water in south australia. <i>Environmental Toxicology</i> 14, 203–209. doi: 10.1002/(SICI)1522-7278(199902)14:1<203::AID-TOX26>3.0.CO;2-X.	123
Flores, N.M., Miller, T.R., Stockwell, J.D., 2018. A Global Analysis of the Relationship between Concentrations of Microcystins in Water and Fish. <i>Frontiers in Marine Science</i> 5, 30. doi: 10.3389/fmars.2018.00030.	45
Greer, B., Meneely, J., Elliot, C., 2018. Uptake and accumulation of Microcystin-LR based on exposure through drinking water: An animal model assessing the human health risk. <i>Scientific reports</i> 8. doi:10.1038/s41598-018-23312-7.	86
Johnson, R., Orme, B., 2003. <i>Getting the Most from CBC</i> . Sawtooth Software, Inc. Sequim: Sawtooth Software Research Paper Series.	223
Lancaster, K.J., 1966. A new approach to consumer theory. <i>Journal of Political Economy</i> 74, 132–157. doi: 10.1086/259131.	17337
Matsushima, R.N., Ohta, T., Nishiwaki, S., Suganuma, M., Kohyama, K., Ishikawa, T., Carmichael, W., Fujiki, H., 1992. Liver tumor promotion by the cyanobacterial cyclic peptide toxin microcystin-LR. <i>Journal of Cancer Research and Clinical Oncology</i> 118, 420–424. doi: 10.1007/BF01629424.	1063
Mbonde, A.S., Sitoki, L., Kurmayer, R., 2015. Phytoplankton composition and microcystin concentrations in open and closed bays of Lake Victoria, Tanzania. <i>Aquatic Ecosystem Health & Management</i> 18, 212–220. doi: 10.1080/14634988.2015.1011030.	31

Table 1, continued.

Paper	Citations
McFadden, D., 1974. Conditional logit analysis of qualitative choice behavior, in: Zarembka, P. (Ed.), <i>Frontiers of Econometrics</i> . Academic Press, New York. chapter 4, pp. 105–142.	25370
Mulvenna, V., Dale, K., Priestly, B., Mueller, U., Humpage, A., Shaw, G., Allinson, G., Falconer, I., 2012. Health risk assessment for cyanobacterial toxins in seafood. <i>International Journal of Environmental Research and Public Health</i> 9, 807–820. doi: 10.3390/ijerph9030807.	81
Poste, A.E., Hecky, R.E., Guildford, S.J., 2011. Evaluating microcystin exposure risk through fish consumption. <i>Environmental Science & Technology</i> 45, 5806–5811. doi: 10.1021/es200285c.	195
Roegner, A., Sitoki, L., Weirich, C., Corman, J., Owage, D., Umami, M., Odada, E., Miruka, J., Ogari, Z., Smith, W., Rejmankova, E., Miller, T.R., 2020. Harmful algal blooms threaten the health of peri-urban fisher communities: A case study in kisumu bay, lake victoria, kenya. <i>Exposure and Health</i> doi: 10.1007/s12403-019-00342-8.	27
Rousu, M.C., Colson, G., Corrigan, J.R., Grebitus, C., Loureiro, M.L., 2015. Deception in experiments: Towards guidelines on use in applied economics research. <i>Applied Economic Perspectives and Policy</i> 37, 524–536. doi: 10.1093/aapp/ppv002.	43
Simiyu, B.M., Oduor, S.O., Rohrlack, T., Sitoki, L., Kurmayer, R., 2018. Microcystin content in phytoplankton and in small fish from eutrophic nyanza gulf, lake victoria, kenya. <i>Toxins</i> 10. doi: 10.3390/toxins10070275.	46
Sitoki, L., Kurmayer, R., Rott, E., 2012. Spatial variation of phytoplankton composition, biovolume, and resulting microcystin concentrations in the nyanza gulf (lake victoria, kenya). <i>Hydrobiologia</i> 691, 109–122.	136
WHO, 2017. Chemical fact sheets. In: <i>Guidelines for drinking-water quality: 4th edn. Incorporating the First Addendum</i> , License: CCBY-NC-SA 3.0 IGO. Technical Report. World Health Organization (WHO). Geneva.	120

Table 2: Web of Science database search for “discrete choice experiments” with different restrictions and the corresponding results for each search.

Search	Restrictions	Number of Results
“discrete choice experiments”	(AND) “Kenya” OR “Tanzania”	7,325
“discrete choice experiments”	OR “Uganda”	82
“discrete choice experiments”	(AND) “Kenya”	38
“discrete choice experiments”	(AND) “Lake Victoria”	2

Results

Algal Blooms and Human Health

Eutrophication caused by human activities in bodies of water worldwide has resulted in an increase in the formation of harmful algal blooms. These algal blooms contain the cyanobacteria *Microcystis*, which can contaminate drinking water and the food chain (Sitoki et al., 2012). This issue is only further exacerbated by the warming temperatures due to climate change (Griffith & Gobler, 2020). Microcystins produced from algal blooms can be dangerous as they can act as an inhibitor for protein phosphatases, generally targeting the liver. In humans, exposure to the harmful toxins from HABs comes through multiple routes: dermal contact, ingestion of contaminated waters, fish, or scum, and inhalation. Dermal contact with toxins produced by cyanobacteria can result in skin irritation, and sometimes severe contact dermatitis or severe skin lesions may result. Inhalation of aerosols containing toxins from HABs has been linked to respiratory symptoms and discomfort (Roegner et al., 2023; WHO Guidelines, 2021). Other health risks such as gastrointestinal illness, and even poisoning (especially for animals) are a concern with the recreational use of freshwater with cyanobacteria (WHO Recreation Criteria 1999).

Fish Consumption and Algal Blooms in Lake Victoria

In Lake Victoria, toxic algal blooms have significant effects on the community, especially in terms of public health. Research has shown that during the dry season, the average microcystin concentrations in drinking water from Winam Gulf, Lake Victoria, consistently exceeded the WHO's guidelines (Roegner et al., 2023). The World Health Organization (WHO) guidelines indicate that 20,000 cyanobacterial cells/ml in water puts individuals at risk for short-term health risks (WHO Recreation Criteria 1999). When sampling water quality in Kisumu Bay, Lake

Victoria, for eight months, researchers found that 83.7% of surface-level samples exceeded the guidelines for short-term health risks (Roegner et al., 2023). Long-term health risks from recreational activities are associated with cyanobacteria cell counts of 100,000 cells/ml (WHO Recreation Criteria 1999). In the study, 68.5% of the surface water samples exceeded the 100,000 guideline (Roegner et al., 2023).

Fish from Lake Victoria serve as an important source of food for those in the surrounding communities, adding to the concern about cyanobacteria blooms and the health risks associated with consuming fish from an area where there has been a bloom (Olokotum et al., 2020). During the bloom season, seafood consumption can pose health risks due to microcystins for fishing communities, especially the more vulnerable subpopulations. In a study of Winam Gulf that looked at fish consumption and HABs, the top five most common fish catches reported when surveying 400 female household heads were reported to be (in order from most to least frequent): adult *Lates niloticus*, *Rastrineobola argentea*, adult *Oreochromis nolticus*, *Clarias gariepinus*, and *Synodontis victoriae*. Notably, it was found that the average daily intakes of small species, like *R. argentea*, can be 5 to 10 times the permissible limit from the lifetime tolerable daily intake for chronic exposure of 0.04 µg per kg body weight per day throughout a lifetime (Toxic Cyanobacteria in Water 2021; Roegner et al., 2023). Research indicates that seafood consumption is a health concern for the fishing communities in the Lake Victoria Basin, especially for children and immunocompromised people, due to the presence of microcystins. However, despite the risk of toxin consumption from fish, in the Lake Victoria survey, fish consumption did not emerge as something subjects perceived as a health risk when surveyed, while water was more of a widespread concern (Roegner et al., 2023).



Figure 2: Algal Blooms in Kisumu Bay, Lake Victoria, Kenya.

Discrete Choice Experiments

Further research is required to properly understand how consumers of fish perceive the risk of toxins from fish consumption in the areas surrounding Lake Victoria, and how consumers might change behavior if informed of that risk. One way to accomplish this goal would be through the use of a discrete choice experiment. Discrete Choice Experiments (DCEs) have grown rapidly as a way to understand food choices. In DCEs, subjects are given a context (e.g., buying food in a grocery store) and then are asked to choose between various alternatives. This method allows researchers to elicit willingness to pay estimates, market shares, and/or elasticities of goods (Lizin et al., 2022). DCEs try to model real-world decisions better than regular choice experiments by attempting to mirror real-world shopping situations. For example, experiment subjects may be offered different food choices at different prices and then asked to choose what to buy, like they would in the store. DCEs can help researchers examine the everyday tradeoffs shoppers face in real time (Caputo & Scarpa, 2022). In the context of Lake Victoria, Kenya, discrete choice experiments could be used to understand the tradeoffs everyday people face when deciding whether or not to purchase fish that may pose health risks due to HABs. For example, consumers may choose to eat potentially dangerous fish because of a lack of information about food safety or because of socioeconomic factors, two different

reasons that require different policy solutions. Using discrete choice experiments, researchers could help determine what exactly is influencing food choices.

Choice experiments can also be used as a method of environmental valuation by showing consumers' tradeoffs and using it to elicit their willingness to pay (WTP) for that environmental resource (Hanley et al., 1998). Unfortunately, the discrete choice experiment method is still relatively new, which comes with its drawbacks. One downfall of DCEs is that they often tend to disregard how the subject's choice can influence the overall dynamic of the market. For example, products tend to have substitutes or compliments whose demand depends on that product. Conducting this experiment will likely require reducing the choices of fish consumers to certain fish, which introduces bias as consumers will be substituting between fewer choices than they would in real life (Marette et al., 2008). For example, in the real world, consumers may substitute fish for other sources of protein, not just different types of fish. In the case of conducting a DCE in fish markets, a significant restriction on the experiment is the fact that pricing constraints may mean that it is only feasible to offer subjects choice options with restricted quantities. Research indicates that willingness to pay may be overestimated in existing DCE studies, as they tend to rely on smaller experimental quantities. Furthermore, this impact has been shown to be more likely

to affect high-income consumers than low-income consumers, which could skew results (Lin et al., 2023).

One of the primary challenges that could arise from designing an experiment to be conducted in Lake Victoria, Kenya, stems from the fact that the majority of past DCEs have been conducted in Western or developed countries. The limited literature does play a role in restricting the level of preparation available to understand the potential nuances of the area, especially when trying to limit potential biases (Lizin et al., 2022). However, a similar DCE on fish products and consumer preferences was conducted in four European countries (Germany, Italy, Spain, and the UK). Generally, there tend to be positive premiums for safety and health claims around fish (Menozzi et al., 2020). In the European study, nutrition and health claim estimates had a positive impact on consumers' utility of 0.142. Additionally, consumers were willing to pay a premium for fish with nutrition and health claims of an average of €0.51 per kg. Unfortunately, the exact premiums that exist in the Lake Victoria, Kenya, fish market are still unclear (Menozzi et al., 2020).

Designing Discrete Choice Experiments

Cultural and language barriers in this experiment provide a unique challenge when determining study design. To reduce bias or other complications, previous studies have emphasized the importance of pretesting questionnaires to vet potential problems before they occur. Additional aids, such as pictures, diagrams, symbols, etc., will be crucial to help assuage the effect of a potential lack of literacy among study participants (Mangham et al., 2009). The challenge of delivering information about food safety to participants directly is further complicated because the Lake Victoria fish market is home to multiple types of fish with varying toxicity levels, even varying throughout the year. A previous study in France looked at how women respond to health advisories around fish consumption, both in the lab and in the field,

to examine how to make health advisories more successful. Subjects were tested on their ability to recall what fish species were mentioned in the recommendation, and it was found that only a minority of the subjects remembered the species. Most consumers only remembered a few species. More specifically, the study found a low correlation between percent recall and consumption habits, indicating that the women had better memory for fish species that they consumed more frequently. Their experiment did find that there was a decrease in fish consumption after receiving health information, even though the majority of consumers did not remember specific species (Marette et al., 2008). When applied to a Lake Victoria consumer choice experiment, these findings may provide insight into how people will respond to health advisories around microcystins, especially because, like in the French experiment, this experiment will involve multiple species that the consumers need to remember.

Conclusion

The presence of cyanobacteria blooms in Lake Victoria, particularly those that exceed the WHO's guidelines for recreation, threatens the people who rely on the lake as a livelihood and a source of food and water. This much is clear from the literature. However, the lack of studies specifically focused on this topic, especially regarding the impact of HABs on consumer choices, leaves gaps for further research on how these blooms may affect the surrounding community. While a search for "discrete choice experiments" on the Web of Science yielded approximately 7,325 results, many of these results were from developed countries. For example, of the 7,325 results, 3,982 of those results came out of either the USA, England, or Australia. A search for "discrete choice experiments" in Kenya only had 38 results on the Web of Science. My searches did not yield any discrete choice experiments directly looking at the impact of microcystins in fish on consumer choice experiments, leaving room for future research on this subject.

Looking towards the future, this literature review could be improved by looking at more databases for literature besides the two that I utilized (Web of Science and Google Scholar), as well as looking at other sources, like newspapers. I mainly focused on research papers, so sources like reports, policies, or newspapers could provide more useful information. Additionally, looking at databases in other languages could yield more results, as this search was constrained to papers written in English, which may exclude some papers that were written by African research teams or news articles from Kenya. My research was also focused primarily on recent updates in the literature from the past decade. Looking at papers published further back in time may yield more results.

Finally, beyond research, educating the public about preventing HABs and the safety precautions to take when they occur is crucial, both in Lake Victoria and worldwide. As the world continues to grow in population and climate change worsens, the frequency of these blooms may increase. To adequately protect against the future challenges that may come, further research on HABs and their impacts, along with possible solutions, is vital.

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