Social Ecological Analysis of an Outbreak of Pufferfish Egg Poisoning in a Coastal Area of Bangladesh

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Abstract. Recurrent outbreaks of marine pufferfish poisoning in Bangladesh highlight the need to understand the context in which the outbreaks occurred. In a recent outbreak investigation, a multidisciplinary team conducted a mixed-method study to identify the demography and clinical manifestation of the victims and to explore different uses of pufferfish, and local buying, selling, and processing practices. The outbreak primarily affected a low income household where an elderly woman collected and cooked pufferfish egg curry. Nine persons consumed the curry, and symptoms developed in 6 (67%) of these persons. Symptoms included vomiting, diarrhea, paresis, and tingling sensation; 2 (22%) persons died. The unstable income of the affected family, food crisis, and the public disposal of unsafe pufferfish byproducts all contributed to the outbreak. A multi-level intervention should be developed and disseminated with the participation of target communities to discourage unsafe discarding of pufferfish scraps and to improve the community knowledge about the risk of consuming pufferfish.

INTRODUCTION

In Bangladesh, 13 species of pufferfish are found in salt and fresh water.¹ Not all species of pufferfish are deadly; some are only mildly toxic.² *Takifugu oblongus* is the most common marine species and is frequently identified in fish catches off the coast of the Bay of Bengal.^{3–5} Laboratory studies have found tetrodotoxin in this marine species of pufferfish.^{1,4} The marine female pufferfish contains a high level of toxin in their ovaries, and produces more tetrodotoxin before and during the season when they are developing and depositing eggs.⁶ Tetrodotoxin is mainly found in the eggs and liver.^{4,7} Because tetrodotoxin is heat stable and does not decompose during the traditional cooking process, these toxic components can cause death in approximately 50–60% of persons who ingest them.^{8,9}

Tetrodotoxin poisoning is a paralytic disease. The toxin blocks voltage-gated sodium channels in nerve tissues at the same site as saxitoxin, the dinoflagellate toxin that causes paralytic shellfish poisoning.¹⁰ Common symptoms of tetrodotoxin poisoning include perioral paresthesias, dysesthesias, dysphonia, visual disturbances, bradycardia, vomiting, abdominal pain, and potentially fatal neuromuscular weakness and ensuing hypoxic injury. Symptoms usually occur within 10 minutes to 15 hours of ingestion, most commonly within six hours in fatal ingestions.^{7,11} Although there is no specific antidote or treatment of tetrodotoxin poisoning, neostigmine and atropine have been anecdotally reported as being effective in restoring neuromuscular function in some cases. Gastric lavage and supportive treatment, most prominently mechanical ventilation, have been shown to reduce deaths.^{6,7,11}

Tetrodotoxin intoxication after consumption of toxic pufferfish is widespread in coastal Asia.⁹ Seven outbreaks of marine pufferfish poisoning have been reported in national newspapers, scientific articles, and unpublished work through-

out Bangladesh during 1998–June 2008, which affected 156 persons and caused 40 deaths (case-fatality rate = 26%).^{3,4,12–14} However, most investigations have been limited to quantitative epidemiologic outbreak analysis, which primarily focused on the immediate risk factors associated with illness, and to signs and symptoms of case-patients and their management; a few studies highlighted the toxicologic characteristics of pufferfish.^{1,4,5,8,15–17} Only one study explored the use of pufferfish in the coastal region and the inhabitants' understanding about puffer toxicity and epidemiologic information.¹² Because the number of outbreaks being reported increased in 2008, it was important to explore if there had been recent changes in availability of pufferfish and its use.

This report focuses on an outbreak that occurred in late October 2008. The Institute of Epidemiology, Disease Control and Research, Ministry of Health and Family Welfare, Government of Bangladesh learned about pufferfish egg poisoning in southeastern Bangladesh through their event-based surveillance of daily newspapers. A collaborative team from the Institute of Epidemiology, Disease Control and Research and the International Center for Diarrheal Disease Research, Bangladesh investigated this outbreak.

In a conventional outbreak investigation, the objectives are to identify the etiology, and risk factors for disease that often ignores the social determinants of population health.¹⁸ To understand an outbreak thoroughly enough to develop a context appropriate intervention, we often require not only the proximate, individual-level risk factors of the outbreak, but an understanding of the factors that enabled the outbreaks to occur. This intervention can best be understood through a social-ecological system perspective.^{18,19} The social ecological model is a comprehensive public health approach that not only addresses the risk factors and prevention strategies at the individual level, but also the social norms and the economic factors that can create the opportunity for an outbreak's occurrence.²⁰ According to this framework, health-related outcomes can be best understood from a multi-level analysis that can include individual, family, community, and national levels, all of which can contribute to the development of health promotion programs.^{21,22}

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Previous investigations pufferfish poisoning outbreaks by our research group confirmed that these outbreaks occurred repeatedly in Bangladesh. However, to develop sound intervention strategies, we needed a broader understanding of the socioeconomic and ecological context that enables such outbreaks.¹² We used quantitative and qualitative approaches to identify the timeline of events and clinical manifestation of the affected persons, and to explore persons' understanding about pufferfish toxicity, the history of the use of pufferfish for food and income generation, and the local buying, selling, and processing practices.

The analysis in our report was inspired by the study of Bovin, in which he used the ecological paradigm in outbreak settings to understand the social and environmental context, and to develop preventative interventions in rural Zaire and throughout sub-Saharan Africa.²³ The pufferfish egg poisoning outbreak we investigated occurred in a coastal community where most residents have low incomes and catch, trade, and consume salt water fish. In this particular social context, we used a social ecological model.²⁴

METHODS

Study site. The outbreak occurred in the village of Maiskhal, which is on a remote island in southeastern Bangladesh. The outbreak village was a rural isolated community approximately 15 km from the nearest city of Cox's Bazaar on the mainland. Motorboats and trawlers were the only available transport to reach this community. The motorboat takes approximately 45 minutes and the fare is US\$1 per person. By trawler, it takes more than an hour and the fare is US\$ 0.36 per person. The remote location and poor communication that limit economic activity and social development indicate that these communities have less access to high-quality education and public health information.²⁵ The population of this island is approximately 250,000; the literacy rate is 23%.²⁶ In Cox's Bazaar, the literacy rate is 46%.²⁷

Study design, sampling, and data collection. Our collaborative team of a sociologist, an anthropologist, a medical doctor, and an epidemiologist conducted this investigation by using quantitative and qualitative methods during October 28–November 1, 2008. The sampling framework, data collection tools, and data collected are shown in Table 1. The team went to Cox's Bazaar Sadar Hospital, reviewed hospital records, and asked health authorities to identify persons who had been admitted to the hospital with a history of ingesting pufferfish

eggs on or after October 26, 2008. We then asked the admitted patients how many persons also shared and consumed pufferfish egg curry in their community, and we subsequently tracked these persons. For those who died after consumption of pufferfish, we selected family members as proxy respondents. We conducted in-depth interviews with surviving patients and proxies for dead patients. We also interviewed witnesses and neighbors who saw the paternal grandmother carrying fish scraps, who took care of the affected persons and accompanied them to health facilities, and who had regular interaction with the affected household. We conducted group discussions with the villagers to explore the recent pufferfish egg poisoning, previous outbreaks of pufferfish poisoning on the island, how pufferfish are used for food and income generation, and their understanding about pufferfish toxicity. The group discussion with local doctors helped us to understand the signs and symptoms of the patients and the subsequent treatment that patients received in the hospital. Through group discussions with the workers from the dry fish, poultry, and shrimp industries and local businessmen dealing in fish industries, we explored the history of puffer fish trade and the existing local buying, selling, and processing practices. We visited the fish market and identified the location of fish processing activities and where byproducts were discarded.

We collected data in Bengali and took detailed field notes during the in-depth interviews and group discussions. The notes were expanded in the field by using an interpreter to understand any local terms used by the respondents.

Data analysis. The team analyzed the data during a 30-day period. We used descriptive statistics to characterize the demographic and clinical profiles of persons exposed to pufferfish eggs during the outbreak. For qualitative data, we developed a coding system to capture the main research themes and concepts.²⁸ Following the social ecological framework,²² the team categorized the data in terms of social, economic, and ecological context and interpreted these data according to different levels of contributors involved in the outbreak.

Ethics. We sought and obtained informed verbal consent from all adult respondents or their proxies and guardians. All interviews were conducted in the affected households or in the informants' workplace. Because this investigation was part of an emergency response to an outbreak, the study protocol was not reviewed by a human subjects committee. However, the outbreak investigation methods were approved by the Government of Bangladesh.

TABLE 1
Data collection tools, sources of data, and the data collected, Bangladesh

Methods	Data collection tools	Source of data	Collected data
Quantitative	Structured questionnaire	People who ate puffer egg curry or their proxies	Age, sex, outbreak time line of events, signs and symptoms, and the ingested amount of puffer egg curry
Qualitative	Review hospital records	Hospital registers	Signs, symptoms, and management of patients
	In depth interviews	Surviving patients, proxies for dead patients, witnesses, and neighbors	Income, education and role in the family along with illness and exposure history of the affected persons
	Group discussion	Workers from the dry fish, poultry, and shrimp industries; local fish businessmen, community people, and local doctors	History of pufferfish trade; different uses of pufferfish; existing local buying, selling, and processing practices; inhabitants' understanding about pufferfish toxicity; signs, and symptoms; and treatment patterns in the local hospital

FIGURE 1. Relationships between persons who cooked and persons who ate pufferfish eggs during the outbreak and their age, Cox's Bazaar, Bangladesh.

RESULTS

The October 2008 outbreak. This outbreak affected two low-income rural families who were related by kinship (Figure 1). Neither of the households owned any land and the houses they resided in were made of mud and thatch. The household primarily affected by the outbreak had six family members and only one wage earner. The household head worked seasonally in a betel leaf plantation as a day laborer for US\$3 per day to support the family. Adult household members did not have any formal education (Table 2). The wife reported that recently it had been difficult to provide three meals a day because of high food prices. The paternal grandmother was approximately 80 years old and visually impaired. She often went to the local market to scavenge for discarded vegetables to feed the family, although she did not usually prepare meals. The wife usually prepared meals, but because of the household

cash crisis, she went to work as a day laborer in a neighboring village for the first time on the day of the outbreak.

On the day of the outbreak, fishermen had caught their usual fish, including pufferfish, and had sold it to the buyers from the dry fish and shrimp industries. Fishermen and workers from the shrimp industry had discarded the pufferfish viscera and eggs during the process of making fish meal. On that morning, the paternal grandmother went to the local fish market and obtained approximately 300 grams of puffer eggs and some fat and liver of other fish that was discarded near the processing area. While the paternal grandmother was returning from the fish market, a hardware shop owner identified the fish eggs as pufferfish eggs and recommended that she discard them because they were poisonous. The paternal grandmother ignored his warning and returned home to make a pufferfish egg curry for lunch. She told the family that the eggs were *hilsha* fish eggs and that she had bought them for US\$0.21. She saved the fat and liver for the evening meal. After rinsing the puffer eggs, she threw the rinse water out in the courtyard. On the same day, four chickens in that courtyard died. After this episode of pufferfish poisoning, neighbors suspected that the chickens may have died because they consumed water used to wash the pufferfish eggs.

The paternal grandmother was home alone when she cooked the pufferfish egg curry in a traditional manner for the family's lunch. However, she did not eat this curry because she was invited to eat lunch at her neighbor's *Shraddha* ceremony; the Hindu ritual of feeding people in the name of the deceased.²⁹ At mid-day, the household head, his wife, son, daughter, and wife's nephew consumed the puffer egg curry. While eating the curry, the wife told us that they found the curry bitter, but reasoned that the curry might not be boiled properly. Therefore, the family consumed the curry because they believed that the bitter taste resulted from improper cooking. Relatives from the adjacent household (two nephews and two grand nieces) also tasted the pufferfish curry, but reported that it was too bitter to eat.

The wife reported that the paternal grandmother deceived the family members by saying the puffer eggs were *hilsha* fish eggs so that she could keep the money intended to buy food for the family. We attempted to interview the paternal grandmother, but found her so grief-stricken that she could not physically or mentally respond in depth to our questions. She died two weeks after the outbreak.

Of the nine persons who shared the curry, six (67%) showed development of symptoms. Five of these persons became severely ill and were taken to the local hospital. The median age of these persons 13 years (range = 4–50 years) (Table 2). The most common symptoms were vomiting (56%) and diarrhea (56%), followed by paresis of the limbs (44%) and a tingling sensation (33%) (Table 2). The median duration between consumption of the pufferfish eggs and illness onset was three hours (range = 1–6 hours).

The five persons who consumed a larger amount (> 20 grams) of the pufferfish egg showed development of severe illness. The household head's daughter died at the Maishkhal Upazilla Health Complex. Because three of these persons had a history of paresis of the limbs and two were semi-conscious, the Upazilla Health Complex doctors lavaged their stomachs and transferred them to the district hospital for more comprehensive management. On the way to this hospital, the household head died. The wife, son, and the nephew were

TABLE 2

Characteristics and clinical manifestations of nine persons exposed to pufferfish eggs during an outbreak in Maishkhal Upazila, Cox's Bazaar District, Bangladesh, September 2008*

Characteristic	Value
Age	
Mean, years	18
Median (range)	13 (4–50)
Education	
None	5 (56)
Grades 1–5	3 (33)
Grades 6–9	1 (11)
Amount of egg ingested (grams)	
< 5	3 (33)
5–10	1 (11)
20–30	1 (11)
31–40	1 (11)
> 40	3 (33)
Clinical manifestation	
Vomiting	5 (56)
Diarrhea	5 (56)
Paresis of limbs	4 (44)
Tingling sensation	3 (33)
Perioral paraesthesia	3 (33)
Burning sensation	3 (33)
Drowsiness	3 (33)
Chest tightness	3 (33)
Black skin	2 (22)
Vertigo	2 (22)
Unconsciousness	2 (22)
Difficulty speaking	2 (22)
Death	2 (22)

*Values are no. (%) unless otherwise indicated.

treated with neostigmine and atropine at the district hospital and two of them also received oxygen support; all three survived.

Community understanding about pufferfish and toxicity.

Some villagers reported that they understood that marine pufferfish should not be eaten because they had heard that it was poisonous from family members or knew about episodes of pufferfish toxicity. The villagers reported that one year ago, 20 chickens and 2 crows died in one community after pufferfish eggs were thrown away by some fishermen. Three years ago, respondents described another outbreak involving 40 persons and one death that they attributed to marine pufferfish ingestion among a minority community. The elder respondents reported another outbreak of pufferfish poisoning with eight deaths in Dholghata, which is 19 km from the outbreak community, approximately 20–25 years ago. The Residential Medical Officer of Maiskhal Upazilla Health Complex reported that three persons from a village near the local fish market were admitted to the hospital after consuming pufferfish eggs in May 2008; all survived.

Changes in availability of pufferfish. Approximately five years ago, fishermen in the outbreak community would catch pufferfish along with other target fish, but would throw the pufferfish back into the water because nobody would buy them. A dry fish businessman reported that he used to discard the pufferfish he found mixed with other fish he had purchased. However, when he discovered that there was a market for dried pufferfish at largest dry fish market in Chittagong, Bangladesh, he stopped throwing out the puffer fish. He reported that “There is a market value of pufferfish inside the country. I got 50–60 kgs of pufferfish when I bought one boat full of fish (approximately 2,500 kg). If I discard them, I will be at a loss. Now I do not throw the pufferfish away.”

Current use of fresh and dried pufferfish. A few local minority communities buy fresh pufferfish for human consumption. Some local fishermen use it for bait. The main buyers of fresh pufferfish are the dry fish industries and shrimp farms operating in this area. Each morning, after the fishing trawlers sell their catch of the day, the workers from the shrimp industries begin processing the fish, including pufferfish, into fish meal in the market. They cut it into pieces in the fish-processing room, and discard the viscera and eggs on the open ground. There is no marked waste receptacle for the toxic parts of the pufferfish.

Dried pufferfish is popular in certain local minority communities, particularly the *Shammu* and *Mong*, and in other minority groups in northern Bangladesh, who come to the outbreak region to buy it at a low price. During the investigation, 1 kg of dry pufferfish was sold for US\$1.10; other dry sea fish sold for US\$3–8.50. The poultry food industry also mixes inexpensive dry pufferfish with other dry fish to produce poultry feed.

DISCUSSION

The unstable income of the affected family, the food crisis, the availability of pufferfish, and the public disposal of unsafe byproducts contributed to the outbreak. In this low-income setting, when persons find free or less expensive fish in the market, they take advantage of the opportunity.^{4,13,16} The social ecological theory explores how a societies' struggle for livelihoods can produce certain disease patterns.²³ We

explored this outbreak at multiple levels of the society by identifying factors from the individual, family, community, and national levels that enabled the outbreak to occur.

The paternal grandmother collected pufferfish eggs from a pile of various types of discarded fish scraps. It is likely that she confused the pufferfish eggs with other fish eggs, and that similar misidentification could have contributed to previous outbreaks in the same district.^{4,13} Despite being informed by a community member that the pufferfish eggs were poisonous, the paternal grandmother may not have understood the toxicity of the pufferfish eggs. It is also possible that cognitive impairments prevented her from making a sound decision about using pufferfish eggs to feed her family.

The individual behavior of the paternal grandmother was not solely responsible for this outbreak; the family's low socioeconomic status also contributed to it. Before the outbreak, the family's shortage of money and subsequent food crisis changed the lifestyle of the family members. The person who usually cooked meals had to go out of the house for work; if she had been present at the home, the pufferfish eggs might not have been prepared for lunch. Moreover, the victims were so hungry that they ate the curry even after tasting its peculiar bitterness, whereas the adjacent household threw it away.

At the community level, unemployment and readily available pufferfish also contributed to the outbreak.³⁰ In the outbreak community, pufferfish are increasingly available because local fishermen, along with poultry, shrimp, and dry fish workers, have begun to process pufferfish in an effort to increase their own livelihoods.²³ At the same time, unsafe disposal of fish scraps by the fish and shrimp industries can put low-income households, particularly those who are more vulnerable to economic and nutritional hardships, at risk. These unsafe practices threaten the environment for humans and animals. Moreover, the community level Upazilla Health Complex lacked important critical care resources, including mechanical ventilators, monitoring, and critical care staff, which are necessary for severe tetrodotoxin poisoning case management.³¹ The lack of this life-saving support might increase the number of deaths caused by accidental tetrodotoxin poisoning.

Nationally, the Fish Inspection and Quality Control Service under the Ministry of Fisheries and Livestock is responsible for inspecting the products and the hygienic conditions of fish-processing plants.²⁵ However, these types of food safety controls are not commonly implemented in Bangladesh because of an insufficient number of qualified inspectors, their lack of motivation to visit remote fish-processing plants, and corruption at different levels.^{25,32} Therefore, persons are at increased risk of pufferfish poisoning because of the limited capacity of government authorities to ensure safe handling of toxic fish.

In the months leading up to the outbreak, food prices increased globally. As a result of local and global failed harvests, compounded by the rising demand for biofuels, the cost of living for poor families increased.^{33,34} During June 2006–June 2008, approximately 45% of persons in Bangladesh experienced food insecurity, reflected in the consumption of less than 2,122 calories per person per day.³⁴ The food crisis also limited access to essential food, and the family in this outbreak had to rely on unsafe foods.^{23,35} Therefore, high food prices and food scarcity contributed to the fatal toxic food poisoning outbreaks in Bangladesh in 2007 and 2008.^{12,36} A summary of the multi-level factors that contributed directly or

FIGURE 2. Social ecological framework of pufferfish egg poisoning outbreak 2008, Cox's Bazaar, Bangladesh.

indirectly to this outbreak and how they are mutually related and contributed to the outbreak is shown in Figure 2.

Although a few minority communities in this area have a long-standing tradition of preparing and eating pufferfish, apparently without harm, our interviews with community members and local physicians suggested that many outbreaks have occurred in this area that were not reported to health authorities.

We were unable to measure the toxicity of the ingested pufferfish eggs because the prepared curry was already consumed and the leftovers had been thrown away before the investigation began. All persons who became ill reported eating the pufferfish egg curry immediately before illness onset, and the main ingredient was identified as marine pufferfish eggs by the shop keeper. The toxin in marine pufferfish eggs has been described as tetrodotoxin.^{4,5} In addition, the clinical presentation of the affected persons was similar to that of persons who consumed marine pufferfish and eggs in 1998 and more recently in 2008. Therefore, the patients likely had tetrodotoxin poisoning.^{4,12}

In addition, we could not interview the paternal grandmother. Therefore, we have limited information on what her perception was regarding the toxicity of pufferfish eggs. However, the interviews with family members suggested that she might not have had any knowledge about pufferfish toxicity.

The social ecological framework gives rise to recommendations for potential interventions at the individual, family, community, and national levels. If persons follow the framework, health education could help local individuals and families to understand the risks of ingesting the fish. At the community level, interventions are needed to encourage fishermen and workers from the shrimp and dry fish industries to discard puffer scraps in a marked waste receptacle that would reduce the risk that humans or animals accidentally consume them. At the national level, collaboration with the coastal Fish Inspection and Quality Control Service could motivate safe disposal of toxic fish waste products with more effective monitoring systems.

In the long term, addressing poverty and lack of affordable nutritious food at the national level will require a expansion

of economic opportunities to increase the purchasing power of lower-income communities in this area of Bangladesh through agricultural and food import policies.^{37–39} Because outbreaks of marine pufferfish have occurred beyond the coastal areas, further research in other areas of Bangladesh that explores selling and consumption patterns at the individual and community levels are needed to prevent future outbreaks.⁴⁰

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