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**SPATIAL AND ENVIRONMENTAL RISK FACTORS FOR DIARRHEAL
DISEASE IN MATLAB, BANGLADESH**

By

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ABSTRACT

SPATIAL AND ENVIRONMENTAL RISK FACTORS FOR DIARRHEAL DISEASE IN MATLAB, BANGLADESH

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The primary objective of this dissertation is to assess risk for diarrheal disease in rural Bangladesh by analyzing the complex and dynamic interaction of biological, socioeconomic, cultural/behavioral, and environmental factors over time and space. A secondary objective is to extend the use of geographic information systems as a tool in disease modeling. The differences between the spatial and temporal patterns of cholera and non-cholera watery diarrhea are analyzed. Risk factors of the two disease types are calculated to compare the relative importance of risk for several independent variables.

This study is guided by the medical geographic theoretical approach called disease ecology and uses a methodological approach called ecological association analysis which uses quantitative methods to model spatial and temporal disease variation. This approach facilitates understanding disease causation in a spatio-temporal framework. The author claims that, in order to increase our understanding of complex phenomena such as diarrheal disease, it is necessary to expand the theoretical holism of disease ecology and practice methodological pluralism when doing this type of research.

The main cholera epidemics from January 1992 to December 1994 occurred just after the rainy season and smaller epidemics occurred at the end of the dry season. There were almost no cases during the beginning of the dry season of each year. There was an irregular temporal cycle to non-cholera watery diarrhea. The peaks did not follow a regular seasonal pattern and the largest epidemics occurred at different times of the year. Cases of cholera were widely dispersed throughout the study area, whereas cases of non-cholera watery diarrhea were more clustered. These spatial and temporal patterns provide support for Colwell's (1985) theory that cholera is a disease with an environmental reservoir while non-cholera diarrhea is not. After periods when there is no cholera, people contract cholera from environmental sources and subsequent cases are due to both primary transmission from the environment and secondary transmission from other people. Non-cholera, watery diarrhea is caused exclusively by secondary transmission since there is no environmental source.

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Michael Edward Emch
1998

To Sheryl,
For coming to Bangladesh
while I did this research.

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1. Introduction: research objective, research setting, and review of literature

1.1 Research objective

Diarrheal diseases cause one-third of the 15 million annual deaths in children under five years old in the developing world (Snyder & Merson, 1982). Because of resource constraints in developing countries like Bangladesh it is necessary to identify risk factors so preventative health programs can focus on specific interventions. Assessing risk for diarrheal disease requires knowledge of the complex and dynamic interaction of biological, socioeconomic, behavioral, cultural, and environmental factors over time and space. The objective of this study is to advance such knowledge in the context of rural Bangladesh. Specifically, the study identifies the variables related to diarrheal disease risk and analyzes the spatial and temporal patterns of diarrhea.

Humans were the only known reservoir of *Vibrio cholerae* until the mid-1980s when theories of the ecology of cholera were substantially revised. During this time, Colwell et al. (1985) published the results of a study claiming that *vibrios* can live freely in an aquatic environment even under conditions of nutrient deprivation if the environment is not sodium-free. Prior to this study, it was maintained that cholera was only transmitted by ingestion of fecally contaminated food or water. However, Colwell's research suggests that transmission can occur through water without fecal contamination. If transmission can occur without fecal contamination then these findings dramatically change longstanding conceptions

of the ecology of cholera.

This study differentiates between two types of diarrhea, cholera and non-cholera. Cholera is defined as watery diarrhea caused by the bacterium *Vibrio cholerae*. Non-cholera watery diarrhea is defined as watery diarrhea caused by microorganisms other than *Vibrio cholerae*. Ideally, this study would have distinguished between all of the non-cholera diarrheal agents; however, the microbiological tests associated with obtaining this information would have been exorbitantly expensive.¹ Given constraints of time and money, non-cholera watery diarrhea is a logical and useful grouping based on the assumption that none of the organisms in this group have an environmental reservoir while the organisms in the cholera group do.

This study has two distinct parts. The first part of the study analyzes the differences between the spatial and temporal patterns of cholera and non-cholera watery diarrhea. This study was premised on the expectation that such differences exist due to the presence of free-living cholera *vibrios* in aquatic reservoirs along with the absence of an environmental reservoir for non-cholera watery diarrhea. The spatial and temporal patterns of these two disease types have neither been thoroughly described nor differentiated elsewhere. Differentiating between the spatial and temporal patterns of the diseases can not only provide supporting evidence concerning the existence and importance of the cholera reservoir but it also provides a basis for spatial and temporal forecasting

¹ This would require a community-based prospective study, which would take several years.

of both diseases.

The second part of this study differentiates between risk factors of cholera and non-cholera diarrhea. The author believes that different reservoirs, and thus different spatial and temporal patterns, will lead to different risk factors. There are differences in the risk factors because the ecology of the diseases exist within a dynamic spatio-temporal framework so that differences in the spatial and temporal patterns cause differential exposure to the diseases. The cause of a disease is not a simple concept. The doctrine of specific etiology cannot provide a complete account of the causation of disease. Microbiological evidence of a disease is an essential part of understanding a disease but is only the first step to explaining the disease process. Some call the specific etiological agent the direct cause and factors affecting the outcome of disease indirect determinants. We can thus refer to a causal pathway in which more distant indirect determinants lead to the direct determinants of disease. It is within the realm of the biological sciences to describe properties of the direct determinants but studying the indirect determinants requires an interdisciplinary effort (Dubos, 1965). Statistical association does not always mean that a variable is in the causal pathway, there could be a spurious association. The only way one can jump from association to the causal pathway is through logic; that is, the association must make theoretical sense.

This study is guided by the medical geographic theoretical approach called disease ecology (see Chapter 2). It also uses a methodological approach called ecological association analysis that uses quantitative methods to model

spatial and temporal disease variation. This approach facilitates understanding disease causation in a spatio-temporal framework. No such study has previously been conducted on watery diarrhea. Understanding the complexities of risk for watery diarrhea is important for ameliorating this significant health problem in Bangladesh, as well as in other developing countries throughout the world.

This research project provides essential information about the disease ecology of severe watery diarrheal disease. More specifically, the study accomplishes the following goals.

1. It offers corroborating evidence concerning the existence and importance of an environmental reservoir for cholera by differentiating between spatial and temporal patterns of cholera and non-cholera watery diarrhea.
2. It identifies and compares risk factors for cholera and non-cholera watery diarrhea.
3. It extends the use of geographic information systems (GIS) as a tool in disease modeling.

The study was conducted at the International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B), where the author created an extended-household GIS database in 1993. Medical geography studies have historically used aggregate data sources because individual-level data are seldom available and extremely expensive to collect. The ICDDR,B was chosen as a research institution because of its unique watery diarrhea data collection system which makes a micro-level study possible.

1.2 Research setting

Bangladesh suffers markedly from endemic diarrheal disease. Diarrhea is the largest cause of death among children under five in this underdeveloped country (D'Souza, 1985; Hoque & Hoque, 1994). The people of Bangladesh suffer not only directly when they contract the disease, but also indirectly from economic hardship due to lost productivity and medical expenses. The research site for the ICDDR,B and for this project is called Matlab because the Centre's hospital is located in Matlab Town. It is in south-central Bangladesh approximately 50 km south-east of Dhaka, adjacent to where the Ganges River meets the Meghna River forming the Lower Meghna River. Figure 1.1 shows the study location within Bangladesh relative to Dhaka City, the location of three major South Asian rivers, and the Bay of Bengal. The blue lines showing the three large rivers represent each of the bank lines.

The study area is difficult to access from Dhaka by road or rail. Thus, the main point of entry is by river (Figure 1.2). Figure 1.3 shows the Matlab study area relative to the Meghna River. The river running next to Matlab Town is the Dhonagoda River. Figure 1.4 is a picture of the approximately three kilometer wide Meghna River taken in the southwest corner of the study area.

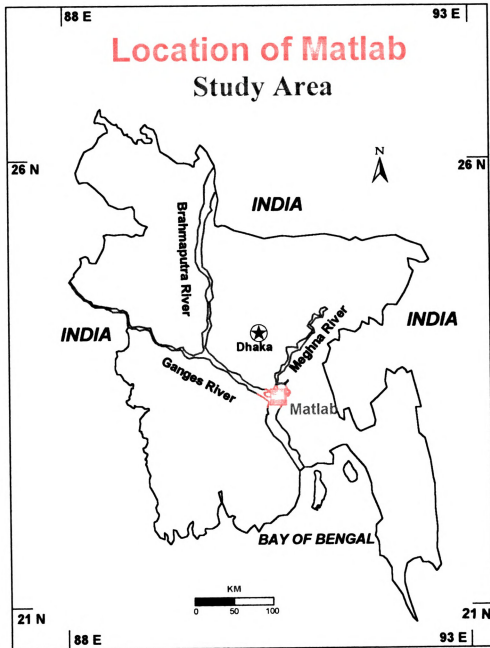
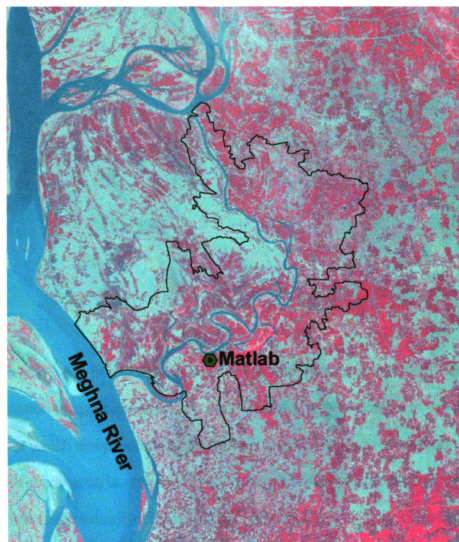


Figure 1.1 Study area location.



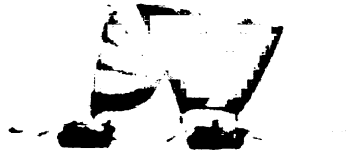
Figure 1.2 Study area relative to rivers and terrestrial transportation network.

Figure 1.3 Study area superimposed on Landsat TM satellite image.



 Study Area

Figure 1.4 The Meghna River.



The ICDDR,B has operated this field research area since 1963. The study area population is approximately 200,000. There are 142 villages in the study area, 128 of which are predominantly Muslim and 14 of which are predominantly Hindu. The study area is almost entirely rural and most people's occupations are in agriculture or fisheries. Increasing population in the past 100 years in combination with the tenure system have led to a major problem of landlessness in the area. The monsoon climate of the study area is characterized by high temperatures, heavy rainfall and marked seasonal variation (Rashid, 1991; Hall, 1988). Table 1.1 lists average monthly rainfall and temperature data that were collected at a weather station near Matlab.

Table 1.1 Seasonal climatic variation in the Matlab area.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
RF	0.66	2.7	4.98	19.3	28.6	52.2	52.7	41.6	29.1	23.7	4.88	0.69
MaxT	26.1	29.5	33.6	33.8	33.6	32.2	31.4	31.9	31.2	31.8	29.9	26.9
MinT	10.7	14.8	17.9	22.2	23.2	23.8	25.1	24.7	24.2	22.9	18.2	11.8

RF-Rainfall (cm) (1947-77)

MaxT- Maximum Temperature (degrees C) (1947-77)

MinT- Minimum Temperature (degrees C) (1971-81)

The Matlab study area has a major environmental division. During the mid-1980s, as part of the Bangladesh Flood Action Plan, a flood-control embankment was built in an attempt to increase the agricultural productivity of approximately half of the Matlab study area. It is called the Meghna-Dhonagoda Irrigation Project by the Government of Bangladesh because the embankment regulates the amount of water that enters the embanked area from the Meghna and Dhonagoda Rivers. The entire study area is part of a flood-plain, however, during the monsoon season flooding is regulated inside the embankment. There are three growing seasons for rice inside the embankment and only two outside the embankment where flooding is unregulated. Figure 1.5 shows the distribution of *baris* in the study area relative to the Dhonagoda River and the flood control embankment. *Baris* are patrilineally-related clusters of households that are raised above the surrounding land area, which is used for agriculture. The area northwest of the embankment is the flood-regulated area and the area southeast of the embankment is the unregulated area. Figure 1.6 is a picture of a *bari* during the dry season and Figure 1.7 is a picture of a *bari* during the monsoon.

Figure 1.5 Distribution of *baris* in study area.

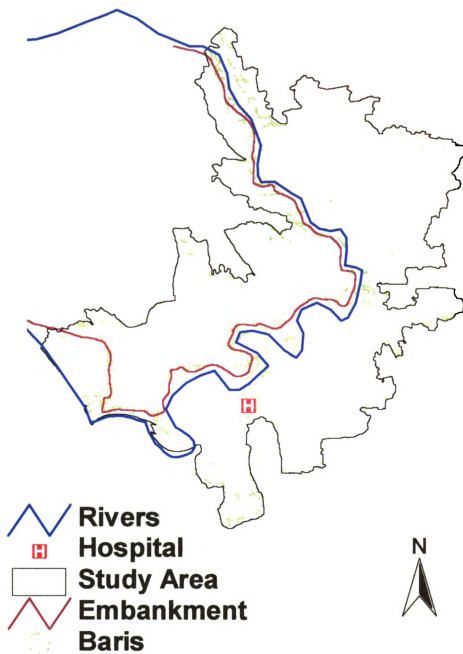


Figure 1.6 A *bari* during the dry season.



Figure 1.7 A *bari* during the monsoon.



Because of its proximity to the confluence of the Padma and Meghna Rivers, the southern part of the study area was traditionally subject to massive erosion. During the 1988 flood, several square kilometers of land were lost into the Meghna River. The embankment was built in part as an attempt to contain the floods to decrease erosion and increase the number of rice growing seasons from two to three. Since the Meghna-Dhonogoda embankment was finished in 1988 it has had a major impact on the flood conditions in the area. There have been large reductions in flood depths in low-lying areas. The project has resulted in a large growth in rice output and livestock production but it has had a devastating effect on fisheries. Daily fish catches have fallen by approximately 40 percent within the flood-controlled area (HTSL, 1992).

Rice dominates agriculture in the highly fertile Meghna Floodplain of which the Matlab study area is a part. Rice crops are mainly local varieties, including *aman*, *aus*, and *boro*, but high-yielding varieties are increasingly used inside the embankment. Other crops include potatoes, jute (although its production has declined in the past 15 years), mustard, onions, garlic, and chili peppers. Sugarcane and various vegetables and fruits are grown in small amounts. The other main occupation in Matlab is river fishing. Much of the fishing in Matlab is done from river banks with small nets for subsistence. People also fish from small boats using cast nets and they sell their catch in the small Matlab market or at the major fishing center of Chandpur, which is ten kilometers south of the study area (Rashid, 1991; Hall, 1988). Figures 1.8 and 1.9 are pictures of the diverse types of fishing in the study area.

Figure 1.8 Large-scale fishing in Matlab on the Meghna River.



Figure 1.9 Small-scale fishing in Matlab.



Another mostly subsistence economic venture in the area is livestock rearing. Approximately 81 percent of households have chickens and ducks, 47 percent have draught animals, and 30 percent have goats or sheep (HTSL, 1992). Other economic activities in the area include trading, shop keeping, and transport services. The trading is mainly in agricultural inputs and outputs, and the transport services include rickshaw pulling and flatbed rickshaw pulling of goods. There are other smaller economic activities in the area that can be called rural industrial activities and enterprises. They include activities such as rice milling, saw milling, carpentry, pottery making, net making, handloom weaving, tailoring, blacksmithing, goldsmithing, and rickshaw repairing (HTSL, 1992).

While at the ICDDR,B in 1993 the author created a vector GIS database of the Matlab field research area. Features in digital format include *baris*, rivers, roads, schools, religious structures, village boundaries, and the flood-control embankment. Figure 1.10 shows three features in the GIS database including the flood-regulating embankment, the Dhonagoda River, and *baris*. The three map views in Figure 1.10 are displayed at different scales. The map view on the far right has the individual *bari* identification numbers visible. The *baris* are all identified by an ICDDR,B demographic surveillance system (DSS) census number within the structure of the GIS database. This allows attribute data to be linked to the spatial database. Thus, disease incidence data can be linked to specific *bari* locations.

The Matlab field research center is a diarrhea treatment center (DTC) which has in- and out-patient services, a laboratory for the identification of

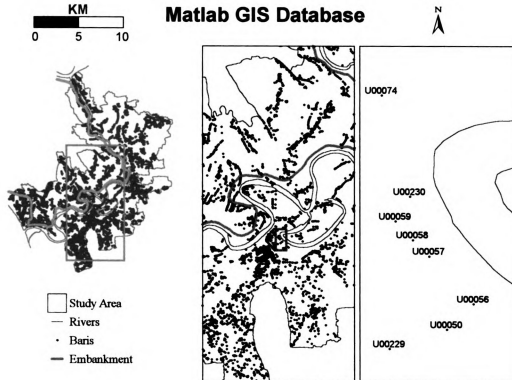


Figure 1.10 Study area GIS database.

pathogens, and research facilities. The Matlab DTC treats about 7,000 to 8,000 diarrhea cases per year, and to date, more than 230,000 diarrhea patients have been treated by the Centre. There are motorized boats which function as a free ambulance service for diarrhea patients so access to the hospital is remarkably good. All DTC services are free as well. The research center maintains a community-based data collection system. One-hundred twenty community health workers (CHWs) visit each household every two weeks to collect demographic, morbidity, and other data. The DSS conducts periodic censuses (most recently in 1993) and uses CHWs to update demographic data (births, deaths, and migrations). The DTC laboratory consists of microbiology, clinical

pathology, and bio-chemistry units which provide diagnostic services to the hospital and for field research activities.

In the southwest corner of the study area where the Meghna and Dhonagoda Rivers join there has been much channel migration. A retrospective study of bank line changes between 1984 and 1993, which used Landsat TM satellite imagery, found that between 1000 and 2500 meters of the river bank were eroded from this area. Most of this erosion occurred during the 1987 and 1988 floods, which displaced a large number of people (ISPAN, 1995). Many people became landless and were forced to migrate or settle on the nearby embankment, which is considered public land. Presently, there are still many people living in makeshift housing structures that are built on stilts and hang off the sides of the embankment. These people must survive by share cropping or as laborers. They are some of the poorest people in the entire study area.

1.3 Review of literature

Diarrheal disease can be caused by many etiological agents. For practical purposes diarrhea can be classified into two manifestational categories, dysentery and watery diarrhea (Benenson, 1990; ICDDR,B, 1993). This study will focus on watery diarrhea, thus the agents that cause dysentery will not be considered². Two studies were conducted in Matlab to examine the relative

² The dysenteric agents that are present in Matlab include *Shigella*, *Campylobacter jejuni*, *Entamoeba histolytica*, enteropathogenic *Escherichia Coli*, and enteroadhesive *Escherichia Coli*.

importance of various enteropathogens that cause diarrheal diseases; see Table 1.2 (Baqui et al., 1992; Black et al., 1980). The non-cholera, non-dysentery organisms that are listed in the table are all watery diarrheal agents. Cholera is caused by the colonization of the small intestine with *Vibrio cholerae* O1. During the Spring of 1993, *Vibrio cholerae* O1 was replaced by another strain, *Vibrio cholerae* O139. While the clinical manifestations of the two agents are identical, little is known about the newer strain (Siddique et al., 1994). There are several distinct differences between the four different studies shown in Table 1.2.

Variation in relative importance in different studies can be attributed to differences between community-based studies and hospital-based studies because people only visit the hospital when the case is severe. Other variation is due to the different microbiological tests that were done as well as year to year variation in epidemics.

In rural Bangladesh, cholera transmission can be divided into primary and secondary types (Colwell & Spira, 1992). Primary cases are the result of infection by surface water sources. An example of this is when people are directly infected with the bacteria by drinking untreated pond water or eating undercooked shellfish. Secondary cases consist of people who are infected by fecal-oral transmission by people with primary infection. An example of this is when a family member is infected by a sick member of his/her family when the sick person puts his/her hands in the family's drinking water pot. Another example of secondary transmission is when a mother is infected by the feces of her baby. Primary transmission is controlled by factors such as temperature,

salinity, nutrient concentrations, the number of available attachment sites (plankton), shellfish consumption, and contact with water (Colwell & Spira, 1992).

Table 1.2 Percent of diarrheal episodes associated with etiological agents in Matlab

Pathogen	Black et al. 1981 Community- based	Black et al. 1981 Hospital-based	Baqui et al. 1990 Community- based	Baqui et al. 1991 Hospital- based
<i>Vibrio cholerae</i> 01	0.3	13	0.4	39
<i>Vibrio cholerae</i> Non 01	1.1	7	2.9	3
<i>Shigella</i>	12.8	5.5	8.6	11
Enterotoxigenic <i>Escherichia Coli</i>	26.9	29	12.2	14
<i>Campylobacter</i>	-	-	17.6	11
<i>Salmonella</i>	-	<1	0.1	1
Enteroadhesive <i>Escherichia Coli</i>	-	-	34.3	-
Enteropathogenic <i>Escherichia Coli</i>	-	-	13.5	-
<i>Aeromonas</i>	-	-	2	-
<i>Pleismonas</i>	-	-	0.1	-
<i>Rotavirus</i>	3.8	24	4.3	-
<i>Entamoeba</i> <i>histolytica</i>	0.2	4	.4	2
<i>Giardia lamblia</i>	0.5	2	2.2	2
<i>Cryptosporidium</i>	-	-	1.9	-
No pathogen	49.5	-	42.1	-

(- not tested) (Derived from Baqui et al., 1994)

In rural Bangladesh cholera transmission is seasonal, with a peak after the monsoon, which extends from September to December (Baqui et al., 1994).

Colwell and Spira (1992) suggested that the post-monsoon season is associated with a heavy bloom of zooplankton, maximum recreational water contact, and maximum available *crustacea* in the marketplace. They postulated that there is a permanent environmental reservoir for *Vibrio cholerae* in the brackish ponds and

canals of rural Bangladesh.

Many studies have identified risk factors for cholera in rural Bangladesh and they can be roughly divided into four types, namely biological, behavioral, environmental and socioeconomic. Some risk factors, however could be placed in two or more of these variable classes. Although not exhaustive, these studies represent the most important findings related to cholera risk by investigators from many different disciplinary backgrounds.

The following studies have identified biological risk factors. First, Glass et al. (1985) found that individuals with type O blood are predisposed to cholera. Second, Glass and Black (1992) found that breast-feeding protects infants against cholera; however, this finding might be related to contamination of water during bottle-feeding, a behavioral variable. Third, malnutrition was long thought to be associated with cholera infection but Stanton and Clemens (1986) found the long-standing belief that malnutrition was associated with cholera not to be true. Glass and Black (1992) also found that children aged 2 to 15 are at greatest risk of contracting cholera. While age is a biological variable its involvement in disease transmission is surely very complex and involves many types of variables.

Several behavioral variables have also been identified. In Bangladesh, women of child-bearing age have high cholera incidence rates presumably because of increased person-to-person contact (Glass & Black, 1992). This is an example of a behavioral variable that is intertwined with culture. Glass et al. (1982) found that villages with daily bazaars have higher cholera rates. This is

an example of an aggregate behavioral measure.

Environmental variables have been identified in four studies. Sommer and Woodward (1972) found that people who lived close to tubewells had a much lower incidence rate than those who lived further away because they had access to clean water. Khan et al. (1981) found that cholera attack rates were higher for families with access to canal water as opposed to river water or tank water. In Matlab, Glass et al. (1982) found that cholera is more common in villages that are not adjacent to the main river. Hughes et al. (1982) found that rural Bangladeshi families who used contaminated surface water for cooking and bathing were more likely to get cholera than those who did not.

Glass et al. (1982) found that predominantly Hindu villages have higher cholera rates. It is unclear whether this is because of socioeconomic reasons or cultural reasons. Becker et al. (1986) found that children in poorer households had a higher proportion of days with all diarrhea and *Rotavirus* than more affluent households. Chen et al. (1981) found that undernutrition is not a predictor of diarrheal incidence.

There are several significant gaps in the literature on watery diarrheal disease. No study has used a disease ecology approach and few studies have identified indirect socioeconomic determinants of diarrheal disease. While many studies have used simple non-parametric statistical methods, few have identified the multivariate relationships between the different types of variables. Also, no studies have differentiated between cholera and non-cholera diarrheal disease risk. Craig (1988) looked at spatio-temporal clustering of cholera, but no studies

looked at spatial and temporal patterns and their associations with other variables. This dissertation will use a disease ecology approach to begin to fill in these gaps.

Several studies support a hypothesis that the temporal and spatial patterns of cholera and non-cholera watery diarrhea will be different from one another. Baqui et al. (1994) described that there are two cholera peaks, one sometime between September to December and the other between March and June. Black et al. (1981) found that incidence of *Rotavirus* is relatively constant except for a small peak in December, and that enterotoxogenic *Escherichia coli* occurs more frequently in the hot months.³ An environmental reservoir is not known to exist for non-cholera organisms; humans and animals are the only reservoirs for these organisms (Benenson, 1990; Warren & Mahmood, 1993). The dichotomy between cholera and non-cholera diarrhea was chosen because it has been hypothesized that cholera has an environmental reservoir and there is no evidence of one for non-cholera diarrhea. Accurate descriptions of the spatial and temporal patterns of these diseases have never been completed but the creation of a GIS database made this task manageable. Although this study will not accurately identify the location of the cholera reservoir it can offer corroborating evidence of its existence/importance by describing the spatial and temporal patterns of the disease. If the cholera reservoir is important then the spatial and temporal patterns of cholera and non-cholera watery diarrhea will be

³ *Rotavirus* and *Escherichia coli* are non-cholera watery diarrheal agents.

very different. More specifically, the pattern of severe cholera watery diarrhea should generally correspond to the environmental reservoir especially at the beginning of the season. It is hypothesized that the environmental reservoir of cholera is the brackish aquatic environment of the rivers, canals, and ponds of the study area. These brackish water bodies are throughout the study area thus it is hypothesized that cases will be highly dispersed. Figures 1.11, 1.12, and 1.13 are pictures of the aquatic environment that is thought to be the cholera reservoir. Since it is hypothesized that non-cholera diarrhea does not have an environmental reservoir then the pattern of this disease should be less dispersed.

Figure 1.11 Homesteads adjacent to a large pond.



Figure 1.12 Small canal during the dry season.



Figure 1.13 People living near the Dhonogoda River.



Since it is hypothesized that these two disease categories have different spatial and temporal patterns it is thought that their risk factors will be different. This is because spatially and temporally heterogeneous risk is what determines the spatial and temporal patterns of the diseases. If funding or time were not a consideration the study would distinguish between all of the non-cholera diarrheal agents, however, the microbiological tests associated with obtaining this information would be extremely expensive and time-consuming.

As described in Chapter 1, understanding watery diarrheal disease is complex and involves many different types of variables. Chapter 2 describes the theoretical context from which this dissertation investigated cholera and non-cholera diarrhea. This study is guided by the medical geographic theoretical approach called disease ecology and uses a methodological approach called ecological association analysis which uses quantitative methods to model spatial and temporal disease variation. This approach facilitates understanding disease causation in a spatial and temporal framework. In order to increase our understanding of complex phenomena such as diarrheal disease, it is necessary to expand the theoretical holism of disease ecology and practice methodological pluralism when doing this type of research. Chapter 3 describes the specific methods that were used to investigate the disease ecology of diarrheal disease. These methods include disease mapping techniques that utilize the aforementioned GIS database as well as both non-parametric and parametric statistics. Chapter 4 describes the findings of the study and Chapter 5 brings all of these pieces together by describing the most important results and their

theoretical and practical implications. The main cholera epidemics from January 1992 to December 1994 occurred just after the rainy season and smaller epidemics occurred at the end of the dry season. There were almost no cases during the winter of each year. There was an irregular temporal cycle to non-cholera watery diarrhea. The peaks did not follow a regular seasonal pattern and the largest epidemics occurred at different times of the year. Cases of cholera were widely dispersed throughout the study period, whereas cases of non-cholera watery diarrhea were more clustered. These spatial and temporal patterns provide support for Colwell's (1985) theory that cholera is a disease with an environmental reservoir while non-cholera diarrhea is not. Chapter 5 also offers a heuristic model, which can be used to understand the disease ecology of diarrheal diseases in rural Bangladesh.

2. The use of medical geography for the investigation of diarrheal disease in rural Bangladesh

In order to advance the philosophical and theoretical implications of this study it is necessary to situate the study within the field of geography and within the sub-field of medical geography.

2.1 Ecologic theory within the field of Geography

The human-environment tradition in geography was born and has evolved throughout the 20th century in American geography. Early proponents of this tradition highlighted how they thought the physical environment affects humans. Consequently this approach has been called environmental determinism (Semple, 1911; Brigham, 1915; Davis, 1915; Huntington, 1924). Many environmental determinists were actually trained in geology and were well versed in Darwinian natural selection theory. Influenced by their training, they professed that human activities are controlled by their environment. Thus, the beginning of human-environment theory in human geography saw environment as the stronger force in the human-environment dyad. Approximately a decade later at the University of Chicago, H.H. Barrows (1923) introduced a geographic human-environment tradition called "human ecology." The reference to ecology is derived from the biological sciences and refers to the human-environment ecosystem. Barrows' human ecology used a more social science oriented perspective to study relationships of human society within its biophysical

environment (Haggett, 1977). Zimmerer (1996) differentiates between five ecological traditions in human geography including:

- 1) human ecology
- 2) cultural-historical ecology
- 3) systems ecology
- 4) adaptive dynamics ecology
- 5) political ecology

Human ecology as defined by Barrows in 1923 was the study of "mutual relations between man and his natural environment." This sub-field of geography viewed humans and environment as coexisting forces and investigated how humans make adjustments to their environment through economic and political organization (Zimmerer, 1996). Barrows' human ecology evolved into a field that primarily investigated natural hazards (Burton, Kates, and White, 1968; Burton and Hewitt, 1974; White, 1945; White, 1974). Burton and Kates (1964) defined natural hazards as "those elements in the physical environment, harmful to man and caused by forces extraneous to him." They went further to classify natural hazards as geophysical or biological. Geophysical hazards are climatic or meteorological events such as floods and geologic or geomorphic events such as earthquakes. Biological hazards are caused by flora, such as poison ivy or fauna, such as bacterial infections. The human ecology study of natural hazards emphasized the role of individual decision-making when adapting to their environment but overlooked historical and socioeconomic circumstances which put people at risk to hazards (Zimmerer, 1996, 167).

Since these early days of the human-environment tradition several other ecological traditions have been born. Cultural-historical ecology, firmly established by Sauer, focuses on cultural manifestations of the human landscape. Sauer and his philosophical successors studied changes in the landscape such as vegetation distribution. The cultural-historical ecologists were different from the human ecologists in that they separated environment and society and thought that culture was the most important variable guiding human action as it related to landscape change (Zimmerer, 1996, 169).

Systems ecology was a perspective born in a theoretical period dominated by quantitative methods and geography as science. Kates (1971) continued with his natural hazards research but within the rubric of General Systems Theory. He wrote of this new ecological perspective that "with its focus on man as the ecological dominant, the interactions between men and nature tend, over the short run, to be stable, homeostatic, and self-regulating over the long run, to be dynamic, adaptive, and evolutionary in the direction of increasing control over nature's resources and buffering from nature's hazards." Humans were seen as part of a holistic ecosystem. Biological ecology concepts such as ecosystem, equilibrium, niche, carrying capacity, succession were all used to explain how humans are part of a large negative feedback system (Zimmerer, 1996, 172-73; Kates, 1971). Adaptive dynamics ecology focuses on individual decision making as it pertains to humans adapting to environments. Humans have a more dominant role in the human-environment dyad although they are seen as inseparable (Zimmerer, 1996, 1974-75).

Political ecology, although not a unified approach that can be easily defined, is a holistic approach to understanding human-environment relations (Blaikie, 1994). Blaikie and Brookfield (1987, 17) defined political ecology as a combination of ecology and political economy. Zimmerer (1996) suggests that political ecology disengages the study of ecology and political economy. Campbell and Olson (1991) developed a political ecology model for studies of human-environment relations called the kite. This heuristic model purports that one must understand political, economic, environmental, and socio-cultural variables at different spatial and temporal scales to fully understand the relationship between society and the environment. Contrary to Zimmerer's understanding of the field of political ecology in general, the kite model suggests that ecology and political economy are interwoven into an inseparable web. In Section 2.2 it will be argued that the sub-discipline of medical geography has developed a parallel theory to some of these human-environment theories in the sub-disciplinary tradition of disease ecology.

This dissertation can be situated within the human environment tradition of geography but it also has characteristics of the tradition of spatial organization. The study is spatial because it is interested in the distribution of a phenomenon (disease) in space and time. It is ecological in that it is based on the theory of disease ecology, a holistic approach to understanding disease in the context of human-environment interaction.

2.2 Medical geography theory

Analyzing risk of contracting watery diarrheal disease in Bangladesh requires a conceptual framework that addresses the complexities of biological, socioeconomic, cultural/ behavioral, and environmental factors over time and space. A medical geographic theoretical approach that addresses these issues is disease ecology, which maintains that disease results from a dynamic complex of variables that coincide in time and space (May, 1958, 1977; Mayer, 1982, 1984; Mayer and Meade, 1994; Meade, 1977; Meade et al., 1988; Learmonth, 1988; Paul, 1985; Pyle, 1977, 1979). Hunter (1974) argues that we must not have a pathogencentric view of disease, i.e. one that focuses only on the disease agent. He suggests that our studies of disease "must co-jointly involve pathogen, host, and environment" (Hunter, 1974, 1). He views environment broadly as consisting of "diverse physical, biological, social, cultural, and economic components" (Hunter, 1974, 3). Hunter defines geography as a discipline that bridges the social and environmental sciences and writes that "its integration and coherence derive from systems-related analysis of man-environmental interactions through time and over space" (Hunter, 1974, 3).

This dissertation is intended to demonstrate the value of a medical geographic approach that is holistic and which includes the integration of many different types of variables responsible for disease. The types of variables to be investigated have been classified in many different ways but Mayer's (1986) classification system is most useful. Mayer differentiated between biological, socioeconomic, behavioral, and environmental variables. Biological variables are

those that describe biological characteristics of the host such as blood type. Behavioral variables are those that describe individual or group behaviors and may be related to culture or individual decision making such as what types of food people eat. Environmental variables are those of the biophysical environment such as climatic variables. Socioeconomic variables are variables that affect the coincidence of agent and host such as wealth or class. Different patterns of socioeconomic, behavioral, and environmental variables result in different spatial and temporal patterns of disease. Virtually every disease exhibits spatial and temporal variation and medical geographers attempt to explain this variation.

The theory of disease ecology fits into both the spatial organization and human-environment traditions of geography. Different medical geography studies throughout the history of the sub-field can be classified into all five of Zimmerer's (1996) ecological traditions in human geography. However, disease ecology is more specialized than the previously mentioned human-environment theories in geography because the dependent variable in disease ecology is always disease. Human-environment interaction can essentially be viewed as the cause of disease. The spatial tradition of disease ecology is evident in that all definitions and studies are interested in the spatial distribution of disease.

A methodological approach which utilizes the theory of disease ecology, called ecological association analysis, holds that quantitative studies which associate environmental, physical, and cultural variables can help explain the spatial and temporal variation of disease occurrence (McGlashan, 1967; Mayer,

1986). The fundamental question asked using this approach is, "What factors are associated with the spatio-temporal variation of disease?" Mayer states that "the term ecological association implies the existence of specific links between the environment and both individuals and groups" and that "in the context of medical geography, the focus is on those relationships which are consequential in disease pathogenesis" (Mayer, 1986, 66). He also states that "in ecological analysis, the emphasis is therefore on the complex set of interactions between people and their environment" (Mayer, 1986, 66).

The method of ecological association is best used within a theoretical approach such as disease ecology. Mayer (1986) addresses one of the main challenges of ecological association analysis, which is the possibility of spurious correlation.

"One of the most vexing problems in ecological analysis is that of moving from statistical association to causal relationships. It is one thing to identify cultural, environmental, or social factors which are associated statistically with disease occurrence. This may be accomplished in the absence of a theoretical framework, or a logical association, between the disease and the environment. Correlation between the disease, and a host of related independent variables, may be so spurious as to defy the formation of meaningful causal hypotheses. For example, there is a very strong correlation between multiple sclerosis prevalence and annual per capita steel consumption, at the national level. The relationship may be tenuously meaningful, in that steel consumption may be a surrogate for concepts such as economic development, or the correlation may be meaningless, since it may be coincidental that multiple sclerosis and steel consumption show the same pattern of variation" (Mayer, 1986, 66).

Several researchers have also identified the ecological fallacy as a serious

problem in many aggregate-level ecological association studies (Mayer, 1982; King, 1979). The ecological fallacy states that conclusions made at the aggregate level (e.g., county, state, national) are not always true at the individual level. For example, if an association is found between cancer and smoking when grouped by county, one cannot be sure that the association exists at the individual level. That is not to say that finding an association is not important information, but that further investigations must be conducted to determine whether it is correct. Mayer (1982) suggests that individual-level case-control⁴ studies should be conducted to alleviate this problem. To date, very few medical geography studies have been done at the individual level because these data are expensive to collect and thus seldom available.

Past disease ecology and ecological association analysis studies have ranged from speculative studies to multivariate explanatory studies. Jacques May wrote (1958) several voluminous descriptive studies of the ecology of many infectious diseases including brucellosis, poliomyelitis, tuberculosis, and leprosy. These studies are recognized as the formal beginning of the disease ecology tradition but have been criticized as being atheoretical and overly idiographic. Burkitt (1962) described the existence of a "lymphoma belt" straddling the equator where a childhood cancer occurred (later named Burkitt's Lymphoma). He found that this cancer only occurred in specific locations. Roundy (1976) identified associations between disease and altitude in Ethiopia. Kloos (1985)

⁴ Discussed in Chapter 3.3.2 of this dissertation.

found that schistosomiasis in the Awash valley in Ethiopia is associated with migrant labor. Hunter (1982, 1992) brought attention to associations between irrigation projects and infectious disease throughout the tropical world and called for health policy considerations when development projects are implemented.

While much of the disease ecology literature has been devoted to infectious diseases especially in the developing world, the approach has also been used for diseases in the developed world. Hunter (1976, 1977) described a seasonal cycle for childhood lead poisoning and identified geographic concentrations of the disease in older residential areas along traffic arteries in the United States. Meade (1980) studied cardiovascular mortality in the southeastern United States and Glick (1979, 1980) used a GIS to analyze the spatial characteristics of cancer mortality in Pennsylvania.

Since the inception of disease ecology and ecological association, greater attention has been paid to temporal patterns, spatial scale, and statistical methods. Studies should always have a temporal dimension because temporal changes in biological, socioeconomic, behavioral, and environmental variables affect how agents and hosts come into contact with one another. Disease associations at one spatial scale may not be present at other spatial scales. Therefore, multi-scale studies should be conducted whenever possible. The use of a GIS makes spatial analysis methods more efficient and accurate. Also, the interface between GISs and statistical methods has recently begun to be explored. A few of the studies in the literature reviewed above utilized a GIS to analyze their data and many have used statistics.

This dissertation is informed by a holistic disease ecology that views the human-environment dyad as inseparable. It is the author's view that the kite model's inclusion of political, economic, environmental, and socio-cultural variables at different spatial and temporal scales is needed to understand the disease ecology of a particular place. However, this study only begins to fulfill these requirements. The study is done at only one spatial scale and does not investigate political causes of diarrheal disease. However, understanding the political and economic context is necessary to fully explain the disease ecology of a particular disease. Mayer (1997) recently argued that "because the political ecological framework is very powerful in focusing attention on the interaction between political interests, social institutions, and human-environment interaction, it has great potential in leading to a greater systematic understanding of health and disease. Thus, in order to have a complete understanding of diarrheal diseases in rural Bangladesh, it is necessary to do further research on the political and social institutions involved in the ecology of these diseases.

Complex diseases such as cholera and non-cholera watery diarrhea require a pluralistic methodological approach to ensure complete understanding. Richard Norgaard wrote, "science only gives insights into complex issues" (1989: 52). He criticizes traditional positivistic methods, of which ecological association analysis is a part, because they assume:

- methods of understanding are independent of culture;
- reality is independent of methods of understanding;
- reality can be understood in terms of universal laws; and

- reality can be understood through one set of universal laws.

Norgaard, however, goes on to say that "logical positivism is necessary because modern people perceive science in terms of objective, universal truths" and that "it is clearly too early to limit methodologies" (page 51). In essence he argues for methodological pluralism, which means we need to use multiple methods to solve research problems. He also warned that "pluralism will lead to multiple answers to complex issues" but that "it is easy to suffer the delusion that the insight of a particular method is the answer when no other methods have been tried to provide other insights" (page 52). Lastly, he wrote that "multiple insights of multiple methods constantly remind us of the complexity of social and ecological systems and the difficulties of taking action" (page 52). This study is an attempt to tap into the complexity of diarrheal disease by using different types of statistical methods appropriate for many different types of data, disease mapping techniques, and GIS tools.

The sub-field of medical geography is presently in a state of turmoil. Kearns (1993) sparked a debate, which is played out in journal articles, rebuttals, and conferences, by arguing that medical geography has a preoccupation with the spatial relationships between individuals, places, and institutions rather than with health-related characteristics of place. This may be true of the sub-discipline, however others have taken this argument further and argued that medical geography should be a sub-field of social geography and medical geographers should specialize in social theory as it relates to disease. Kearns argued that medical geography should renew its focus on the context of

"experienced place rather than its catalogued characteristics" (page 140). Some of the calls to change medical geography are calls to narrow the field of study to understanding social phenomena through qualitative methods. A more narrow medical geography will certainly hinder understanding of complex diseases such as diarrheal disease. Social theory and qualitative methods, however, are key elements to understanding diseases; these types of studies should be welcomed and used in conjunction with positivistic studies. The more holistic studies are and the greater the methodological pluralism used, the better the understanding of diseases will be in the future.

This debate is not isolated within medical geography. Many people are calling for a paradigmatic shift within the entire field of geography. The post-modern debate has included many people who are calling for a shift to geography as a field of social theory and qualitative methods (Dear, 1994). The author contends that narrowing the field of geography in both theory and methods will limit our understanding of complex phenomena and that theoretical holism and methodological pluralism should be embraced. To increase our understanding of complex phenomena such as diarrheal disease it is necessary to expand the theoretical holism of disease ecology and practice methodological pluralism when doing this type of research. This will enhance our understanding of not only diarrheal disease in rural Bangladesh, but also the ecology of diseases throughout the world.

The following chapter describes the specific methods that were used to

investigate the disease ecology of diarrheal disease in Bangladesh.

3. Methods: specific research questions, data sources, and analytical methods

3.1 Specific research questions

This research project measured whether there were differences in spatial and temporal patterns and risk factors between cholera and non-cholera watery diarrhea. The following questions were addressed:

- What are the spatial and temporal patterns of these two disease categories?
- What are the similarities and differences between the spatial and temporal patterns of the two diseases?
- What are the biological, socioeconomic, cultural/behavioral, and environmental variables (risk factors) responsible for occurrence of cholera and non-cholera watery diarrhea?
- To what degree are the risk factors for these two diseases similar or different?

3.2 Data sources and collection methods

A number of data sources were utilized and many data collection methods were employed in this study. They included:

- Creation of a computerized spatial database of the study area.
- Collection of diarrheal disease data (dependent variables) from hospital records.
- Collection of primary data for independent variables hypothesized to be related to diarrheal disease by administering a questionnaire to diarrheal

disease patients and people from the community who did not contract the diseases (control group).

- Collection of secondary data from the ICDDR,B Demographic Surveillance System records and community health worker record books.
- Administration of a survey to collect primary data on the distribution of latrines and tubewells in the study area. This was done for the entire study area, not only for study participant households.
- Spatial calculations such as distance measures were done to construct new variables by using the Matlab GIS database.

These data collection methods are each discussed in further detail in sections 3.2.1 through 3.2.8.

3.2.1 Creation of the study area geographic information system database

A geographic information system database was needed in order to be able to model the spatial patterns of the study diseases as well as to allow several of the independent variables to be measured by performing spatial calculations.

The spatial database was created in the following stages.

1. **Assessment of base map accuracy.**
2. **Identification of individual *baris* on base maps.**
3. **Digitization, spatial editing, edgematching adjacent maps, and projection of base maps.**
4. **Update of *baris* missing from the GIS database.**
5. **Accuracy assessment of GIS database *bari* locations.**

Each of these stages is discussed in greater detail below.

Base map accuracy assessment

In 1992, the ICDDR,B contracted the Bangladesh Space Research and Remote Sensing Organization (SPARRSO) to map the Matlab study area. They took air photos from which they mapped the area in six 1:10,000 scale maps. The map features included *baris*, rivers, large ponds, roads, educational institutions, and the flood control embankment. Since it is impossible to distinguish between *baris* in air photos, field workers were hired to determine which clusters of households on the air photos were *baris*. The resulting maps included all of the *bari* locations in the study area but they were not individually identified. In other words, there were over 7000 points on the base maps that represented *baris* but it was impossible to know which people lived in each *bari* without having field workers visit each of them.

An accuracy assessment of the maps was conducted in January 1993 by the author of this dissertation. Several prominent features such as road intersections and the hospital were digitized from hardcopy SPOT Panchromatic satellite images. The same features were digitized from the base maps and their locations were compared. This preliminary accuracy assessment determined that the sample of features on the base maps were accurate enough to pursue their use in building a *bari*-level GIS database. The base maps were considered accurate because the majority of the digitized features from the two sources were within approximately 50 meters of each other.

Identification of individual *baris* on base maps

The initial ground-truthing exercise implemented by SPARRSO identified which clusters of households on the base maps formed individual *baris*. The ICDDR,B Demographic Surveillance System (DSS) maintains a census of all individuals in the Matlab study area. Approximately 200,000 individuals live within the more than 7000 *baris* of the 142 village study area. A village is a group of contiguous *baris* and is not a political unit. Village boundaries are sometimes the same as the lowest-level administrative unit called the *mouza*, but sometimes there are several villages in a *mouza*. Each individual has a unique identification number that is correlated with her/his *bari* residence. The ICDDR,B employs 120 field workers who regularly collect demographic, socioeconomic, and health data from the study population. Each field worker is responsible for data collection in a specific geographic area. Thus, they know the area and the families living in their area very well. These field workers identified the location of each of the more than 7000 *baris* on the base maps so that each of the *bari* location points could be assigned a unique identification number. The field workers went into the field with photocopies of base maps and comprehensive lists of the *baris* they were supposed to identify. They wrote the *bari* codes on the photocopied maps. These maps were collected and the identification numbers were then written on the original base maps that were to be digitized. The entire identification process was completed in approximately four months from February to May 1993.

Digitization, spatial editing, edgematching adjacent maps, and projection of base maps

After the field workers identified the locations of individual *baris*, the six base maps were digitized in ArcInfo. Features that were digitized included each of the *baris*, their six digit, *bari* identification numbers, rivers, health facilities, and the flood-control embankment. After the six base maps were digitized they were edited, edgematched, and projected. In addition, since the course of the Meghna River in the southwest of the study area is constantly changing due to bank erosion, satellite imagery was used to update the river bank location. Digital, Landsat TM imagery was overlaid with the digitized maps and the river features were redrawn based on the more recent data. The entire digitizing process was completed in approximately four months from June to September 1993.

Accuracy assessment of *bari* locations and institution of an updated system

Once the entire GIS database was created, a stratified random sample of 100 *baris* was selected for a differential, global positioning system (GPS), accuracy assessment. The study area was divided into ten quadrants within which 10 *baris* were randomly selected from all of the *baris* within the quadrants. The locations were then identified using handheld Magellan GPS receivers. Differential GPS has a measurement accuracy of approximately five meters. This required that two GPS receivers be used and that differential values be calculated using post-processing software. The accuracy assessment showed that the average difference between the *bari* locations in the digitized maps and

the GPS measurements was approximately 24 meters. This assessment indicates that the database was very accurate. Therefore, spatial analysis of the data was deemed to be feasible.

Since the fieldwork for the GIS database creation was completed in May 1993, new *baris* that formed beyond that date needed to be added to the spatial database for use in the 1996 dissertation data collection survey. In May 1993 there were three full-time, GIS staff employed by the ICDDR,B who regularly maintained the database. *Baris* that split from existing *baris* were added manually to the base maps and then digitized. Those that had no other *bari* as a point of reference were added, using GPS receivers.

3.2.2 Dependent variables

Diarrheal disease data were collected for people from the Matlab treatment area who were hospitalized at the diarrhea treatment center with watery diarrhea from January 1, 1992 to December 31, 1994. The cases were assigned to one of two diarrhea disease categories (cholera or non-cholera watery diarrhea) that were used as dependent variables in the analysis stage of the research. Figure 3.1 is a picture of two children with a diarrheal disease in the Matlab diarrhea hospital. They are being rehydrated with intravenous fluids and are lying on cholera cots, which are cots with holes leading to buckets so patients do not need to use bedpans.

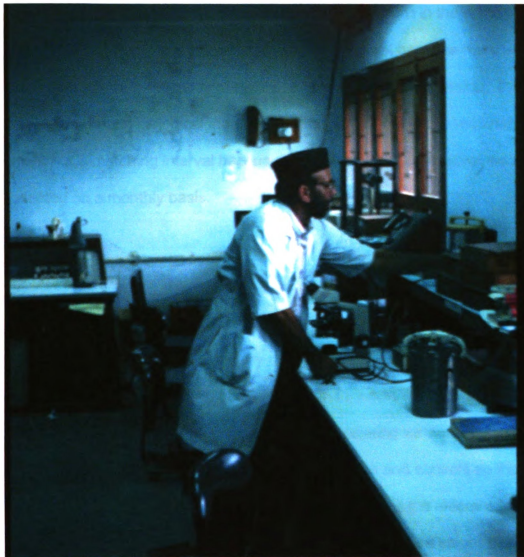
Figure 3.1 Two children on cholera cots, being rehydrated.



For each patient admitted to the Matlab diarrhea treatment center a stool sample is regularly collected and routinely tested for *Vibrio cholerae* and *Shigella*, a dysenteric agent. Figure 3.2 shows the Matlab laboratory manager doing these microbiological tests. In this study, laboratory records of the patients were used to assign one of the two above agent categories. Hospital records specify whether or not there was blood in each patient's stool. Patients who tested positive for *Shigella* or who had blood in their stool were excluded because this study is not concerned with dysentery. The cases that did not have dysentery or cholera were assigned to the non-cholera watery diarrhea category. Approximately 4000 of the patients who are admitted annually to the Matlab hospital are from the Matlab study area. Approximately 70 percent of these patients have watery diarrhea (see Chapter 4.2 for exact numbers during the

study period). The *bari* identification numbers were collected for all cholera and non-cholera watery diarrhea cases so they could be mapped.

Figure 3.2 Matlab microbiology laboratory.



Individuals were randomly chosen from the community to be controls. After the cases were identified, a list of potential controls was compiled from DSS records. A person was eligible to be a control if s/he lived in the Matlab

surveillance area, was not admitted to the diarrhea treatment center during the study period, and did not die of a diarrheal disease during the study period. The controls were age matched. For cases of diarrhea in persons older than five years of age, controls were chosen who were born in the same year. For those below five years old, controls were chosen who were born in the same month. Children under five had a stricter age matching interval because there were more potential controls in the study population that were in this age group. In addition, calculating certain biological independent variables for children required a smaller age-matching interval because the status of these variables was collected on a monthly basis.

3.2.3 Independent variables

Information was collected for independent variables that were hypothesized to be related to watery diarrhea. This information was collected by administering questionnaires, obtaining secondary data from DSS records and community health worker record books, and calculating variables using the GIS database. These data were collected for both cases and controls so that they could be compared. Tables 3.1, 3.2, and 3.3 summarize the different variables that were collected. Some of these variables were assigned values based on data from multiple sources and/or from several survey questions. Appendix 1 discusses the methods used to calculate each individual variable.

Table 3.1: Summary of categorical independent variables with two classes.

Variable	Variable Type	Description
Gender	Cultural/behavioral and biological	Male or female
Source of drinking water	Cultural/behavioral	Tubewell or other
Source of cooking water	Cultural/behavioral	Tubewell or other
Source of bathing water	Cultural/behavioral	Tubewell or other
Source of washing water	Cultural/behavioral	Tubewell or other
Working tubewell in bari	Environmental	Yes or no
Adult male defecation	Cultural/behavioral	Latrine or other
Adult female defecation	Cultural/behavioral	Latrine or other
Male child defecation	Cultural/behavioral	Latrine or other
Female child defecation	Cultural/behavioral	Latrine or other
Presence of latrine in household	Environmental	Yes or no
Type of latrine drainage	Environmental	Septic or not
# of households using a latrine	Environmental	Single or multiple
Consumption of shellfish	Cultural/behavioral	Yes or no
Flood controlled area	Environmental	Yes or no
Breast feeding status of children<5	Biological	Yes or no
Nutritional status of children < 5	Biological	Malnourished or not

Table 3.2: Summary of categorical independent variables with more than two classes.

Variable	Variable Type	Description
Years of education: adult (>15) participant	Socioeconomic	More than six; one to six; none
Years of education: mother	Socioeconomic	More than six; one to six; none
Years of education: father	Socioeconomic	More than six; one to six; none
Knowledge of prevention of diarrhea	Cultural/behavioral	Full; good; partial; none
Knowledge of source of diarrhea	Cultural/behavioral	Good; partial; none
Household construction material	Socioeconomic	Brick,/tin; bamboo/tin; jute/ tin; straw/stick/ bamboo

Table 3.3: Summary of continuous independent variables.

Variable	Variable Type	Description
Number of open latrines	Environmental	Count
Number of non-septic latrines	Environmental	Count
Number of ring septic latrines	Environmental	Count
Number of concrete septic latrines	Environmental	Count
Number of other households using latrines	Cultural/behavioral and environmental	Count
Latrines per person (excluding open)	Environmental	Latrines per 100 people
Number of tubewells in bari	Environmental	Count
Number of households sharing a common tubewell in bari	Cultural/behavioral and environmental	Count
Tubewells per person	Environmental	Tubewells per 100 people
Household area (sq. ft.)	Socioeconomic and environmental	Square feet
Bari population	Cultural/behavioral, environmental, and socioeconomic	Count
Population density around baris	Cultural/behavioral, environmental, and socioeconomic	Persons within half kilometer radius
Total household assets	Socioeconomic	Taka
Annual income	Socioeconomic	Taka
Mid-arm circumference (children under 5 years old)	Biological	Millimeters
Distance from main river	Environmental	Meters

3.2.4 Questionnaire

Data from questionnaires were collected from a random sample of cases and their controls. The questionnaire was administered by seven experienced Bangladeshi enumerators. Upon arrival in Bangladesh, the questionnaire was translated into Bengali. It was then translated back to English by another person to test the accuracy of the first translation. A pre-test of 28 questionnaires was then done. Variable measurement was refined and variables were added and

subtracted based on the pre-test results. Appendix 2 is the final questionnaire and consent form in English. Appendix 3 is a Bengali translation of the questionnaire and consent form. After the questionnaire was completed, it was administered to all of the randomly selected cases and controls. If the individual who was the case or control was present, they were asked the questions. If this person was a minor, had diminished mental capacity, or died during the study period then the enumerator asked to speak with the head of household and administered the questions to this person. Asking the head of household should have accurately measured these variables because many of the variables were socioeconomic, thus they are inherently household-level variables. The enumerators completed 597 control questionnaires and 294 case questionnaires. Thus, there were approximately two controls for each case.

3.2.5 Collection of secondary data from ICDDR,B Demographic Surveillance System (DSS) records and community health worker record books.

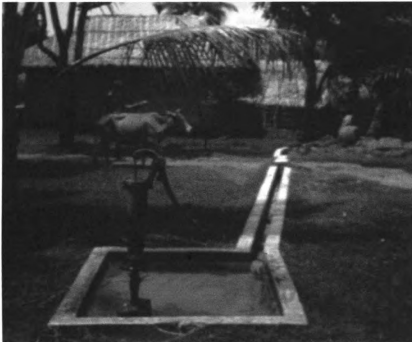
During this research project the Matlab study area had a population of approximately 200,000. The ICDDR,B DSS has a computerized database of everyone in the area. The Centre employs 120 community health workers who regularly visit each household in the study area to collect demographic data. They collect information on births, deaths, and migration. The age of each of the cases and controls was determined from these DSS records. The community health workers also collect information on the health status of children including their breast-feeding status and mid-arm circumference. These two independent

variables were collected from community health worker record books that are housed in the Matlab hospital. The health workers periodically collect socioeconomic data including the household area. This independent variable was also collected from the community health worker record books.

3.2.6 Collection of data on the distribution of latrines and tubewells in the study area.

A survey of the distribution and use of latrines and tubewells in the study area was administered by the author. The 120 community health workers were utilized in this survey to determine where there were functioning tubewells and latrines. Figure 3.3 is an example of a tubewell in the study area.

Figure 3.3 Tubewell in the Matlab study area.



The following types of latrines were differentiated:

1. Open.
2. Closed.
 - a) Non-septic without ring.
 - b) Ring latrine with septic tank.
 - c) Closed concrete septic.

Open latrines are simply fixed sites without any shelter constructed around them.

This could mean a fixed place within a wooded area or hole in the ground at the edge of a *bari*. An open latrine is also one that is hanging over a water body such as two boards on stilts over a pond, which are surrounded by hanging jute cloth for privacy (Figures 3.4 and 3.5). Closed latrines are those that have some shelter around them and are not hanging over water.

Figure 3.4 Hanging latrine on the Meghna River.



Figure 3.5 Hanging latrine on a small canal.



An example of a closed latrine without a septic system is one from which fecal matter drains out of the back of the latrine onto the ground. A ring latrine with a septic tank is the type of latrine that UNICEF has been developing throughout rural Bangladesh. It is an inexpensive technology that includes a cement ring that guides fecal material into a septic system. A closed concrete septic system is a latrine that has cement walls, and an enclosed cement septic system.

Based on the results of this household level survey it was possible to calculate the number of tubewells in each *bari*, the number of households that share specific tubewells, the number and type of latrines in each *bari*, and the number of households that share those latrines. Calculating these variables

required creating a database of all households in the study area that included which individuals belonged to which households and in which *baris* the households were located.

3.2.7 Spatial calculations of new variables using the Matlab GIS database.

The following three variables were calculated using the GIS database and other attribute data: population density around *baris*, distance from the main river, and flood control. These variables involved spatial calculations using features in the GIS database as well as attribute data derived from other sources. See Appendix 1 for descriptions of the creation of each of these variables.

3.2.8 Specific hypotheses about individual independent variables

One of the primary research goals of this study is to determine what biological, socioeconomic, cultural/behavioral, and environmental variables are responsible for occurrence of cholera and non-cholera watery diarrhea and to what degree these risk factors for the two diseases are similar or different. These independent variable categories are similar to those defined by Mayer (1986) however he used the term behavioral, not cultural/behavioral. The term cultural/behavioral implies that human actions are sometimes the result of individual choice (behavioral) and other times because of cultural practices (cultural). This study does not attempt to separate them.

The independent variables were chosen during the preliminary stages of

this research project because they were thought to be important variables in the disease ecology of watery diarrheal disease. This preliminary work included a review of the literature on the subject (summarized in Chapter 1.3) and an extensive informal investigation of the study area during the year-long GIS database creation stage of this project. Many of these independent variables are those concerned with water and sanitation. People in this study area have several sources of water for drinking, cooking, bathing, and washing including tubewells, ponds, canals, and rivers. There is no part of the study area in which participants have access to treated, running water, thus, tubewells are the cleanest source of water. Secondary watery diarrheal transmission is caused by fecal-oral transfer of etiological agents. Thus, if a latrine empties into a pond that is being used as a water source then transmission is likely to occur. Water and sanitation are thus enmeshed with one another and protection from secondary transmission requires good practices on both parts. The different types of latrines in the study area are quite simple with varying levels of sanitation as described in Section 3.2.6. The major consideration for a latrine is whether or not it is septic. It is not only important that a tubewell and septic latrine are available to a person but also that a person uses them. Those independent variables that are concerned with the availability of water and sanitation are environmental and those that are concerned with use are cultural/behavioral in nature. An ideal water and sanitation condition in the study area is one in which all members of a *bari* have access to a tubewell and sanitary latrine and also use them. When latrines are not sanitary or sanitary latrines are not used by some

members of a *bari* it is hypothesized that people in that *bari* will be more likely to contract a diarrheal disease. Also, it is hypothesized that if *bari*-members use tubewells for their water needs, they will be protected from diarrheal diseases.

Several independent variables were collected which try to measure socioeconomic status. Some of these variables are traditional socioeconomic indicators such as household assets, household income, and educational level of different family members. Dwellings in this study area are constructed from a variety of materials including tin and brick in the wealthiest households. Thus, an ordinal-level measure of household material was designed to be a study-area-specific socioeconomic indicator. It is thought that poorer individuals will not be able to avoid contracting diarrheal disease due to many reasons. An individual who is poor may not have as much education concerning the cause of diarrheal disease or may not have as much access to clean water or sanitary latrines. Thus, it is hypothesized that there will be a negative relationship between socioeconomic status and diarrheal disease.

Two cultural/behavioral variables were collected to measure what individuals know about the source and prevention of diarrheal disease. It is hypothesized that there will be a negative relationship between knowledge and disease because people are less likely to avoid the disease if they do not know how it is contracted. Another cultural/behavioral variable that was collected is shellfish consumption. Based on Colwell and Spira's (1992) theory that shellfish are an attachment site for cholera *vibrios*, it is hypothesized that cholera will be related to shellfish consumption but non-cholera watery diarrhea will not. As

described in Chapter 1, the flood-control embankment divides the study area environmentally. It is unclear how this major environmental division may effect the transmission of watery diarrheal disease. These data were collected to document whether or not there are differences in transmission rates in- and outside the embankment. The null hypothesis is that there will be no difference in transmission rates. Another environmental variable is distance from the main river. In a village-level study in Matlab from 1968 to 1977, Glass et al. (1982) found that people living in villages adjacent to rivers were less likely to contract cholera. It was possible to test this hypothesis more precisely using the GIS by determining the distance of each *bari* from the river. It is hypothesized that distance from the river will be positively related to the incidence of cholera and not related to non-cholera watery diarrheal incidence.

Two biological variables were collected including breast-feeding status and nutritional status (mid-arm circumference). It is hypothesized that breast-feeding will have a protective effect against diarrheal disease in children. As described in Chapter 1.3, there is conflicting evidence from previous studies whether malnutrition is related to diarrheal disease. It is hypothesized that malnutrition will be related.

Several independent variables do not fit neatly into one of the different independent variable categories including household area, *bari* population, population density near *baris*, and gender. The household area is both a socioeconomic and an environmental variable. It is socioeconomic because poorer people have smaller households because they cannot afford the building

materials required to build larger households. It is environmental because living in cramped quarters affects one's living environment. It is hypothesized that household area will be negatively related to watery diarrheal incidence. Even more difficult to classify into only one of the variable types are *bari* population and population density around *baris*. It is hypothesized that they will both be positively related to diarrheal disease. Gender is always an important consideration in health studies. A person's gender not only makes a person biologically different it also affects a person's actions based on cultural norms. It is hypothesized that females will contract watery diarrhea at a greater rate than males.

3.2.9 Data collection schedule and the nature of the study data

The data collection stage of this research took eleven months to complete. The questionnaire pre-test was conducted from October through December 1995. During this time, diarrhea case data were collected from laboratory and hospital records at the Diarrhea Treatment Center, and the community-based controls were chosen. From January through September 1996 the questionnaires were enumerated, the tubewell and latrine survey was administered, and secondary data were collected from the community health worker records and DSS records.

Although continuous variables were used whenever possible, the nature of certain data, as well as the educational level of the study population, made this impossible for many variables thought to influence the occurrence of watery

diarrhea. An example of a variable that is inherently continuous is total assets. All of the family assets can be added and the sum can be compared with the total assets of other families. An example of a variable that is inherently categorical is whether an area is flood controlled or not. An area cannot be partially flood-controlled; it is either flood-controlled or not. While other variables are neither inherently continuous nor categorical, certain traits of the study area population made accurate measurement of a continuous variable impossible. It was the intention of the author to collect continuous data on family member defecation patterns. However, during the pre-test of the questionnaire it was discovered that most people did not understand the concept of proportion or percentage. First, they were asked the proportion or percentage of times they defecated in latrines but the pre-test enumerators reported that most people did not have an understanding of the concept of proportion. Pre-test participants were then asked to choose a number between zero and ten, with zero meaning that they never defecate in a latrine and ten meaning they always defecate in a latrine. The last data collection method attempted in the pre-test was for the participants to choose a point on a line that represented the proportion of time they defecated in a latrine. Unfortunately, none of these methods were successful. Thus, it was decided that in order to accurately measure defecation patterns it was necessary to collect information on where family members regularly defecate which is a categorical variable.

3.3 Analytical methods

Analytical methods used in this study included:

- Disease mapping.
- Case-control methods.
- Simple logistic regression analyses.
- Multiple logistic regression analyses.

The purpose of mapping the incidence of watery diarrhea is to describe the spatial and temporal patterns of the two diarrheal disease categories, as a form of corroborating evidence of the existence and importance of an environmental reservoir for cholera. The case control study and logistic regression analyses identify and compare risk factors of cholera and non-cholera diarrhea. These methods are discussed in further detail below.

3.3.1 Disease mapping

If cholera has an important environmental reservoir then it is aquatic (i.e., rivers, canals, ponds) and there should be seasonal and spatial associations between the occurrence of cholera and such aquatic reservoirs. If there is no environmental reservoir for non-cholera, there will be less temporal association with the seasons and no spatial association with locations such as those thought to serve as cholera reservoirs.

It is impossible to absolutely assert that the presence of an environmental reservoir necessarily leads to a temporal association with seasons. However, if the temporal pattern of cholera follows the seasons quite closely during the

three-year study period then the most logical explanation is some variable that is seasonal. The most notable phenomenon that occurs to this environment seasonally is changes in the aquatic environment. This does not negate the possibility that there is some other variable that changes seasonally and is responsible for cholera. However, there is no better explanation than the aquatic reservoir. There are changes in things such as work patterns, which are also seasonal. However, there is no logical explanation for why someone would contract cholera because of changes in seasonal work patterns. Thus, it is suggested that a temporal association between cholera and the Bangladeshi seasons indicates the presence of an aquatic reservoir.

It is expected that the spatial patterns of cholera and non-cholera diarrheal disease will also differ. If cholera has an important aquatic reservoir then primary transmission from this source is important. The canals, rivers, and ponds that comprise the aquatic reservoir for cholera are scattered throughout the study area. Thus, primary transmission will occur throughout the study area. If non-cholera diarrhea does not have an aquatic reservoir then there is only secondary transmission, which means that transmission only occurs when a person comes into contact with someone who has been infected with the disease. It is suggested that non-cholera diarrhea is only transmitted through secondary transmission and that cholera is transmitted both by primary transmission and subsequent secondary transmissions from individuals who were infected from the aquatic source. If there is no primary transmission for non-cholera diarrhea then the disease will occur when people come into contact with one another. People

are more likely to come into contact with one another if they live closer to one another. Therefore, it is suggested that it is more likely for non-cholera diarrhea to occur in *baris* that are closer to one another rather than dispersed throughout the study area. Thus, it is hypothesized that non-cholera diarrhea will be more spatially clustered than cholera.

The *bari* locations of the two watery diarrhea groups (cholera and non-cholera) were mapped in four-week periods so that the spatial and temporal patterns could be identified. To determine whether there were any differences between the spatial patterns of cholera and non-cholera watery diarrhea, these maps were visually inspected to identify any regular patterns in their distributions. Characteristics of the disease distributions that were investigated included:

- Whether or not there was any part of the study area where the disease occurred more frequently.
- Whether or not there were any environmental differences where the disease occurred more frequently.
- Whether or not there was more apparent spatial clustering for non-cholera watery diarrhea than for cholera.
- Whether or not there was an apparent seasonal pattern to cholera.

One way to test whether non-cholera diarrhea is more spatially clustered than cholera is to summarize the data by calculating the centroids (mean center) of the 39 four-week periods for both of the diseases. Since the aquatic environment that is believed to be the cholera reservoir is throughout the study area, it is also believed that cholera will occur throughout the study area. Since people can contract the disease anywhere in the study area it is hypothesized

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that the mean center of the disease will be widely dispersed. Nearest neighbor analysis was used to quantify the dispersion of the two disease categories. The mean nearest neighbor distance is (Taylor, 1977; Boots and Getis, 1988):

$$\bar{d} = \sum_{i=1}^n d_i / n$$

where d_i is the nearest neighbor distance for each of the sampled points (i) and n is the number of sampled points. It is hypothesized that the mean nearest neighbor value for non-cholera will be lower than for cholera in each of the 39 four-week periods. In other words, cholera cases will on average be farther apart from one another than non-cholera cases in a particular time period.

3.3.2 Case-control methods

A case-control study was done to identify which of the aforementioned variables are risk factors for cholera and non-cholera watery diarrhea as well as to compare the risk factors for the two types of diarrhea. In case-control studies, comparisons are made between a group of persons who have a disease and a group of others who do not. Those individuals with the disease are referred to as "cases" and those without the disease are the "controls." The proportion of cases possessing a risk factor of interest is compared to the corresponding proportion in the control group. Statistical comparisons of the frequencies of individuals with and without risk factors provide information about what variables put an individual at highest risk for a disease. Individuals were the unit of study. Cases were the hospitalized diarrhea victims (cholera and non-cholera diarrhea),

and the controls were from the community, as described in section 3.2.2 of this chapter. Risk ratios were calculated for each of the two-class categorical independent variables by calculating relative risk ratios (a non-parametric, statistical comparison of ratios) and their significance values. A comparison of risk factors of cholera and non-cholera watery diarrhea was conducted so that differences in relative importance of different risk factors for the two types of watery diarrhea could be determined.

The following is an example of a contingency table for which the relative risk ratio was calculated.

Table 3.4 Number of households sharing a latrine.

Latrine Use	Controls	Cholera Cases	Row Total
Not Sharing	218	43	261
Sharing	40	23	63
Column Total	258	66	324

The risk ratio is calculated by comparing the ratio of cases to controls for one class (not sharing latrines) to the other class (sharing latrines). In this case the ratio was 218 controls to 43 cases for those individuals who lived in households that did not share latrines and 40 controls to 23 cases for those individuals who lived in households that share latrines with other households. To calculate the relative risk, the two risk ratios were divided as follows:

$$\frac{218/43}{40/23}$$

The relative risk for latrine use is 2.9. This means that individuals who lived in

households that shared a latrine with other households are 2.9 times more likely to be hospitalized with cholera than individuals who did not share a latrine with other households. This relative risk ratio does not take the number of observations into consideration. Thus, it is common practice to present risk ratios using 95% confidence bounds. In the above example, the lower and upper confidence bounds are 1.58 and 5.35 respectively. This means that it is 95 percent certain that the risk ratio falls between these numbers. Chi-square tests were done to show how well the observed frequencies of the contingency tables fit the expected frequencies. The formula for chi-square is as follows.

$$\chi^2_{observed} = \sum_{i=1}^k \frac{(O_i - E_i)^2}{E_i}$$

k is the number of categories.

O_i is the observed frequency for each cell.

E_i is the expected frequency for each cell.

Comparisons of the observed and theoretical chi-square values were made and probability values were calculated. The critical probability value chosen for this study was 0.05. Thus, associations were accepted if probability values were below this critical number.

Risk ratios cannot be calculated for ordinal-level independent variables. Relationships between ordinal-level independent variables and the study diseases were measured by calculating Kendall's Tau C values. Kendall's Tau C is a non-parametric measure of association for ordinal variables that ranges between negative one and one. The absolute value of the coefficient indicates the strength of the relationship between the variables. Larger absolute values

indicate stronger relationships and the sign indicates the direction of the relationship. Chi-square probability values verify whether or not the observed distribution could be due to chance.

3.3.3 Simple Logistic regression

When the dependent variable is binary, as in this study, normal least-squares regression cannot be used because the assumptions of that model would be violated. The logistic regression model is appropriate for binary outcome variables. This model estimates adjusted odds ratios and can be used for either continuous or categorical risk factors. The logistic model is expressed as follows.

$$\ln\left(\frac{P_i}{1-P_i}\right) = A_1 + B_1 X_i + u_i$$

P_i = the probability of getting the disease.

$(1-P_i)$ = the probability of not getting the disease.

A_1 = constant.

B_1 = slope coefficient for variable X_i which is the change in the log of the odds ratio per unit change of variable X_i .

u_i = error term.

$P_i / (1-P_i)$ = the odds of getting the disease or the odds ratio.

This model does not give the probabilities directly. To compute the probability of getting a disease for an observation the formula is expressed as follows.

$$P_x = \frac{1}{1 + e^{-(a+bx)}}$$

P_x is the probability of the disease for a specific value of a variable represented as x .

Simple regression models were created for both of the categories of watery diarrhea using all of the continuous variables and selected categorical variables as dummy variables. A case was one of the watery diarrhea categories and a control was the control group. Cases were given a value of one and controls a value of zero. This individual-level analysis was conducted using all of the data that were available for specific variables. For example, river distance was a variable that was calculated using the GIS database, thus the total number of observations for which data were available was large. Data for the variables that were collected from the questionnaire, however, were limited to the number of questionnaires.

3.3.4 Multiple logistic regression analysis

When the dependent variable is binary and there are multiple independent variables, multiple logistic regression must be used. This model can be used for either continuous or categorical independent variables or a combination of both. The multiple logistic model is expressed as follows.

$$\ln\left(\frac{P_i}{1 - P_i}\right) = A_1 + B_1X_i + B_2Y_i + u_i$$

P_i = the probability of getting the disease.

$(1 - P_i)$ = the probability of not getting the disease.

A_1 = constant.

B_1 = slope coefficient for variable X_i which gives the change in the log of the odds ratio per unit change of variable X .

B_2 = slope coefficient for variable X_i which gives the change in the log of the odds ratio per unit change of variable X_i .

u_i = error term.

$P_i / (1-P_i)$ = the odds of getting the disease or the odds ratio.

Multiple regression models were created for both of the categories of watery diarrhea using all of the continuous variables and several of the categorical variables as independent variables. As with the simple logistic regression models the cases were given a value of 1 and the controls a value of 0. This multiple logistic regression analysis was conducted using all of the data that were available for all of the variables. Multiple logistic regression models could only be built using observations for which data were available on all of the independent variables.

Criteria had to be set to choose independent variables that would be included in the multiple logistic regression models because there was a wide range of independent variables that could be included in the multiple logistic regression models. The objective was to maximize the amount of variation in the dependent variable accounted for by the independent variable set. Those variables that were moderately significant to at least the 0.15 probability level in the simple regression analysis were chosen to be included in the multiple logistic regression analyses. To test whether there was a multicollinearity problem,

correlation coefficients were calculated between the resulting variables. If multicollinearity was found to be a problem, one of a pair of collinear variables was excluded from the multiple logistic regression model.

3.3.5 Nature of analyses

As discussed in Section 3.2.8, some of the explanatory variables in this study were continuous and others were categorical. Continuous explanatory variables are quantified on some well-defined scale (e.g., price) and categorical explanatory variables are basically qualitative in nature. These qualitative variables indicate the presence or absence of a quality or attribute. In this study the dependent variable is a qualitative variable, i.e., the study participant was either hospitalized with the disease or was not hospitalized with the disease.

The inclusion of dummy variables in the logistic regression models mentioned above basically quantifies categorical variables by creating artificial variables. The dummy variables have values of zero and one; zero indicates the absence of the attribute and one the presence of the attribute. A multiple logistic regression model may contain both continuous variables and dummy variables or only one or the other. The number of dummy variables is one less than the number of categories of the variable. The first category is the benchmark category and each of the additional categories is represented by a dummy variable.

The analysis of qualitative categorical variables in this study is an important element to understanding the nature of this study. Inferential statistics

hold that a large sample, which is a randomly selected subset of a population, can be used to make inferences about a population. Thus, conclusions are made about a population based on a sample. If the variables collected are qualitative in nature, however, can inferences still be made? The author contends that these inferences can still be made but the conclusions should be considered to be descriptive in nature. Thus, the conclusions of this study can be thought of as anecdotal evidence for a complex phenomenon, as opposed to facts that can be generalized to the entire study population.

Having just described the methods used to investigate the spatial and temporal patterns of watery diarrheal disease and to measure risk factors, Chapter 4 will describe what was revealed by using these methods. The spatial and temporal patterns of the two diseases were similar to the hypothesized patterns. Also, the most important independent variables that were related to diarrheal disease occurrence were those concerning water and sanitation.

4. Results: Spatial and temporal patterns of cholera and non-cholera watery diarrhea

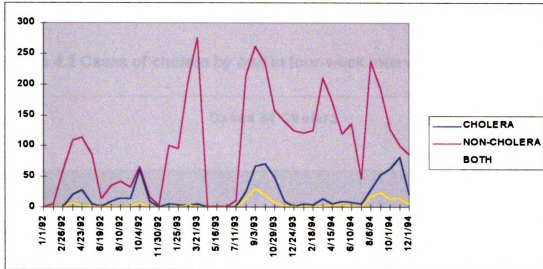
The findings of this study demonstrate that the spatial and temporal patterns of the two disease categories are very different. The temporal distribution of cholera is characterized by marked seasonal epidemics but non-cholera peaks do not correspond to seasons. The spatial distributions are also quite different in where and what frequency cases are distributed within the study area.

4.1 Temporal distributions and disease maps

4.1.1 Temporal distributions

Figure 4.1 shows the frequencies of cholera and non-cholera watery diarrhea within *baris* throughout the study period. These data are displayed in four-week intervals on the X-axis and absolute frequency during these intervals on the Y-axis. The Y-axes of Figures 4.1 through 4.3 represent the number of *baris* that had at least one case of diarrhea. The number of individual cases is discussed in Section 4.2. During the study period, the number of cases of cholera was usually much lower than the number of cases of non-cholera diarrhea, and the three peaks of cholera coincided with peaks of non-cholera diarrhea. There were, however, two peaks of non-cholera diarrhea that did not coincide with cholera peaks.

Figure 4.1 Cholera and non-cholera watery diarrhea by number of *baris* by four-week interval.



The temporal distribution of cases of cholera by *bari* is shown in Figure 4.2. The dates in the X-axis are the beginning of the four-week intervals and the Y-axis is the number of cases in those periods. During the study period, there were three main peaks of cholera. All of these peaks were in September, October, and November. Also, there were smaller peaks of cholera in March and April. Figure 4.3 shows the temporal distribution of non-cholera watery diarrhea by *bari*.

Cholera had a more distinct seasonal cycle than non-cholera watery diarrhea. While two of the three largest non-cholera peaks coincided with the September and October cholera peaks, the largest non-cholera peak of the study period occurred in February and March. This pattern is consistent with one of the

primary hypotheses of this study, that cholera has an important aquatic reservoir and non-cholera watery diarrhea does not. Thus, cholera occurrence is dependent on seasonal changes in the aquatic environment causing distinct seasonal patterns. This will be discussed in greater detail in Chapter 5.

Figure 4.2 Cases of cholera by *bari* in four-week intervals.

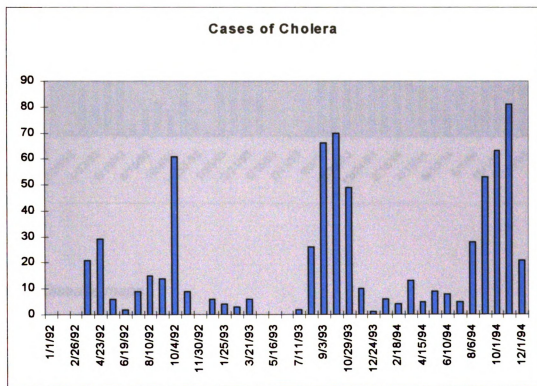
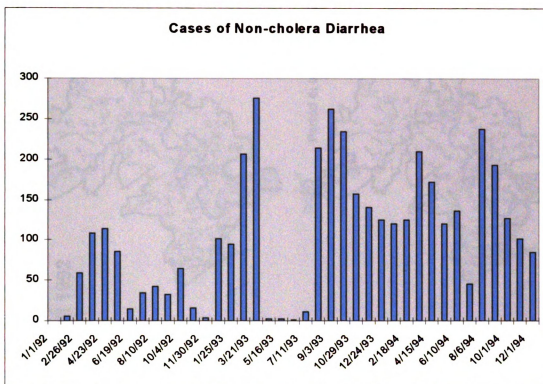


Figure 4.3 Cases of non-cholera watery diarrhea by *bari*.

4.1.2 Disease maps

The distribution of cholera and non-cholera watery diarrhea cases was mapped in four-week intervals throughout the study period (January 1992 to December 1994). *Baris* with at least one cholera case during the time period are symbolized with red dots. *Baris* with at least one non-cholera watery diarrhea case are symbolized with purple triangles. *Baris* with at least one of each are symbolized with green stars. The remaining *baris* that did not have a case of either cholera or non-cholera watery diarrhea are symbolized with a small black dot. Figures 4.4 through 4.13 show the maps in sequential order in four-week periods.

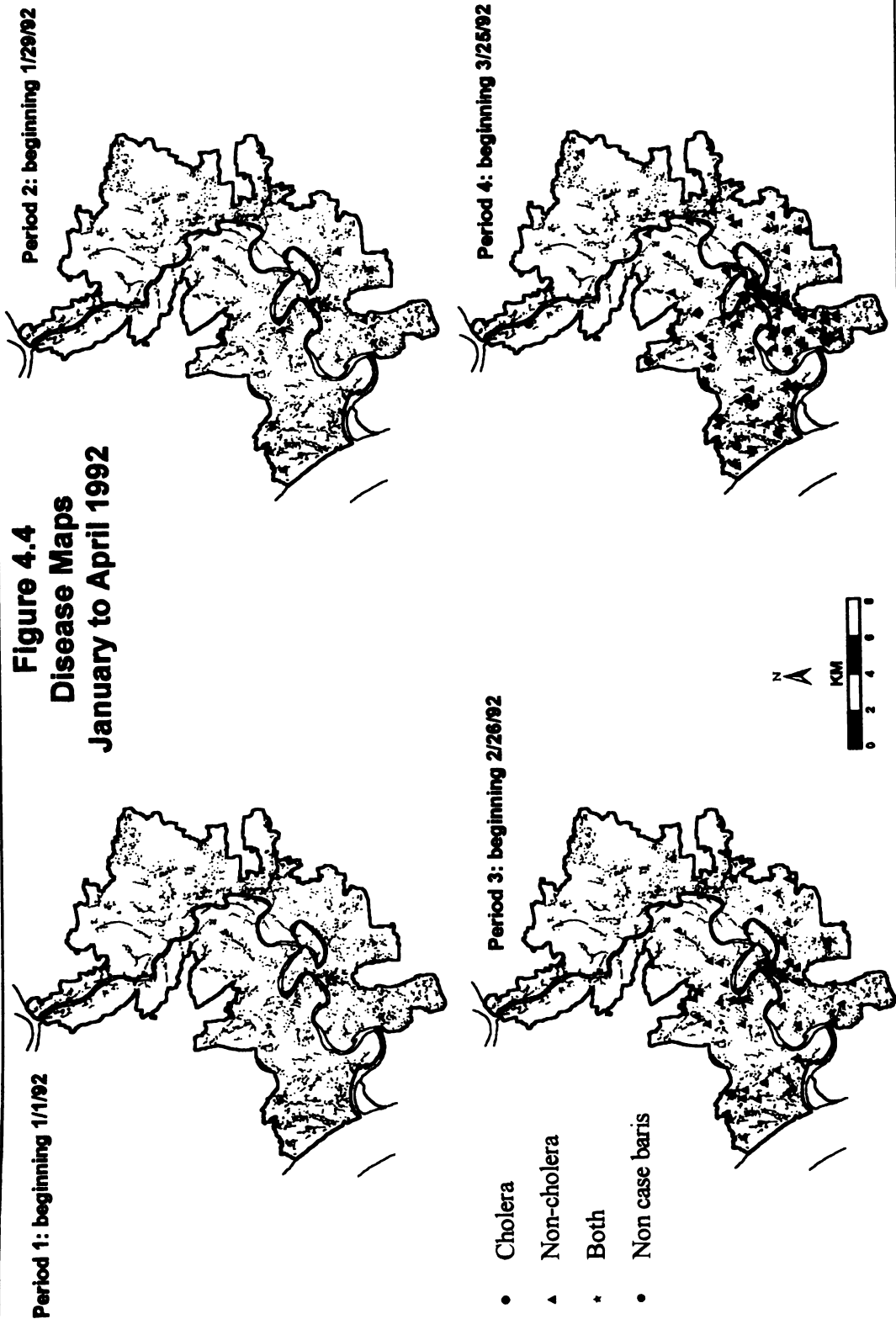


Figure 4.5
Disease Maps
April to August 1992

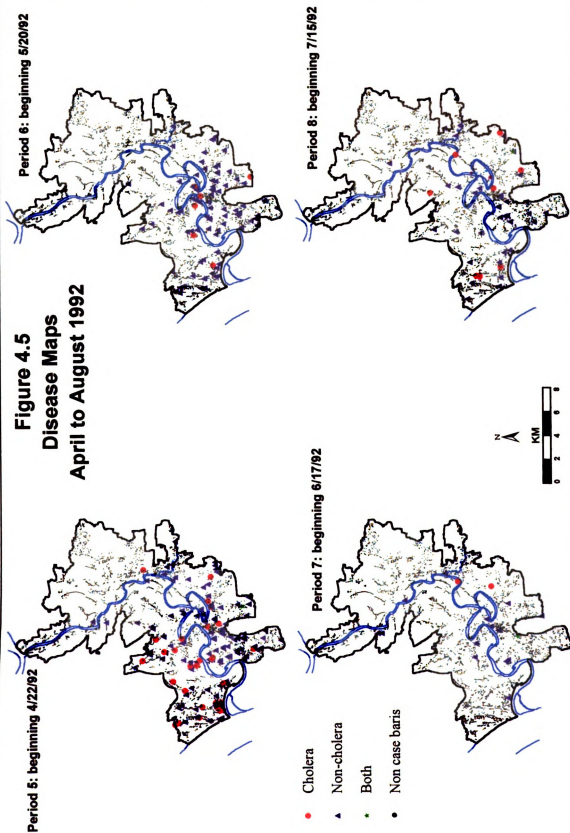
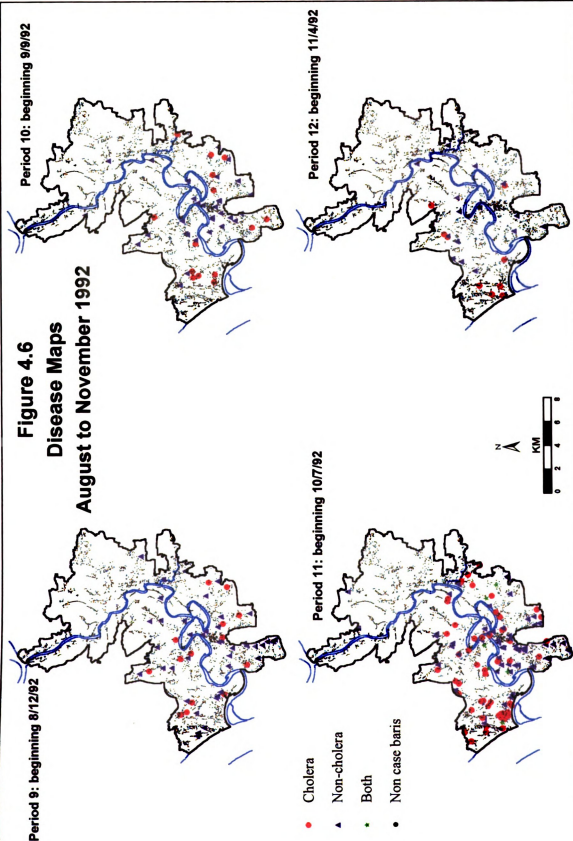


Figure 4.6
Disease Maps
August to November 1992



Period 14: beginning 12/30/92

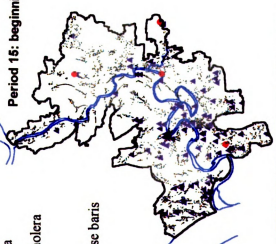
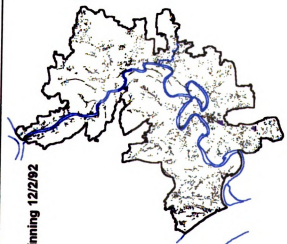
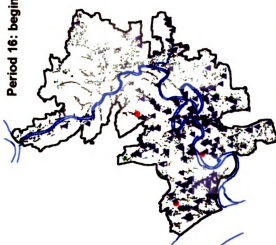
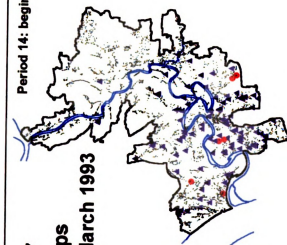
Figure 4.7
Disease Maps
 December 1992 to March 1993

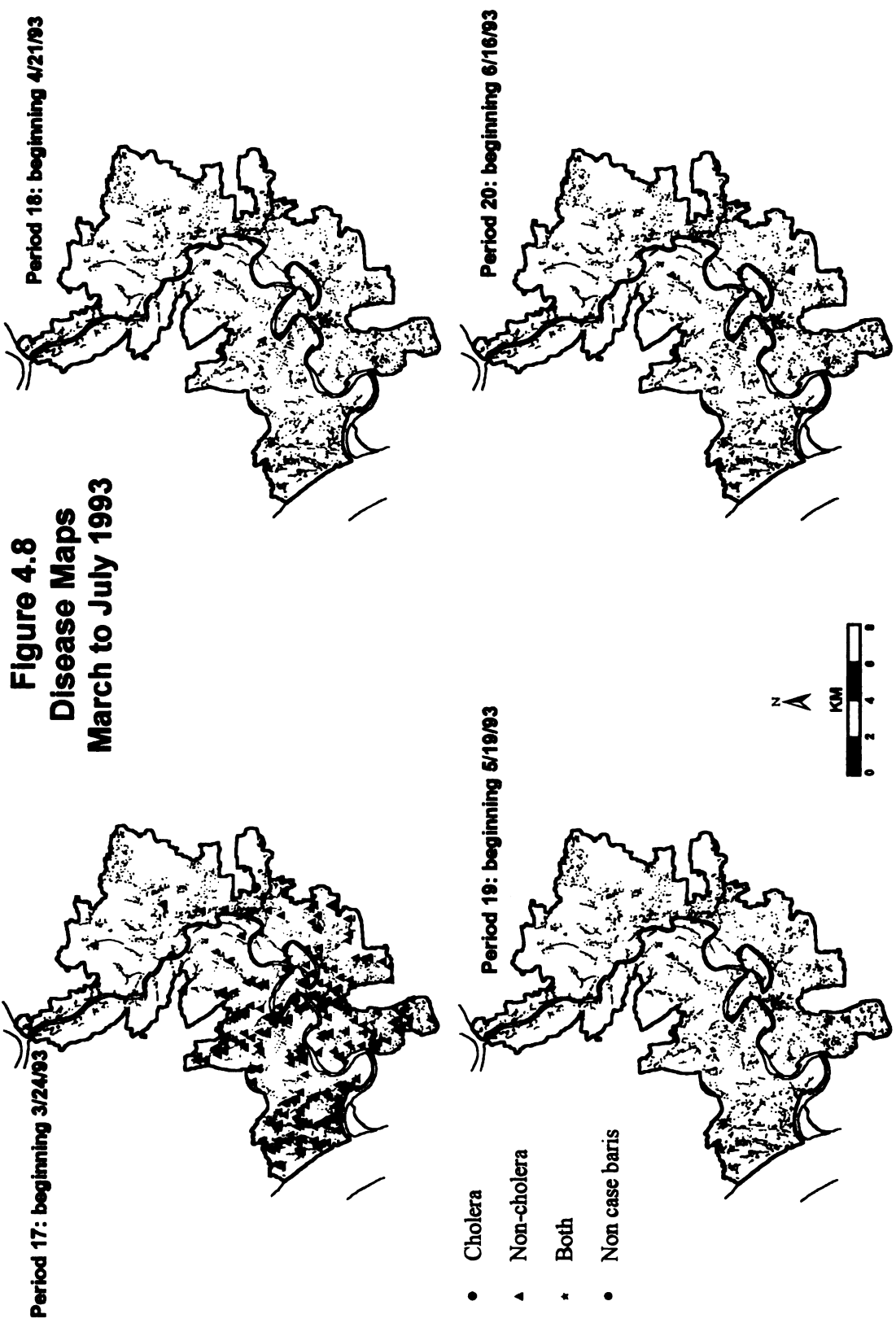
Period 13: beginning 12/2/92

Period 16: beginning 2/24/93

Period 15: beginning 1/27/93

- Cholera
- ▲ Non-cholera
- Both
- Non case baris





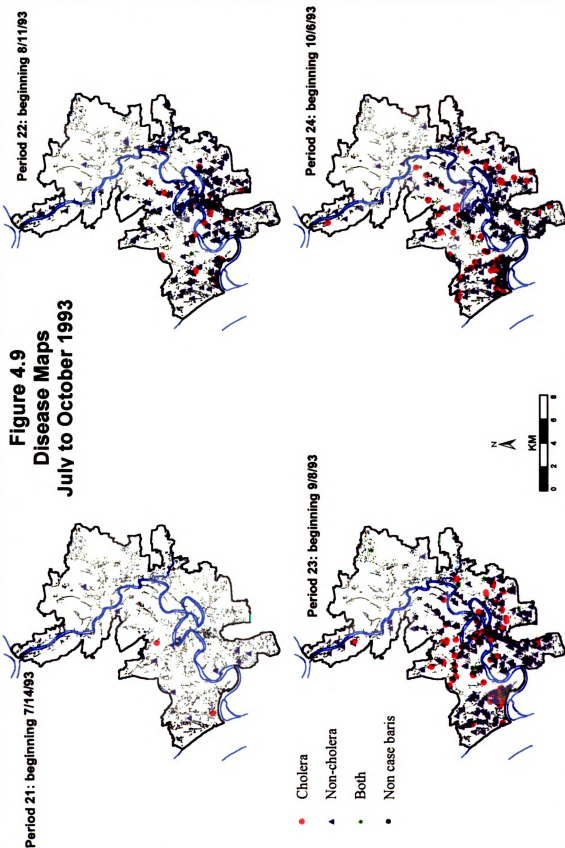


Figure 4.10
Disease Maps
 November 1993 to February 1994

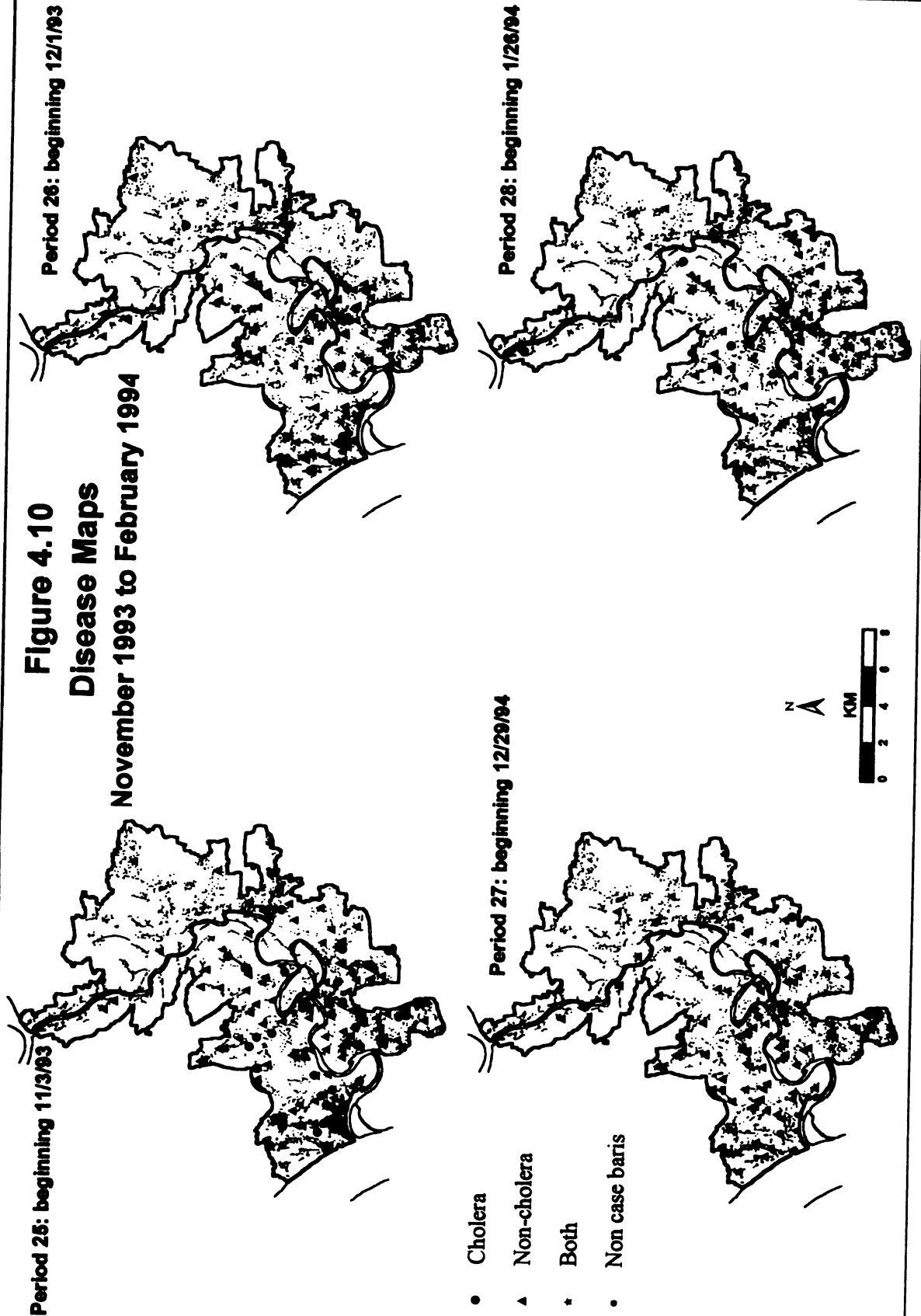


Figure 4.11
Disease Maps
February to June 1994

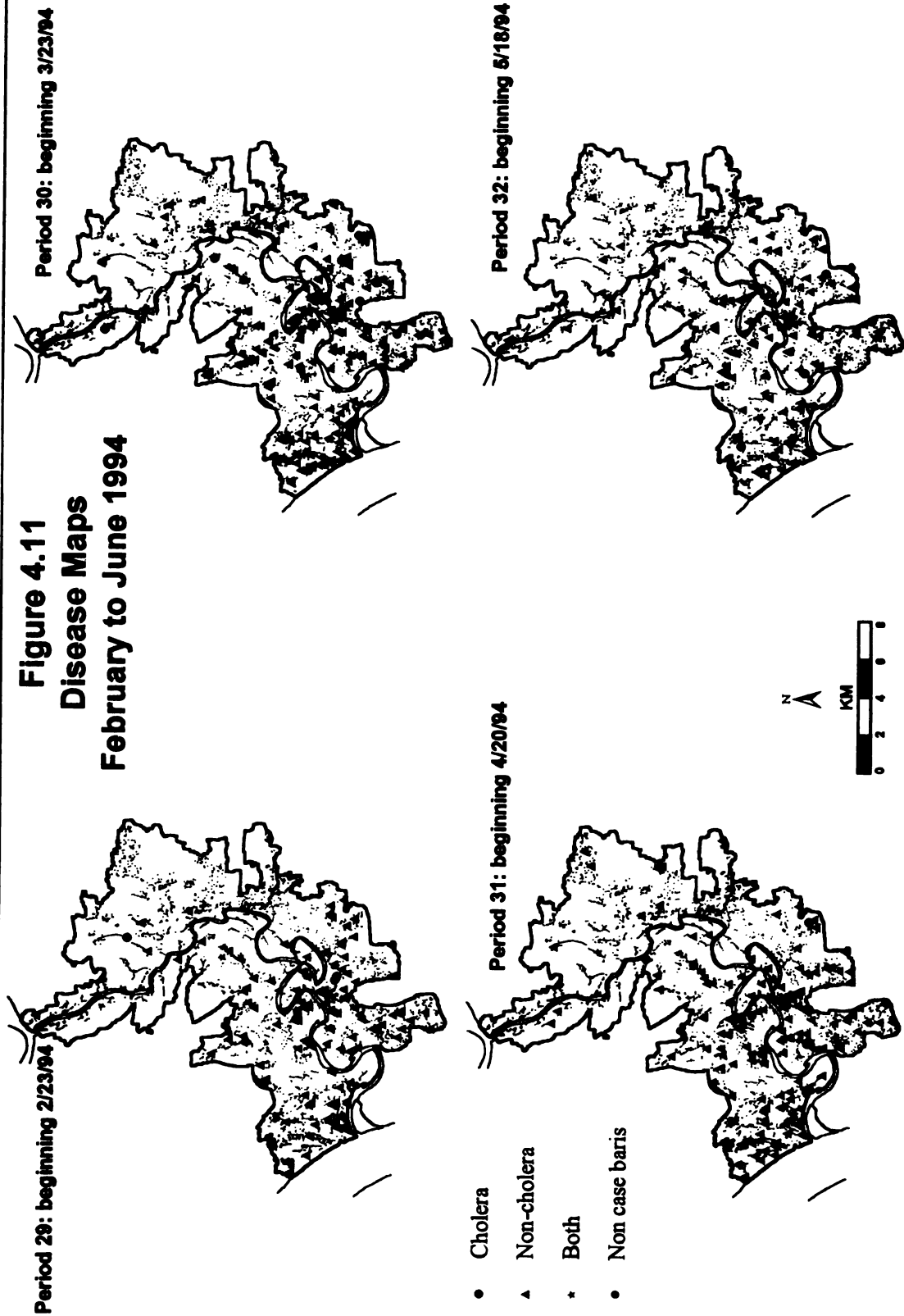
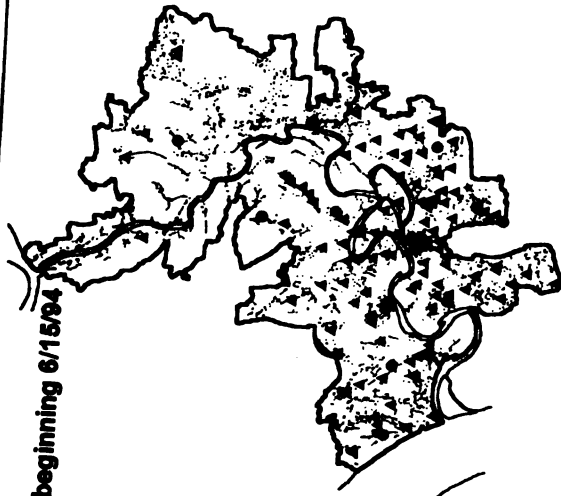
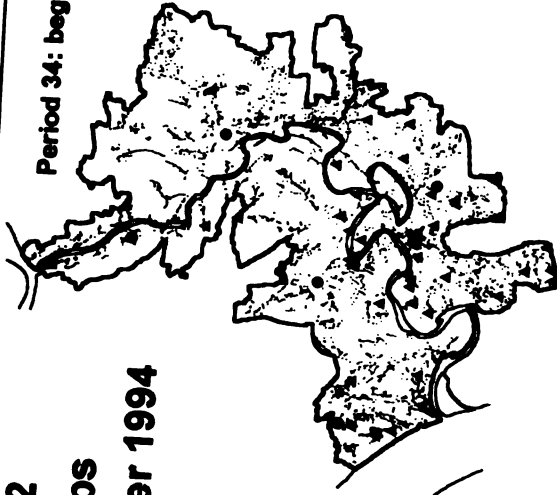


Figure 4.12
Disease Maps
June to September 1994

Period 33: beginning 6/15/94

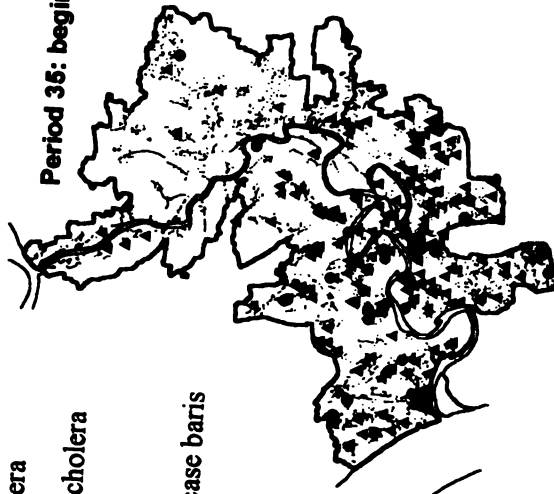


Period 34: beginning 7/13/94

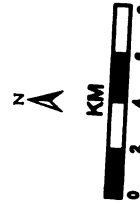
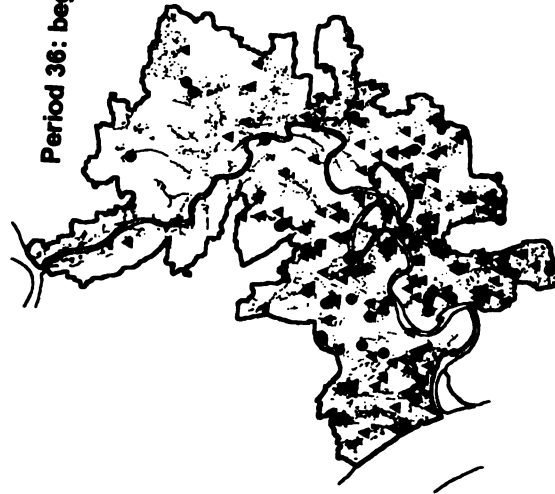


- Cholera
- ▲ Non-cholera
- * Both
- Non case baris

Period 35: beginning 8/10/94



Period 36: beginning 9/7/94



Period 37: beginning 10/5/94

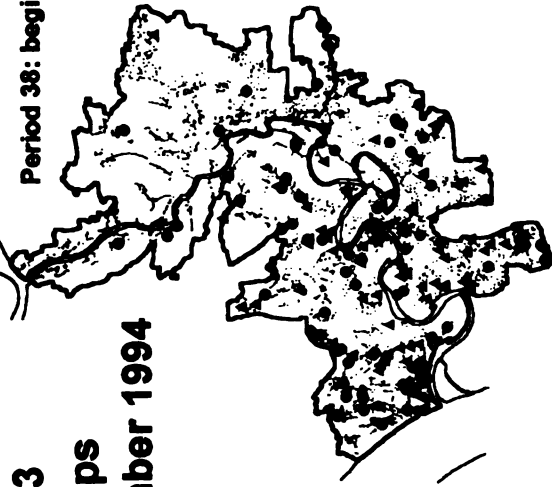
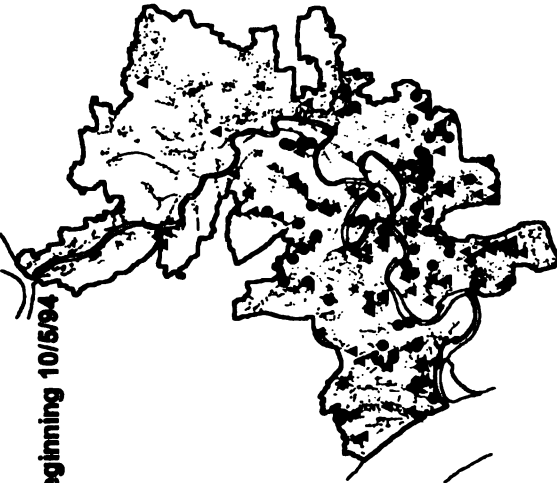
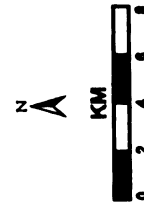


Figure 4.13
Disease Maps
October to December 1994



- Cholera
- ▲ Non-cholera
- Both
- Non case baris



Spatial patterns of cholera and non-cholera diarrheal disease are not readily apparent from the findings displayed in these maps. The following discussion of the spatial distribution of the diseases will first summarize the findings for each of the four-week periods, and then will suggest some of the general patterns. This discussion will first summarize the distribution of cholera during these periods. Periods 4 (March to April 1992) and 5 (April to May 1992) were the first in which people were hospitalized with cholera. The cases were very widely dispersed throughout much of the study area. It is unlikely that the infected people came into physical contact with one another. In Periods 6 through 8 (May to August 1992) there were also widely dispersed cases but in much smaller numbers. Periods 9 and 10 (August to October 1992) again had larger numbers of dispersed cases. Although the locations of cases in Period 11 (October to November 1992) were distributed quite widely, the largest number of cases occurred in a small area in the southwest corner of the study area, near the confluence of the Dhonogoda and Meghna Rivers. Periods 12 and 13 (November and December 1992) had very few cases.

The beginning of 1993 was similar to 1992 in that there were almost no cases of cholera; however, this period of cholera retreat was longer in 1993 than it was in 1992. Periods 14 through 21 (January through August 1993) had very few cases and those that did occur seemed to be dispersed randomly throughout much of the study area. Periods 22 through 25 (August to November 1993) had large numbers of cases which were widely distributed, but each of these periods seemed to have clusters in the aforementioned region in the southwest corner of

the study area. The spatial pattern of cholera in Periods 26 through 34 (December 1993 to August 1994) was similar to the previous year in that there were small numbers of highly dispersed cases. Periods 35 through 38 (August through November 1994) were also similar to the previous year with highly dispersed cases, however there was not a large concentration of cholera cases in the southwest region of the study area except for Period 38 (November 1994). In Period 39 (December 1994) there was a moderate number of highly dispersed cases.

As noted in the Section 4.1.1 of this Chapter, there were much larger numbers of non-cholera watery diarrhea cases than cholera cases and seasonal cycles were not as apparent for the former. This discussion will now focus on the distribution of non-cholera diarrhea during the three-year study period. In Periods 1 and 2 there were almost no cases of non-cholera watery diarrhea. While Periods 3 through 6 had large numbers of cases throughout much of the study area, the cases were more clustered than for cholera. For example, in each of the periods there were a large number of cases near Matlab town. Much of the rest of the study period had a similar spatial pattern. Clusters of non-cholera watery diarrheal disease can also be seen in Period 15 near Matlab town and north of the Dhonagoda River across from town. In Period 16 there were two main clusters, one near Matlab town and the other in the southwest corner of the study area. Periods 17, 22, 23, and 24 all had clusters in Matlab town and the southwest corner of the study area and all except Period 24 had large numbers in the extreme south of the study area. Periods 26, 29, 30, 31, 32, 33,

and 35 had clusters mainly near Matlab town but also in the southwest of the study area. While there was at least one apparent disease cluster in each of the aforementioned periods, there were also isolated cases. Non-cholera watery diarrhea cases occurred in much of the study area but there was a clear absence of high concentrations of cases in the northern part of the study area. It is unclear why this may have occurred.

It is unclear whether or not there is a spatial pattern to the center of the cholera epidemic. The centroid of cholera cases for each of the four-week periods was determined by calculating the mean X and Y coordinate values.⁵ The centroids of cholera are shown in Figure 4.14. The center of cholera cases was quite widely dispersed and there was no apparent seasonal pattern to the center of the cholera epidemic. Cholera occurred in an almost haphazard pattern. Figures 4.15, 4.16, and 4.17 are enlargements of the cholera centroid locations for the three study years. The numbers indicate the sequentially ordered four-week periods that were used for the disease maps (Figures 4.4 to 4.13). Several of the four-week periods do not have centroids because there were no cases. For example, Figure 4.15 begins with Period 4 since there were no cholera cases in Periods 1, 2, or 3.

⁵ The coordinate values were calculated in meters. A derivation of the Universal Transverse Mercator projection, called the Bangladesh Transverse Mercator, was used.

Figure 4.14 Mean X and Y coordinates for cholera by four-week period.

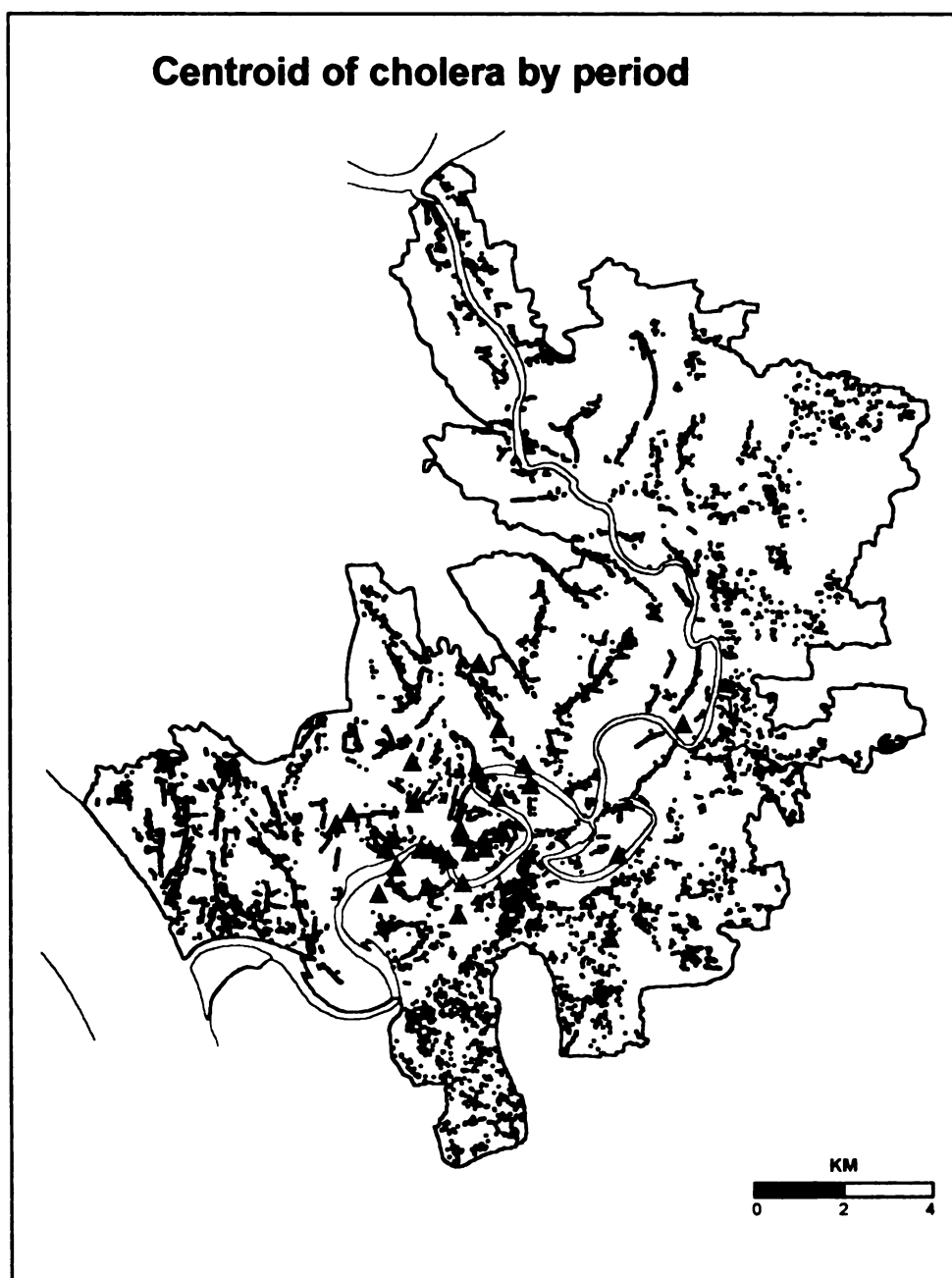


Figure 4.15
Cholera Centroids: Year One

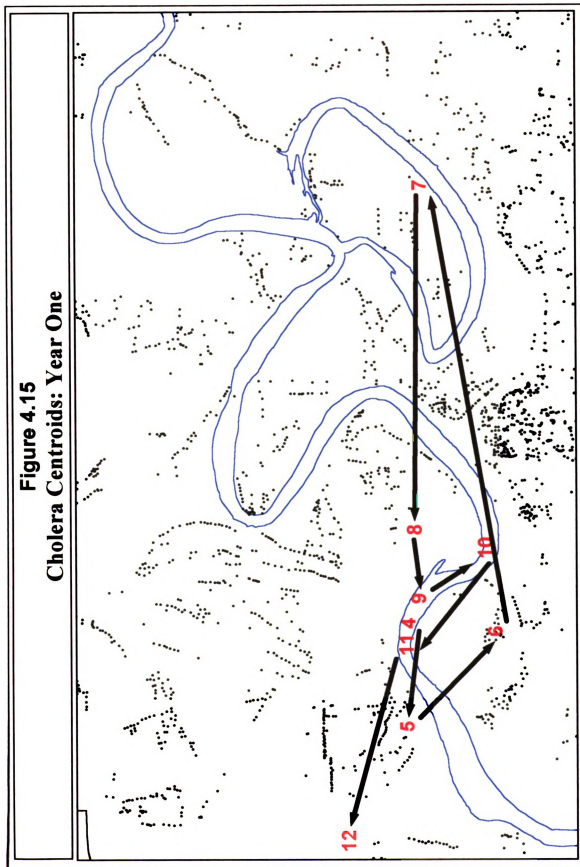


Figure 4.16
Cholera Centroids: Year Two

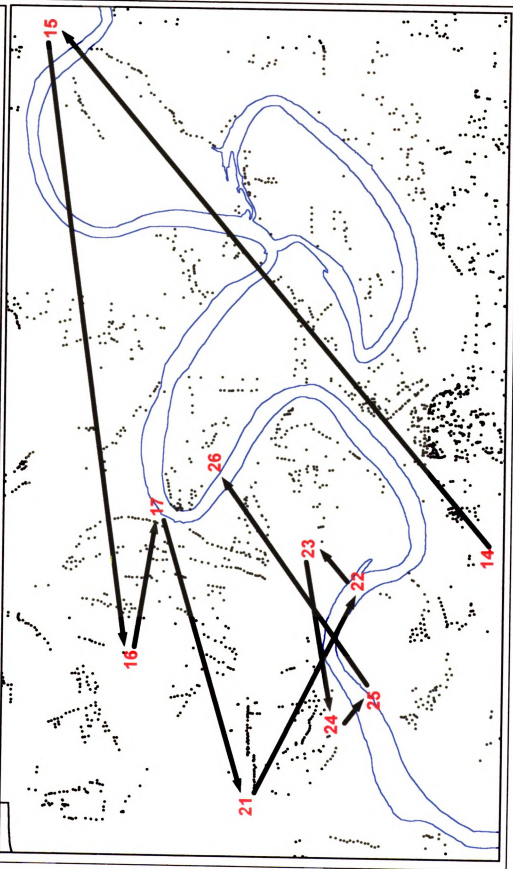


Figure 4.17
Cholera Centroids: Year Three

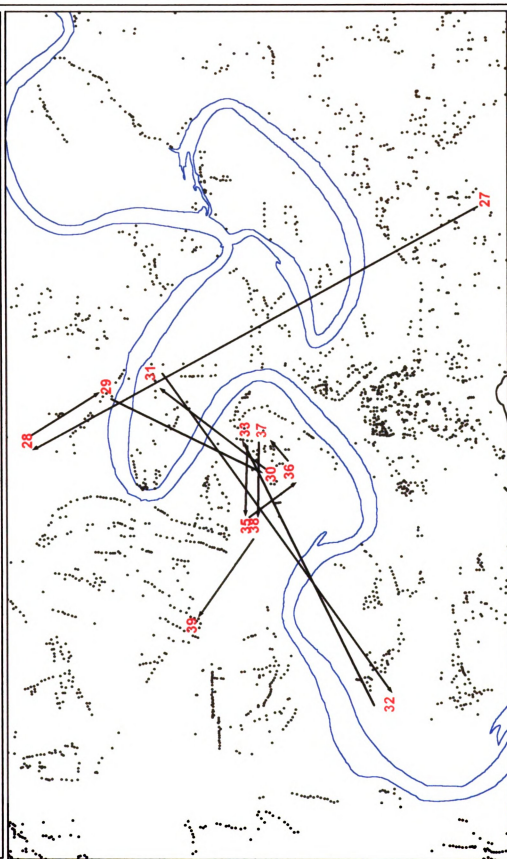
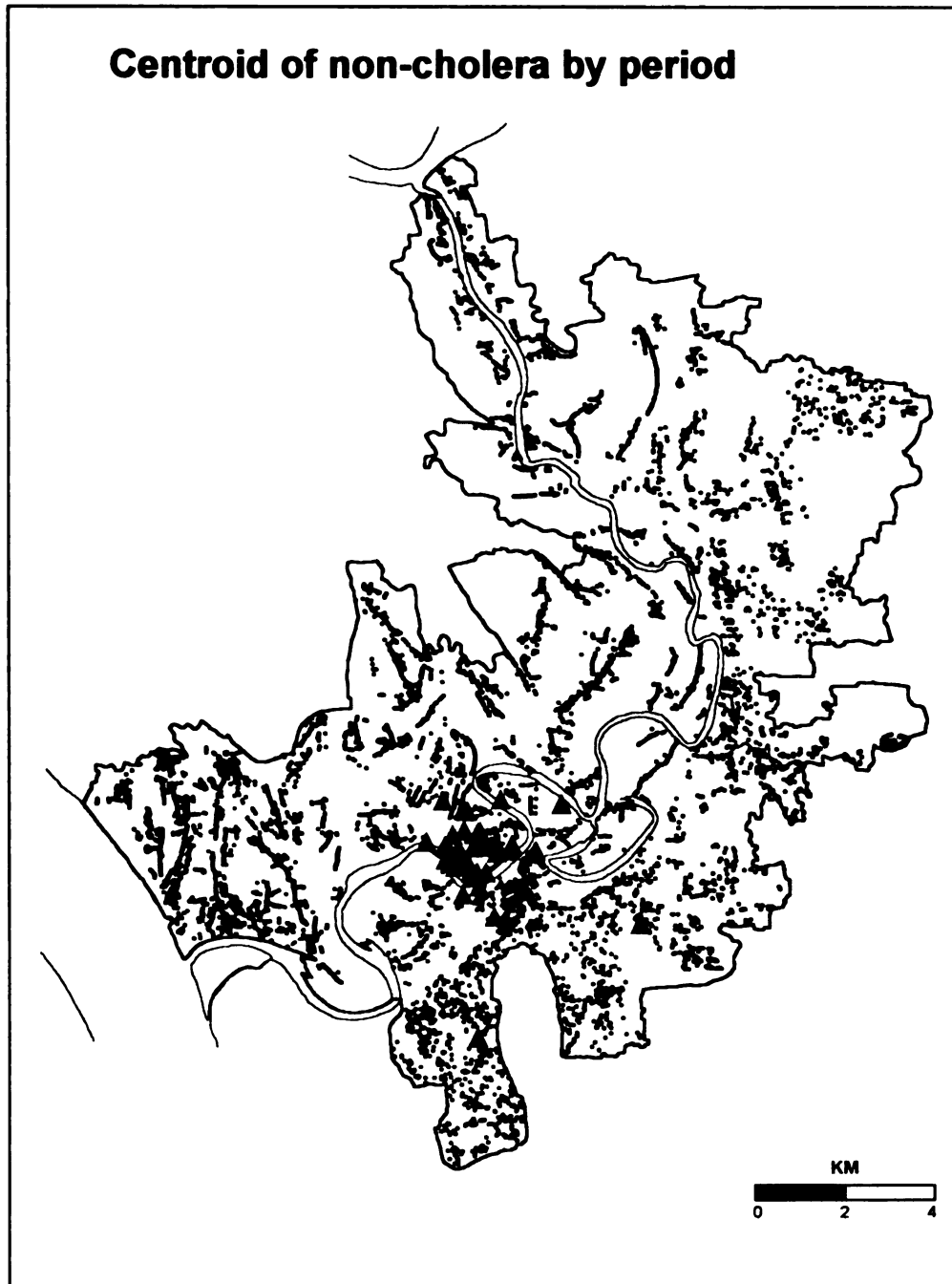


Figure 4.18 shows the centroids of non-cholera watery diarrhea cases.

Figure 4.18 Mean X and Y coordinates for non-cholera by four-week period.



Not only was non-cholera more clustered than cholera, the centroids of non-cholera watery diarrhea were much less dispersed than for cholera. Figures 19, 20, and 21 are enlargements of the centroid locations for the three study years.

Figure 4.19
Non-cholera Centroids: Year One

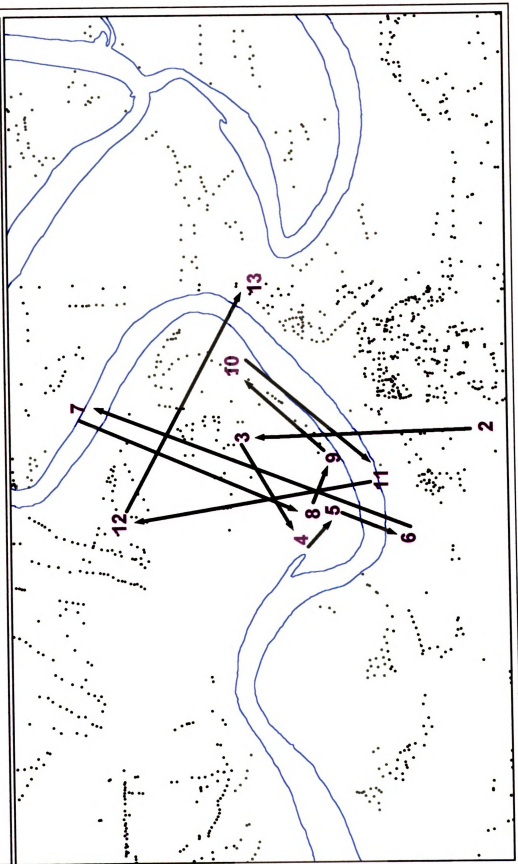


Figure 4.20
Non-cholera Centroids: Year Two

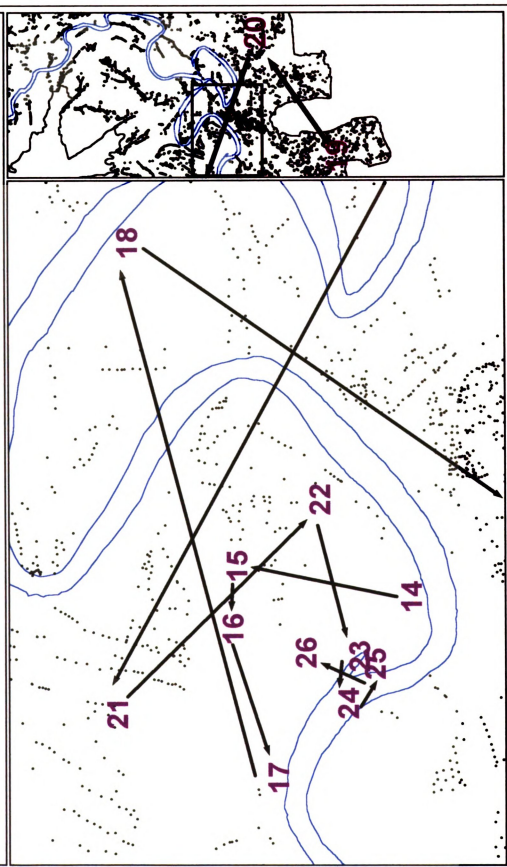
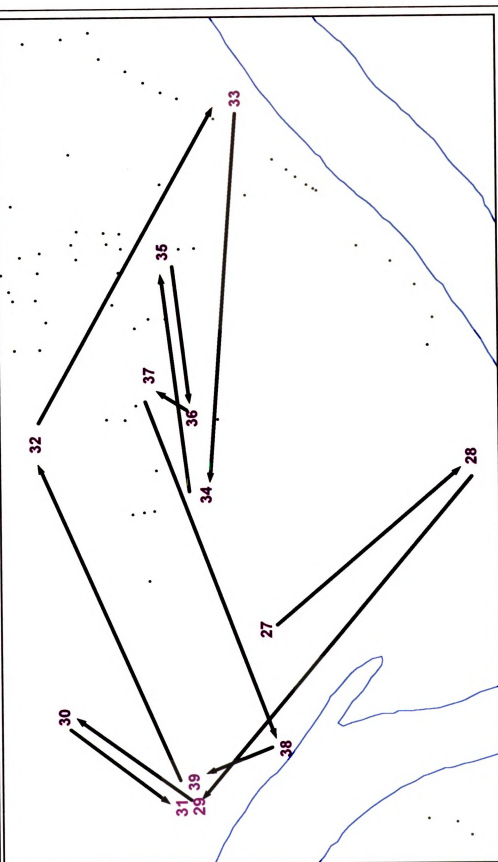


Figure 4.21
Non-cholera Centroids: Year Three



There were no non-cholera water diarrhea cases in four-week Period 1, thus, Figure 4.19 begins with Period 2. These maps do not reveal an apparent diffusion cycle but they do reveal that the locations of the mean centers of non-cholera watery diarrhea were relatively constant compared with cholera.

It was hypothesized that the mean nearest neighbor value for non-cholera would be lower than for cholera in each of the 39 four-week periods. Table 4.1 displays the results of the nearest neighbor analysis for both cholera and non-cholera diarrhea by four-week period. In all but two of the 31 periods for which both cholera and non-cholera mean nearest neighbor distances were calculated, cholera had a larger value. The average nearest neighbor for cholera during the study period was almost two kilometers (1989 meters) whereas the average mean nearest neighbor distance for non-cholera was less than one kilometer (847 meters). This shows that cholera cases were on average farther apart from one another than non-cholera cases in a particular time period. This finding is consistent with one of the major hypotheses of this study, that primary transmission is important for cholera but not for non-cholera diarrhea. It is consistent since non-cholera transmission can only occur if an individual comes into contact with a victim of the disease. Thus, it is logical that non-cholera cases will be closer to one another than cholera cases since cholera cases can be infected by the aquatic reservoir.

Table 4.1 Mean nearest neighbor distances.

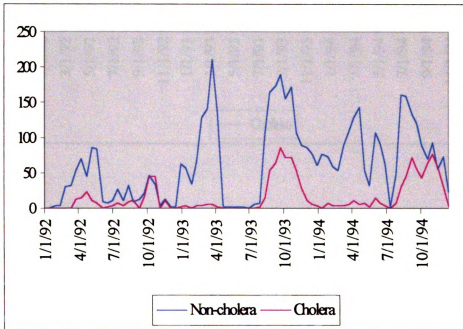
Four-week Period	First Day of Period	Mean Nearest Neighbor Distance for Cholera (meters)	Mean Nearest Neighbor Distance for Non-cholera (meters)
1	1/01/92	N/A	N/A
2	1/29/92	N/A	324.64
3	2/26/92	N/A	645.1
4	3/26/92	1041.58	461.61
5	4/23/92	1016.23	417.03
6	5/22/92	2014.72	498.23
7	6/19/92	3489.44	1430.52
8	6/19/92	1816.21	976.28
9	8/10/92	1388.52	877.08
10	9/7/92	1270.63	1079.09
11	10/4/92	461.09	525.36
12	11/2/92	1498.71	1796.75
13	11/30/92	N/A	4682.72
14	12/28/92	1247.52	482.24
15	1/25/93	6040.22	627.5
16	2/22/93	2130.17	317.61
17	3/21/93	3732.01	277.41
18	4/18/93	N/A	4938.58
19	5/16/93	N/A	949.39
20	6/13/93	N/A	N/A
21	7/11/93	7541.22	1871.38
22	8/8/93	409.64	304.88
23	9/3/93	524.14	259.32
24	10/1/93	433.58	286.55
25	10/29/93	587.79	436.42
26	11/26/93	1340.95	453.47
27	12/24/93	N/A	483.62
28	1/21/94	3442.59	460.22
29	2/18/94	3049.59	510.89
30	3/18/94	1821.01	321.44
31	4/15/94	1781.42	430.24
32	5/13/94	1618.51	532.09
33	6/10/94	2775.72	471.66
34	7/8/94	5484.21	1002.57
35	8/6/94	848.48	304.72
36	9/3/94	557.1	350.7
37	10/1/94	652.47	421.46
38	10/29/94	568.04	476.75
39	12/01/94	1086.63	647.48
Average		1989.36	846.84

N/A (not applicable) is noted for periods that did not have multiple cases of the disease.

4.2 Dependent variables

From January 1, 1992 to December 31, 1994 there were 1273 hospitalized cases of cholera and 4984 hospitalized cases of non-cholera watery diarrhea from the study area. The temporal distributions of cholera and non-cholera watery diarrhea by individual are shown in Figure 4.22.

Figure 4.22 Cholera and non-cholera watery diarrhea during the three-year study period.



Seldom during the three-year study period did cholera exceed non-cholera watery diarrhea in the total number of cases during a two-week period. Figure 4.23 shows the temporal distribution of only cholera during the three-year study period. There were three main cholera peaks during the study period, each of which was in September, October, or November. The 1992 epidemic was far less severe than that of the 1993 and 1994 epidemics. Secondary epidemics occurred in March and April all three years, however, the 1992 epidemic was

more severe than the other two years. Cholera cases were completely absent each year near the beginning of the year.

Figure 4.23 Cholera during the three-year study period.

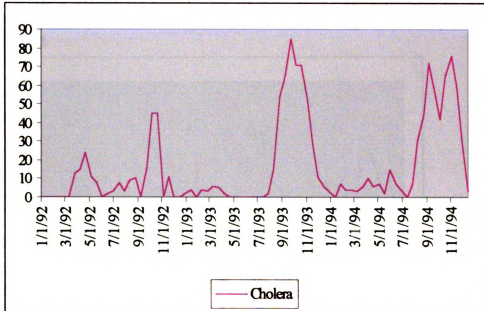


Figure 4.24 shows the temporal distribution of only non-cholera watery diarrhea during the three-year study period. Non-cholera watery diarrhea was far less cyclical than cholera. The four main peaks occurred in February/March 1993, September/October/November 1993, April/May 1994, and September/October 1994. There were only two periods when non-cholera watery diarrhea completely disappeared, in January 1992 and June 1993.

Figures 4.25, 4.26, and 4.27 display the temporal distribution of the two disease categories for each of the three years of the study period respectively. These figures are intended to allow the reader to look at the relationship between the temporal distributions of the two diseases in greater detail than depicted in Figure 4.24. During the first year of the study period, the two main cholera

epidemics corresponded with peaks of non-cholera watery diarrhea. There were also three smaller cholera peaks in July, August, and mid-November that corresponded to smaller non-cholera watery diarrhea peaks.

Figure 4.24 Non-cholera watery diarrhea during the three-year study period.

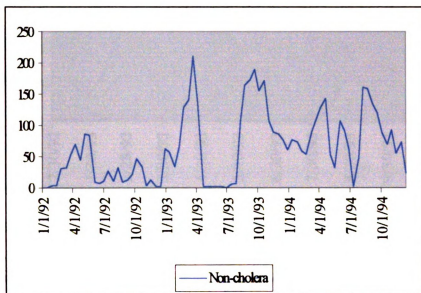


Figure 4.25 Cholera and non-cholera watery diarrhea during the first year of the study period.

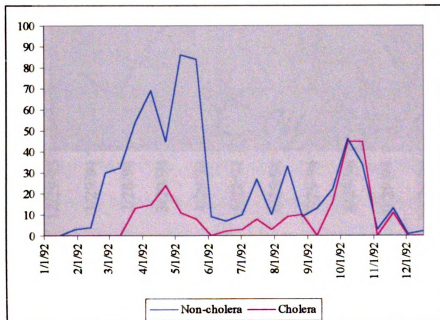


Figure 4.26 Cholera and non-cholera watery diarrhea during the second year of the study period.

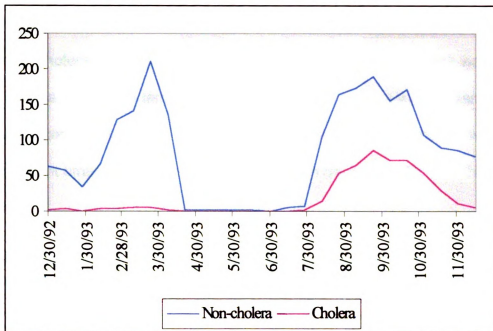
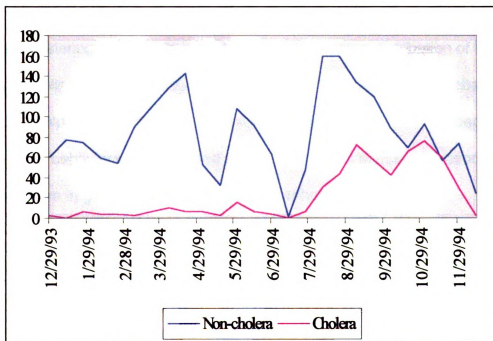


Figure 4.27 Cholera and non-cholera watery diarrhea during the third year of the study period.



During the second year of the study period, the two main cholera epidemics corresponded with peaks of non-cholera watery diarrhea. There were no other smaller peaks of either disease. During the third year of the study period, the two main cholera epidemics corresponded with peaks of non-cholera watery diarrhea. While the temporal distribution of non-cholera watery diarrhea was characterized by several peaks and valleys, the pattern of cholera was quite constant other than for the main epidemics in September/October/November.

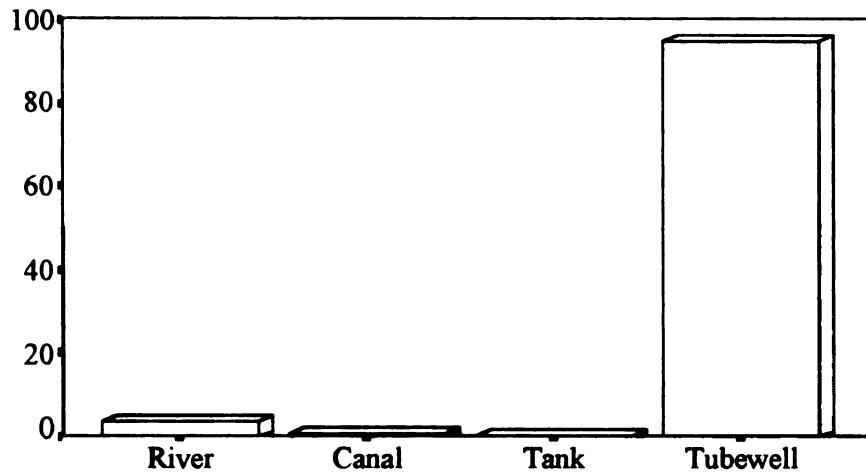
4.3 Descriptive information about study population derived from the questionnaire, latrine & tubewell survey, and secondary data sources.

Independent variable data were collected by administering a questionnaire, by collecting secondary data from the ICDDR,B Demographic Surveillance System records and community health worker record books, by administering a survey to collect primary data on the distribution of latrines and tubewells, and by calculating variables using the Matlab GIS database. These data help describe the study population's environment, their socioeconomic status, behaviors, and selected biological features of this population which may put them in greater risk of contracting diarrheal disease.

The questionnaire includes many questions that help describe the water and latrine use of the respondents. Figures 4.28 through 4.35 reveal the results of several of these questions. The Y-axis in these graphics is the percentage of respondents who answered in the categories shown in the X-axis. Approximately 95 percent of the study group reported that they use tubewell water as their

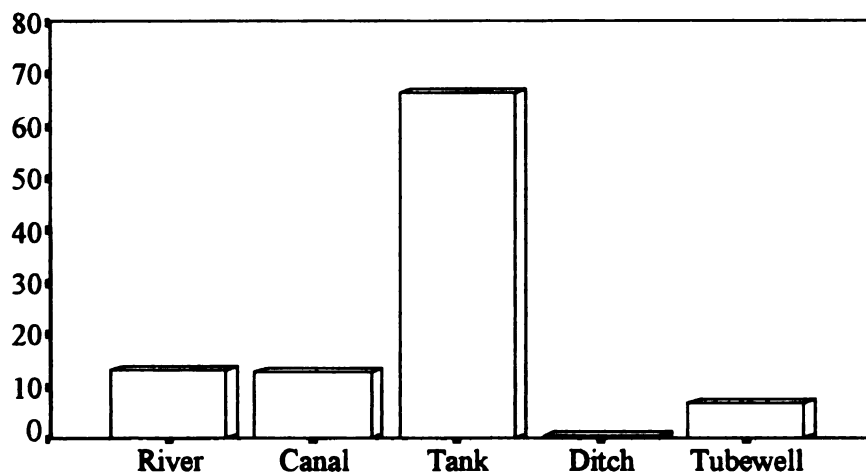
major source of drinking water (Figure 4.28).

Figure 4.28 Source of drinking water: questionnaire responses.



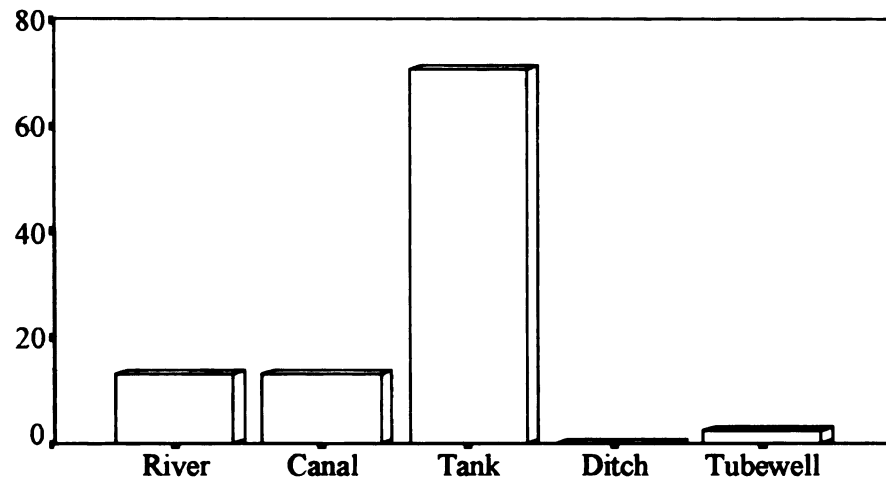
In contrast, for cooking, sixty-seven percent of the respondents regularly used tank (human-made pond) water, 13 percent used river water, another 13 percent used canal water, and only seven percent used tubewell water (Figure 4.29).

Figure 4.29 Source of cooking water: questionnaire responses.



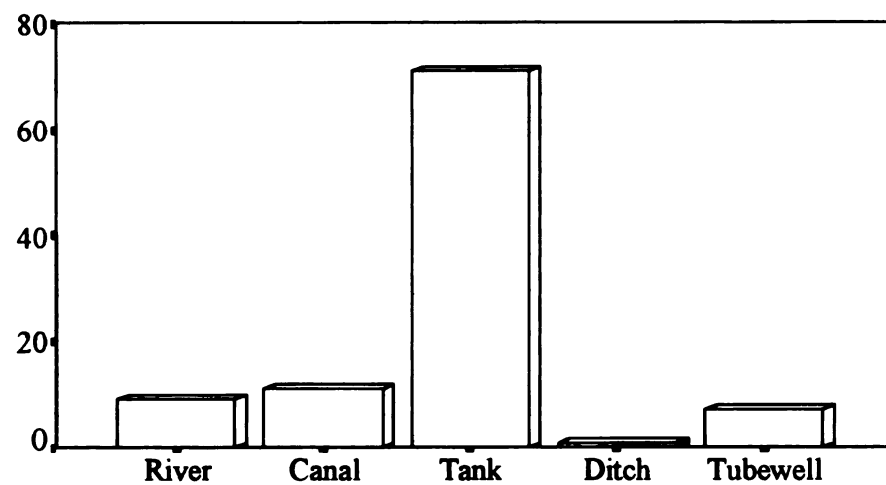
The source of water for bathing was almost exactly the same as for cooking water. The largest number of respondents (approximately 67 percent) bathe in tanks (Figure 4.30).

Figure 4.30 Source of bathing water: questionnaire responses.



While tanks were also the main source of water for washing dishes, river and canal water were significant sources as well (Figure 4.31).

Figure 4.31 Source of washing water: questionnaire responses.



The questionnaire differentiated between the defecation patterns of adults and children by gender because during the pretest it was discovered that they would probably be very different. Adult males and females usually defecate in latrines or in fixed sites that are not latrines (Figures 4.32 and 4.33).

Figure 4.32 Adult male defecation sites: questionnaire responses.

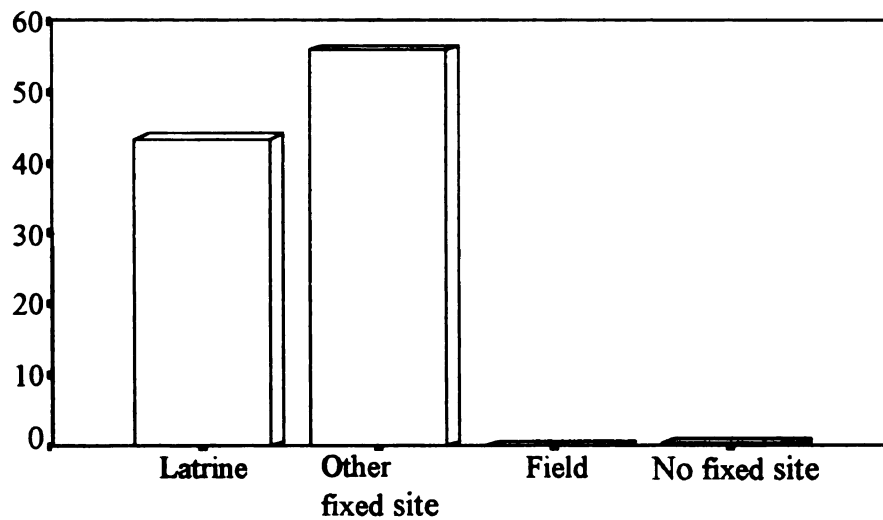
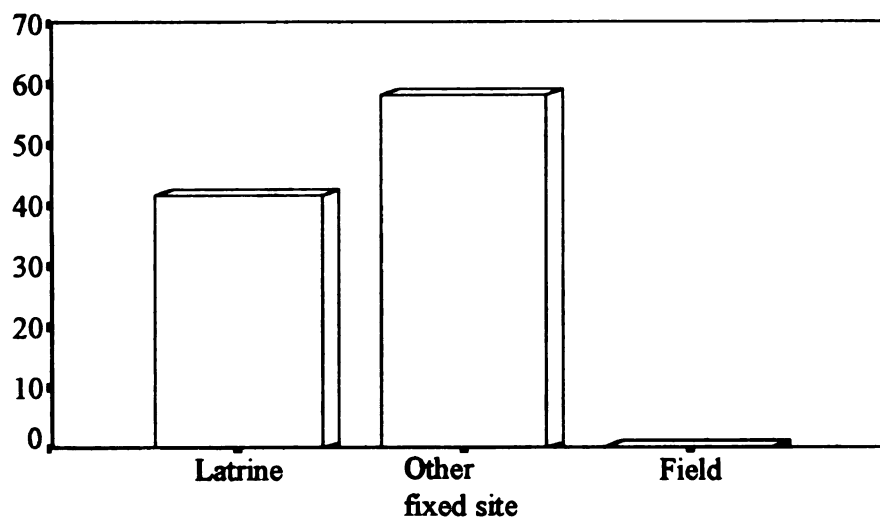


Figure 4.33 Adult female defecation sites: questionnaire responses.



Children were less likely to use a latrine than adults and a substantial number did not use a fixed site at all (Figures 4.34 and 4.35).

Figure 4.34 Male child defecation site: questionnaire responses.

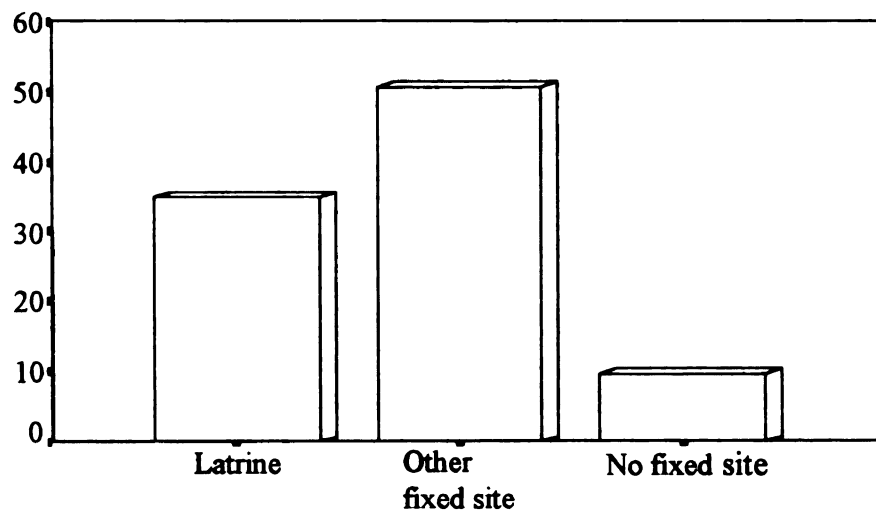
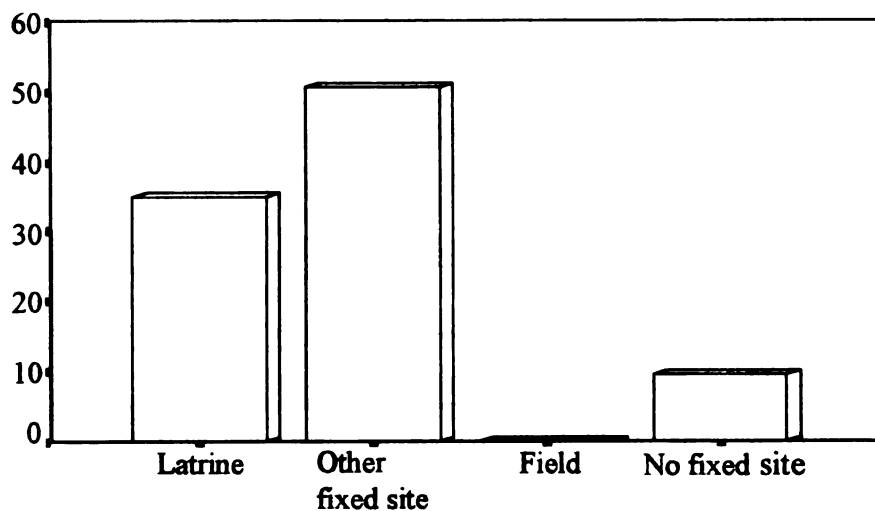


Figure 4.35 Female child defecation site: questionnaire responses.



There were two main sources of information concerning the availability of latrines and tubewells. The questionnaire included several questions on this issue.

These questions included the households where the case control study participants lived. The latrine and tubewell survey was more comprehensive since it included all households in half of the Matlab study area ($N \approx 3750$). Approximately 69 percent of the questionnaire households had a working tubewell in their *bari*. Only forty-two percent of the households had a latrine. The tubewell and latrine survey revealed similar results about tubewell distribution; 73 percent of the households in the study area had working tubewells in their *bari* and 47 percent of the households had either a non-septic, ring septic, or concrete septic latrine. As described in Chapter 3, survey data were collected for four latrine categories, one of which was open latrines. The open latrine, however, would not have been considered a latrine in the questionnaire. An open latrine as defined in the survey included all fixed sites where family members defecate. Approximately 90 percent of the households had a fixed defecation site, 23 percent had a non-septic latrine, 27 percent had a ring latrine, and only 10 percent had a concrete septic latrine. Five percent of the survey households in this study did not even have a fixed defecation site.

The ICDDR,B Demographic Surveillance System collects information concerning the size of a household. The square footage of households for which data were collected ranged from 18 to 1824 feet with an average of 226. The questionnaire included several questions concerning household assets and income. The participants household assets ranged from 20 to 275,910 taka (45 taka = US \$1) with an average of 28,155 taka. Assets include land, livestock, as well as household items such as lamps, radios, and quilts. Their annual income

ranged from zero to 388,260 taka, with an average of 39,140 taka. Income includes any cash source such as wages, sale of cash crops, and remittances from relatives in the Middle East. The education of participants ranged from 0 to 16 years. Approximately 49 percent of the participants over 15 years old had no education, 33 percent had between one and six years of education, and 18 percent had more than six years of education.

Environmental variables that were calculated using the GIS database included distance from the main river, the population density within a half kilometer of *baris* and whether or not the *bari* was in a flood controlled area. The average distance to the main river was approximately one kilometer, with a range of 35 meters to four kilometers. The average population density within one kilometer of a *bari* was approximately 5900 people and the range was from 95 to 30,000. Approximately 36 percent of the study population lived inside the flood-controlled area and 64 percent lived outside the flood-controlled area.

Biological variables that were collected by the ICDDR,B community health workers included mid-arm circumference and breast-feeding status. The average, mid-arm circumference of children under five was 135 mm, with a range of 108 to 162. A threshold of 120 mm is commonly used to define severe malnutrition in this population. Approximately 12 percent of the children had a mid-arm circumference below 120 mm and therefore were considered severely malnourished. Approximately 77 percent of children under five in the study population were breast-feeding.

4.4 Case control study for categorical variables

The data that were collected in this study included both categorical and continuous variables. Table 4.2 shows the frequencies of cholera cases and controls for the different categories of each binary variable. The data collection procedures for each of these variables are described in Chapter 3 and Appendix 1. These categorical variables were analyzed using the non-parametric case-control methods described in Chapter 3. The relative risk of each of these variables was calculated at the 95 percent confidence level. A relative risk value of two means that an individual with the attribute in question is twice as likely to get the disease as an individual without that attribute. For example, if an individual lives in a *bari* that is in a flood-controlled area the relative risk ratio is 2.47. This means that the study population was 2.47 times as likely to get cholera if they lived in a *bari* that was in a flood controlled area compared to an area that was not flood controlled. The risk ratios for the lower and upper limits of 95 percent confidence bounds for this variable are 1.99 and 3.05 respectively. This means that it is 95 percent certain that the relative risk ratio is between these bounds. If the relative risk values for the lower and upper confidence bounds are both above and below 1, the risk ratio can be considered not significant at the 95 percent confidence level. The relative risk values that are significant at the 95 percent confidence level have an asterisk beside them in Table 4.3.

Table 4.2 Frequencies of categorical variables with two classes for cholera.

Variable	Class 1	# of Controls	# of Cases	Class 2	# of Controls	# of Cases
Gender	Male	290	628	Female	307	620
Tubewell is source of drinking water	Yes	559	163	No	38	5
Tubewell is source of cooking water	Yes	45	8	No	552	160
Tubewell is source of bathing water	Yes	14	1	No	583	167
Tubewell is source of washing water	Yes	47	11	No	550	157
Working tubewell in bari	Yes	160	334	No	57	94
Adult male defecation	In latrine	264	66	Not in latrine	333	102
Adult female defecation	In latrine	258	60	Not in latrine	339	108
Male child defecation	In latrine	211	55	Not in latrine	356	106
Female child defecation	In latrine	213	53	Not in latrine	344	107
Presence of latrine in household	Yes	258	66	No	339	102
Type of latrine drainage	Septic	124	32	Open	134	34
# of households using a latrine	Single	216	43	Multiple	41	23
Consumption of shellfish	Yes	584	167	No	13	1
Flood controlled area	Yes	162	590	No	429	633
Breast feeding of children < 5	Yes	51	14	No	18	9
Nutritional status of children < 5	Normal	62	21	Mal-nutrition	7	3

Table 4.3 Cholera relative risk ratios for categorical variables with two classes

Categorical Variable	Relative Risk	Chi-square Probability value	95 Percent Confidence Bounds	
			Lower	Upper
Female gender	0.93	0.48	0.77	1.13
Tubewell not source of drinking water	2.22	0.09	0.86	5.72
Tubewell not source of cooking water	0.61	0.21	0.28	1.33
Tubewell not source of bathing water	0.25	0.15	0.03	1.91
Tubewell not source of washing water	0.82	0.57	0.42	1.6
No working tubewell in bari	0.79	0.22	0.36	1.72
Adult male defecation in latrine	0.82	0.25	0.58	1.15
Adult female defecation in latrine	0.73	0.08	0.51	1.04
Male child defecation in latrine	0.87	0.48	0.61	1.26
Female child defecation in latrine	0.78	0.24	0.55	1.16
Absence of latrine in household	1.17	0.36	0.83	1.67
Open latrine drainage	0.98	0.95	0.57	1.69
Multiple households use latrine	2.80**	0.00	1.53	5.17
Shellfish not consumed	0.26	0.17	0.03	2.07
Flood controlled area	2.47**	0.00	1.99	3.05
Child breast feeding	0.55	0.23	0.20	1.48
Child malnourished	1.26	0.74	0.30	5.34

Variables describing the water and sanitation circumstances are both cultural/behavioral and environmental. Those that describe the water and

sanitation infrastructure of a participant's living space are environmental and those that involve choice of water source or latrine type are cultural/behavioral. Neither the source of water for drinking, cooking, bathing, and washing nor the absence of a working tubewell in the participant's *bari* were related to cholera hospitalization. Defecation in places other than latrines was not associated with cholera hospitalization and participants who lived in households without latrines or who had latrines with open drainage systems did not have a significantly greater chance of being hospitalized with cholera during the study period. Participants who shared latrines with other households had a 2.8 times greater chance of being hospitalized with cholera.

One cultural/behavioral variable that was hypothesized to be associated with cholera is shellfish consumption. Shellfish consumption was not significantly greater for cases versus controls. The flood-control embankment divides the study area environmentally. Individuals living in flood-controlled areas were 2.47 times more likely to be hospitalized with cholera. Another environmental variable not related to cholera hospitalization was the distance from the main river. Two biological variables were collected including breast-feeding status and nutritional status. Child participants that were not breast feeding the month before hospitalization or who were malnourished were not more likely to be hospitalized with cholera during the study period. One independent variable that does not fit neatly into one of the different independent variable categories is gender, which was not associated with cholera hospitalization.

Several independent variables had more than two ordinal level classes. The frequencies of cases and controls for each class are listed in Table 4.4. The non-parametric statistic, Kendall's Tau-C, was used to determine if there were any associations between the ordinal, independent variables in this study and cholera hospitalization. Table 4.5 lists the Tau-C statistics and their associated probabilities. The education of participants over 15 years old (when classified in the aforementioned categories) was not associated with hospitalization. None of the other ordinal level variables were associated with cholera hospitalization either.

Table 4.4 Frequencies of categorical variables with more than two classes for cholera.

Variable	Class 1	# Cnt Cs	Class 2	# Cnt Cs	Class 3	# Cnt Cs	Class 4	# Cnt Cs
Years of education: Adult (>15) participants	More than six	<u>31</u> 7	One to six	<u>53</u> 22	None	<u>91</u> 20		
Years of education: mother	More than six	<u>137</u> 31	One to six	<u>181</u> 59	None	<u>279</u> 78		
Years of education: father	More than six	<u>76</u> 16	One to six	<u>88</u> 31	None	<u>433</u> 121		
Knowledge of prevention of diarrhea	Full	<u>34</u> 9	Good	<u>163</u> 47	Partial	<u>146</u> 43	None	<u>254</u> 69
Knowledge of source of diarrhea	Good	<u>27</u> 8	Partial	<u>452</u> 121	None	<u>118</u> 39		
Household Material	Brick, Tin	<u>41</u> 54	Bamboo tin	<u>26</u> 68	Jute, tin	<u>128</u> 259	Straw, stick, bamboo	<u>17</u> 30

Table 4.5 Kendall's Tau-C values for ordinal level variables.

Categorical Variable	Kendall's Tau C	Chi-square Probability value
Years of education: Adult (>15) participants	0.01	0.36
Years of education: Mother	-0.015	0.34
Years of education: Father	-0.003	0.32
Knowledge of prevention of diarrhea	0.0072	0.98
Knowledge of source of diarrhea	-0.021	0.60
Household material	0.026	0.13

Table 4.6 lists the frequencies of cases versus controls for all of the binary independent variables for non-cholera watery diarrhea. Table 4.7 lists the risk ratios for these variables.

Table 4.6 Frequencies of categorical variables with two classes for non-cholera watery diarrhea.

Variable	Class 1	# of Controls	# of Cases	Class 2	# of Controls	# of Cases
Gender	Male	290	2109	Female	307	1829
Tubewell is source of drinking water	Yes	559	125	No	38	1
Tubewell is source of cooking water	Yes	45	10	No	552	116
Tubewell is source of bathing water	Yes	14	7	No	583	119
Tubewell is source of washing water	Yes	47	8	No	550	118
Working tubewell in bari	Yes	160	1138	No	57	436
Adult male defecation	In latrine	264	57	Not in latrine	333	69
Adult female defecation	In latrine	258	53	Not in latrine	339	73
Male child defecation	In latrine	211	45	Not in latrine	356	77
Female child defecation	In latrine	213	39	Not in latrine	344	77
Presence of latrine in household	Yes	258	54	No	339	72
Type of latrine drainage	Septic	124	23	Open	134	31
# of households using a latrine	Single	216	43	Multiple	41	11
Consumption of shellfish	Yes	584	124	No	13	2
Flood controlled area	Yes	162	1349	No	429	2511
Breast feeding of children < 5	Yes	51	31	No	18	3
Nutritional status of children < 5	Normal	62	25	Mal-nutrition	7	4

Table 4.7 Non-cholera watery diarrhea relative risk ratios for categorical variables

Categorical Variable	Relative Risk	Chi-square Probability value	95 Percent Confidence Bounds	
			Lower	Upper
Female gender	0.81*	0.02	0.69	0.97
Tubewell not source of drinking water	8.49**	0.01	1.15	62.48
Tubewell not source of cooking water	1.06	0.87	0.52	2.16
Tubewell not source of bathing water	2.45*	0.05	1.00	6.20
Tubewell not source of washing water	0.79	0.55	0.36	1.72
No working tubewell in bari	1.07	0.66	0.78	1.48
Adult male defecation in latrine	1.04	0.83	0.71	1.53
Adult female defecation in latrine	0.95	0.81	0.65	1.41
Male child defecation in latrine	0.99	0.94	0.66	1.48
Female child defecation in latrine	0.81	0.35	0.54	1.25
Absence of latrine in household	1.01	0.94	0.66	1.48
Open latrine drainage	1.25	0.46	0.69	2.20
Multiple households use latrine	1.34	0.42	0.64	2.82
Shellfish not consumed	0.72	0.67	0.16	3.25
Flood controlled area	1.42**	0.00	1.17	1.72
Child breast feeding	3.64	0.04	1.00	13.34
Child malnourished	1.42	0.60	0.38	5.27

The cultural/behavioral and environmental variables describing the water and sanitation situation revealed similar results for non-cholera diarrhea as for

cholera. One notable difference was that participants who did not use tubewell water for drinking water were more than eight times as likely to be hospitalized with non-cholera watery diarrhea than people who did. The use of tubewell water for cooking, bathing, and washing was not associated with non-cholera hospitalization. Participants whose *bari* had a working tubewell did not have lower non-cholera watery diarrhea hospitalization rates. Defecation in places other than latrines was not associated with hospitalization and participants who lived in households without latrines or had latrines with open drainage systems did not have a significantly greater or lower chance of being hospitalized with non-cholera watery diarrhea during the study period. Participants who shared latrines with other households did not have a greater chance of being hospitalized.

Shellfish consumption, which is a cultural/behavioral variable, was not significantly greater for cases versus controls for non-cholera watery diarrhea. An environmental variable, flood-control was associated with non-cholera watery diarrhea, however, the relationship was weaker than it was for cholera. Individuals living flood-controlled areas were 1.42 times more likely to be hospitalized. Another environmental variable, distance from the main river was not associated with non-cholera watery diarrhea hospitalization. The two binary biological variables, breast-feeding status and nutritional status, were not associated with non-cholera hospitalization. However, the multifaceted independent variable of gender revealed an association. Female participants had a significantly lower chance of being hospitalized with non-cholera diarrhea

during the study period.

The frequencies for cases and controls for each of the independent variables with more than two ordinal classes are listed in Table 4.8. Table 4.9 lists the Tau-C statistics and their associated probabilities for non-cholera watery diarrhea. None of the ordinal level variables were associated with non-cholera watery diarrhea hospitalization.

Table 4.8 Frequencies of categorical variables with more than two classes for non-cholera watery diarrhea.

Variable	Class 1	# <u>Cnt</u> Cs	Class 2	# <u>Cnt</u> Cs	Class 3	# <u>Cnt</u> Cs	Class 4	# <u>Cnt</u> Cs
Years of education: Adult (>15) participants	More than six	<u>31</u> 12	One to six	<u>53</u> 20	None	<u>91</u> 12		
Years of education: mother	More than six	<u>137</u> 27	One to six	<u>181</u> 51	None	<u>279</u> 48		
Years of education: father	More than six	<u>76</u> 10	One to six	<u>88</u> 24	None	<u>433</u> 92		
Knowledge of prevention of diarrhea	Full	<u>34</u> 6	Good	<u>163</u> 39	Partial	<u>146</u> 33	None	<u>254</u> 48
Knowledge of source of diarrhea	Good	<u>27</u> 1	Partial	<u>452</u> 97	None	<u>118</u> 28		
Household Material	Brick, Tin	<u>41</u> 244	Bamboo tin	<u>26</u> 196	Jute, tin	<u>128</u> 927	Straw, stick, bamboo	<u>17</u> 163

Table 4.9 Kendall's Tau-C values for ordinal level variables.

Categorical Variable	Kendall's Tau C	Chi-square Probability value
Years of education: Adult (>15) participants	0.08	0.35
Years of education: Mother	0.03	0.07
Years of education: Father	-0.01	0.14
Knowledge of prevention of diarrhea	0.02	0.73
Knowledge of source of diarrhea	-0.03	0.13
Household material	0.02	0.45

4.5 Logistic regression analysis for continuous variables.

The study included several ratio-level variables for which summary statistics are listed in Table 4.10. Simple logistic regression models were devised for all of the continuous variables and for selected, categorical variables by creating dummy variables. The results of each of these simple logistic regression models, using cholera as the binary dependent variable, are displayed in Table 4.11. Those independent variables that were significant at the 99 percent confidence level have two asterixes; those significant at the 95 percent confidence level have one asterix.

Table 4.10 Descriptive statistics for continuous independent variables.

Variable	Mean	Standard Deviation	Minimum	Maximum
Number of open latrines	4.17	3.7	0	26
Number of non-septic latrines	0.37	0.83	0	18
Number of ring septic latrines	0.53	1.24	0	12
Number of concrete septic latrines	0.15	0.48	0	3
Number of other households using latrines	9.72	8	0	61
Latrines per 100 people (excluding open)	2.13	3.54	0	33
Number of tubewells in bari	1.43	1.48	0	13
Number of households using tubewells in bari	8.97	8.8	0	55
Tubewells per 100 people	3.07	3.34	0	33
Household area (sq. ft.)	226.55	109.33	18	1824
Bari population	53.51	50.86	2	498
Population density around baris (persons per km ²)	5914.8	3916.72	95.45	30941.42
Total Assets (taka)	28155.56	39725.02	20	275910
Annual Income (taka)	39,140	40,819	0	388,260
Mid-arm circumference (mm)	135.52	11.65	108	162
Distance from main river (m)	1062.69	855.05	35	4049

Table 4.11 Simple logistic regression analysis for cholera cases and controls.

Variable	Beta	Probability
Number of open latrines	0.0873	0.00**
Number of non-septic latrines	0.1151	0.27
Number of ring septic latrines	-0.0664	0.35
Number of concrete septic latrines	-0.0595	0.65
Number of other households using latrines	0.0159	0.11
Latrines per 100 people (excluding open)	-0.0312	0.26
Number of tubewells in bari	0.0830	0.15
Number of households using tubewells in bari	0.0873	0.00**
Tubewells per 100 people	0.0120	0.68
Household area (sq. ft.)	-0.0019	0.02*
Bari population	0.0026	0.01**
Population density around baris (per km)	3.70E-05	0.00**
Total Assets (taka)	-2.2E-06	0.35
Annual Income (taka)	-2.7E-06	0.27
Mid-arm circumference (mm)	-0.0341	0.10
Distance from main river (m)	-5.7E-05	0.30
Flood control	0.903	0.00**

The number of open latrines was related to cholera hospitalization at the 99 percent confidence level. This means that the more open latrines that were in a *bari* the more likely it was that an individual living in that *bari* would be hospitalized with cholera. The number of non-septic, ring septic, and concrete septic latrines was not related to cholera hospitalization. The number of other households using a participant's latrine or the number of latrines per 100 people were not related to cholera hospitalization. The number of tubewells in the *baris*

was not related to cholera hospitalization. However, the number of households using tubewells was positively related at the 0.01 level. Thus, if more people were using a household tubewell, then cholera incidence was greater. The number of tubewells per 100 people was not related to cholera incidence, but *bari* population and population density were positively related to cholera incidence. Neither the household assets nor household income were related to cholera hospitalization. However, another socioeconomic variable, household area, was inversely related to cholera hospitalization. The mid-arm circumference of children was not related to cholera hospitalization. While the distance to the main river was not related to cholera incidence, if a household was in a flood-controlled area, then the individuals living there were more likely to be hospitalized with cholera.

The results of each of the simple regression models using non-cholera watery diarrhea as the binary dependent variable are displayed in Table 4.12.

Table 4.12 Simple logistic regression analysis for non-cholera cases and controls.

Variable	Beta	Probability
Number of open latrines	0.0355	0.09
Number of non-septic latrines	-0.0129	0.88
Number of ring septic latrines	-0.0096	0.87
Number of concrete septic latrines	-0.1049	0.87
Number of other households using latrines	-0.0097	0.27
Latrines per 100 people (excluding open)	0.0154	0.46
Number of tubewells in bari	-0.0062	0.89
Number of households using tubewells in bari	-0.0063	0.43
Tubewells per 100 people	-0.0371	0.10
Household area (sq. ft.)	-0.0014	0.02*
Bari population	0.0002	0.80
Population density around baris (persons per km ²)	2.2E-06	0.84
Total Assets (taka)	-1.5E-06	0.55
Annual Income (taka)	3.69E-07	0.87
Mid-arm circumference (mm)	-0.0399	0.04*
Distance from main river (m)	-6.8E-05	0.17
Flood control	0.352	0.00**

None of the latrine or tubewell variables was related to non-cholera watery diarrhea hospitalization. Also, the *bari* population and population density were not related to non-cholera diarrheal incidence. However, the household area was negatively related to hospitalization at the 95 percent confidence level. Neither the number of household assets nor the household income was related to non-cholera diarrhea hospitalization. The mid-arm circumference of children was negatively related to non-cholera diarrheal incidence at the 95 percent

confidence level. While the distance to the main river was not related to non-cholera diarrhea incidence, if a household was in a flood-controlled area they were more likely to be hospitalized with the disease.

4.6 Multiple logistic regression

All of the continuous variables were first incorporated into one large multiple logistic regression model for cholera. Table 4.13 shows the results of that model.

Table 4.13 Results of all variables added to logistic regression for cholera.

Variable	Beta	Significance
Number of open latrines	-.0273	0.8840
Number of non-septic latrines	0.0521	0.9649
Number of ring septic latrines	-0.8938	0.5096
Number of concrete septic latrines	-0.6355	0.6509
Number of other households using latrines	-.0112	0.8507
Latrines per 100 people (excluding open)	0.1625	0.7336
Number of tubewells in bari	2.0120	0.0773
Number of households using tubewells in bari	-.0914	0.2329
Tubewells per 100 people	-0.8743	0.1403
Household area (sq. ft.)	-0.0070	0.1762
Bari population	0.0016	0.9529
Population density around baris (per km)	-3.3E-05	0.8409
Total Assets (taka)	-9.4E-06	0.4434
Annual Income (taka)	2.84E-06	0.8776
Mid-arm circumference (mm)	0.0223	0.5970
Distance from main river (m)	0.0003	0.6035
Flood control	2.2734	0.0772

None of the variables that were related in the simple logistic regression model were related in the multiple logistic regression model that included all of the variables. A multiple logistic regression model was then devised using the variables that were significant to at least the 85 percent confidence level in the

simple logistic regression models. The mid-arm circumference was not used since data were only available for 29 cases and 64 controls. The results of this multiple logistic regression model for cholera are summarized in Table 4.14.

Table 4.14 Results of multiple logistic regression for cholera.

Variable	Beta	Significance
Number of open latrines	0.0948	0.00**
Number of other households using latrines	0.0265	0.18
Number of tubewells in bari	0.0714	0.35
Number of households using tubewells in bari	0.0022	0.87
Household area (sq. ft.)	-0.0024	0.00**
Bari population	0.0097	0.02*
Population density around baris (per km)	-4.9E-05	0.09
Flood control	0.5128	0.03*

The number of open latrines in a *bari* was related to cholera hospitalization at the 99 percent confidence level. The larger the number of open latrines in a *bari*, the more individuals living in that *bari* were hospitalized with cholera. This variable represents an unsanitary condition in a *bari*. The number of other households sharing latrines and tubewells as well as the total number of tubewells in *baris* were not related to cholera hospitalization. Household area was negatively related to cholera hospitalization at the 99 percent confidence level. The smaller the household the more likely an individual was to be hospitalized with cholera. The household area is a socioeconomic indicator as well as an environmental variable. A household with a small area is usually relatively poor. Being poor can be thought of as an indirect cause of cholera. Also, small households indicate a crowded condition, which is something that may predispose people to

secondary transmission. The *bari* population is also related to cholera hospitalization. Individuals in larger *baris* were more likely to be hospitalized with cholera. The population density is not related to cholera hospitalization. Lastly, people living in flood controlled areas were more likely to contract cholera. A discussion of why these areas might predispose people to cholera is offered in Chapter 5.

Multicollinearity, which is the existence of high correlations between independent variables, can produce unstable estimates of the partial regression coefficients (beta values). Thus, it is desirable to choose predictor variables that are highly correlated with the dependent variable but only modestly correlated to one another. In order to test if multicollinearity was a problem for the above multiple logistic regression model, correlation coefficients were calculated between all of the independent variables. A correlation matrix is shown in Table 4.15 for all of the independent variables included in the model. Only those observations that were built into the multiple logistic regression model were used to calculate the correlation coefficients. The highest correlation coefficient was between the number of tubewells in a *bari* and the number of households sharing tubewells. None of the other variables were highly correlated.

Table 4.15 Correlation matrix of independent variables included in multiple logistic regression model.

	# of open latrines	# HHs using latrines	# of tubewells in bari	# HHs using tubewells in bari	HH area	Bari Pop	Pop density
# of open latrines	1						
# HHs using latrines	0.20	1					
# of tubewells	0.31	0.21	1				
# HHs using tubewells	0.42	0.44	0.58	1			
HH area	-0.06	-0.03	0.14	0.09	1		
Bari Population	0.20	0.37	0.40	0.27	0.03	1	
Population Density	0.12	0.21	0.13	0.18	-0.04	0.33	1

Table 4.16 shows the results of the multiple logistic regression model of non-cholera watery diarrhea that included all of the continuous variables. None of the variables that were related in the simple logistic regression model were related in the multiple logistic regression model that included all of the variables. Therefore, a multiple logistic regression model was devised using the variables that were significant to at least the 85 percent confidence level. Similar to the multiple regression model for cholera, the mid-arm circumference was not used since data were only available for 29 cases and 69 controls. The results of this multiple regression model for non-cholera are summarized in Table 4.17.

Table 4.16 Results of all variables added to logistic regression for non-cholera watery diarrhea.

Variable	Beta	Significance
Number of open latrines	0.0069	0.92
Number of non-septic latrines	0.0664	0.82
Number of ring septic latrines	0.1943	0.35
Number of concrete septic latrines	0.0547	0.91
Number of other households using latrines	0.0554	0.16
Latrines per 100 people (excluding open)	-0.0478	0.55
Number of tubewells in bari	0.1791	0.46
Number of households using tubewells in bari	-0.0480	0.13
Tubewells per 100 people	-0.0307	0.69
Household area (sq. ft.)	-0.0007	0.60
Bari population	-0.0143	0.17
Population density around baris (per km)	-9.8E-05	0.10
Total Assets (taka)	-8.5E-06	0.10
Annual Income (taka)	2.79E-06	0.43
Distance from main river (m)	0.0002	0.17
Flood control	-0.1000	0.84

Table 4.17 Results of logistic regression for non-cholera watery diarrhea.

Variable	Beta	Significance
Number of open latrines	0.0370	.08
Tubewells per 100 people	-0.0499	.03*
Household area	-0.0016	.01**
Flood control	0.0096	.00**

The number of open latrines in a *bari* was not related to non-cholera hospitalization. As the number of tubewells per person increased, non-cholera, diarrheal hospitalization decreased. Also, household area was negatively related to cholera hospitalization at the 95 percent confidence level. The smaller the

household, the more likely an individual was to be hospitalized with non-cholera, watery diarrhea. Similar to the findings for cholera, people living in flood controlled areas were more likely to be hospitalized with non-cholera, watery diarrhea. In order to test if multicollinearity was a problem for the above multiple logistic regression model, correlation coefficients were calculated and are shown in Table 4.18.

Table 4.18 Correlation matrix of independent variables included in multiple logistic regression model.

	# of open latrines	Tubewells per 100 people	HH area
# of open latrines	1		
Tubewells per 100 people	0.1378	1	
HH area	-.0640	0.1968	1

None of these variables was highly correlated and, thus, it is assumed that they are not multicollinear.

The previous four chapters described the research problem, discussed the theoretical foundation of the study, explained what methods were used, both in the field and after the data were collected, and described the results of the study in detail. Chapter 5 brings all of these pieces together by describing the most important results and their theoretical and practical implications.

5. Discussion of results and conclusions

This research project investigated the similarities and differences between the spatial and temporal patterns and risk factors of cholera and non-cholera watery diarrhea. It tested whether many biological, socioeconomic, cultural/behavioral, and environmental variables were risk factors involved in the disease ecology of cholera and non-cholera watery diarrhea. This chapter will discuss the findings of those tests. It will be argued that this research accomplishes the following:

- It offers corroborating evidence of the existence and importance of an environmental reservoir for cholera, based upon observed differences between the spatial and temporal patterns of cholera and non-cholera, watery diarrhea.
- It identifies and compares risk factors for cholera and non-cholera watery diarrhea.
- It extends the use of geographic information systems (GIS) as a tool in disease modeling.

This chapter will first discuss the most important results of the spatial and temporal patterns of cholera and then the most important risk factors for the two disease categories. Disease ecology models of the two diseases will then be offered followed by discussions of the health policy and research implications of the study.

5.1 Spatial and temporal patterns of cholera and non-cholera diarrhea

Several regular characteristics were observed in the temporal distribution of 1273 cholera cases and 4984 non-cholera, watery diarrhea cases, clearly revealing differences between the temporal distribution of the two disease categories. Non-cholera cases were more numerous than cholera cases for almost the entire study period. The main cholera peaks were in September and October in each of the three study years. The 1992 peak had fewer cases than the 1993 and 1994 peaks but one can still consider each of them a major epidemic. Smaller peaks of cholera occurred in March and April. During the winter of each year, there were no cases or almost no cases, thus the annual temporal distribution of cholera begins in January, with a period of dormancy or near dormancy. Winter in the study area is characterized by almost no rainfall and relatively low temperatures (Table 1.1, page 10). There is a small peak at the end of the dry season that leads to a period with sporadic cases during the rainy season. At the end of the rainy season there is a major epidemic which gradually declines at the end of the year.

There was an irregular cycle to non-cholera watery. The main peaks during the study period occurred at different times of year and the lengths of these epidemics varied more than the seasonal, cholera epidemics. This pattern is consistent with the main presumption of this project that cholera is a disease with an environmental reservoir and non-cholera diarrhea is not. Colwell (1985) and the author contend that the seasonal pattern of cholera is due to changes in the physical environment and that primary transmission is very important. The

physical environment of the study area is relatively homogeneous. Colwell's theory of the location of the cholera environmental reservoir is that the rivers, canals, brackish ponds, and streams contain dormant bacteria which multiply at certain times of the year because of salinity changes and the number of available attachment sites (plankton) for the bacteria. Rivers, canals, brackish ponds, and streams are distributed throughout the study area so the postulated environmental reservoir also exists throughout the study area. Thus, the spatial pattern of cholera is consistent with Colwell's theory of an environmental reservoir since the cases are widely dispersed. After periods of dormancy, people contract cholera from environmental sources; subsequent cases are due to either primary transmission from the environment or due to secondary transmission from other people. Non-cholera, watery diarrhea is caused exclusively by secondary transmission since there is no environmental source.

Another temporal pattern indicated by the results was a correspondence between two of the three cholera epidemics and the peaks of non-cholera, watery diarrhea. There were several other smaller peaks of cholera that also corresponded with peaks of non-cholera diarrhea. It is unclear why these correspondences occurred. However, secondary transmission paths are similar for both diseases. Thus, if primary cholera transmission has already occurred, then the variables that predispose an individual to secondary transmission may result in the two disease frequencies corresponding to one another. Specific secondary disease transmission paths are discussed below.

Mapping cases of cholera and non-cholera watery diarrhea in four-week

periods throughout the study period showed the spatial distribution of the diseases. The differences between the spatial distribution of cholera and non-cholera diarrhea are less pronounced than the differences in the temporal patterns. The first cases of cholera occurred in March of 1992 at extreme locations in the study area. The likelihood of the cholera victims coming into contact with one another, when living so far from each other, is negligible. Thus, the possibility of secondary transmission can almost be ruled out. During much of the study period, the cases of cholera were widely dispersed, thus it is evident that primary cholera transmission is very important throughout the non-dormant parts of the year. While there is no way to distinguish between primary and secondary cholera cases, the more dispersed cases are, the less likely that secondary transmission has occurred. Therefore, the more dispersed the cases the more likely they were due to primary transmission.

There were several periods when the largest number of cholera cases occurred in a small area in the southwest corner of the study area, near the confluence of the Dhonogoda Meghna Rivers. It is unclear why these small epidemics occurred, but it is possible that there were a large number of secondary cases in this particular area. Also, undetected characteristics peculiar to this population may have predisposed this group to greater secondary transmission.

The spatial pattern of non-cholera watery diarrhea cases was characterized by more clustering than was observed in the case of cholera. There were very few isolated cases and the largest clusters of disease occurred

near Matlab town and in the southwest corner of the study area. There were several other locations in the study area, however, where there were epidemics. It can also be noted that there were very few cases of non-cholera watery diarrhea in the northern part of the study area. It is unclear why this occurred, but it may have been because people living in this area were less likely to report to the hospital. The spatial pattern of non-cholera, watery diarrhea is characterized by outbreaks in many different locations with very few isolated cases. This pattern is consistent with exclusively secondary transmission. Non-cholera watery diarrhea epidemics start in a community when an infected person brings the disease from outside and then infects another person and so on.

The centroids of cholera cases for the four-week study periods were widely dispersed as compared with non-cholera, watery diarrhea. There was no regular spatial seasonal pattern to where cholera occurred in different seasons. This spatial pattern can be explained by the fact that the aquatic cholera reservoir is relatively homogeneous throughout the study area in that rivers, canals, brackish ponds, and streams are distributed throughout the study area. The nearest neighbor distance calculations revealed that cholera cases were on average farther apart from one another than non-cholera cases in a particular time period. Average nearest neighbor distances were 1989 meters for cholera and 847 meters for non-cholera, watery diarrhea. This spatial pattern is consistent with the theory that primary transmission is important for cholera but not for non-cholera diarrhea. Since secondary transmission only occurs if an individual comes into contact with a victim of the disease, it is logical that non-

cholera cases will be closer to one another than cholera cases since cholera cases can also be infected by the aquatic reservoir.

5.2 Risk factors of cholera and non-cholera diarrhea

The spatial patterns of the two diseases discussed above are the result of a complex interaction between people and their environment. Hunter (1974) argues that disease results from the coincidence of agent and host in time and space. Therefore, this disease ecology study involves the analysis of variables that may be responsible for agent and host being coincident in time and space. Many different types of independent variables were collected, and thus several different types of statistics were used to measure relationships between variables. It is important to note that negative relationships can be just as revealing as positive relationships. Two of the environmental independent variables were strongly associated with cholera hospitalization. Participants who shared latrines with other households had a 2.8 times greater chance of being hospitalized with cholera. Sharing latrines is a variable that represents increased exposure to the fecal material of others and this may lead to secondary transmission. Individuals living in flood-controlled areas were 2.47 times more likely to be hospitalized with cholera. It is not entirely clear why this should be true. One theory is that flood control exacerbates cholera bloom⁶ by some

⁶ Bloom refers to exponential multiplication of the bacteria.

unknown mechanism (Colwell and Spria, 1992). Flood-control may change salinity levels or may impede the natural flushing out of cholera-laden water. However, the association between cholera and flood-control may be unrelated to flood-control altogether. There may be another variable that is associated with flood-control causing a spurious association to exist between flood-control and cholera hospitalization. Future work should be done comparing cholera incidence rates in other flood-controlled areas of Bangladesh with their surrounding areas. Similarities of the environments of these flood-controlled areas should be identified so that if cholera is more incident in these areas, then a causal pathway can be determined. The multi-billion dollar Bangladesh Flood Action Plan may or may not be responsible for increased cholera rates. Thus, it is important to investigate whether or not flood control is contributing to transmission of this disease.

Several of the cultural/ behavioral variables that describe the water and sanitation situation of study participants did not reveal associations. Tubewell water used for drinking, cooking, bathing, and washing was not related to cholera hospitalization. This certainly does not mean that people do not need to use tubewell water to avoid contracting cholera. Almost all of the questionnaire respondents (95 percent) said that they regularly use tubewell water for drinking so there is not a big problem with drinking water use. Defecation in places other than a latrine, households without latrines, and households with open latrines were not associated with cholera transmission. It is unclear why these variables that represent an unsanitary environment were not associated with cholera, since

they are no doubt responsible for secondary cholera transmission. There were also continuous variables associated with sanitation and water availability, which will be discussed below.

The cultural/ behavioral variable, shellfish consumption, was not associated with cholera transmission either. This is contrary to one of Colwell's (1985) theories about an environmental reservoir for cholera. She believes that shellfish are one of the attachment sites for the bacteria. The lack of an association might be due to the fact that 92 percent of the people in the study population consume shellfish. The only people that might not consume any type of shellfish are extremely poor and are thus already more prone to contracting cholera because of other variable types such as socioeconomic and those involved with their access and use of clean water and proper sanitation.

Two biological variables, breast-feeding and malnutrition, were not associated with cholera transmission. This may be attributed to the low number of child participants who were not breast feeding during the month before hospitalization (23 percent) or who had a mid-arm circumference below 120 millimeters (12 percent).

The independent variables that had more than two ordinal classes included level of education for different household members, household material, and knowledge of diarrhea prevention and source. Educational level and household material are socioeconomic variables that were hypothesized to show a negative association with cholera incidence. Surprisingly, there were no associations. Knowledge about the source and prevention of diarrhea were

hypothesized to be inversely associated with cholera hospitalization, however there were no associations in this case either.

Modeling a complex problem such as what makes someone susceptible to contracting cholera requires that a variety of methods be used. Non-parametric statistics were used to measure associations between cholera and potential risk factors, and simple regression analysis was used for the continuous variables. The larger the number of open latrines in a *bari*, the more likely a resident was to contract cholera. Open latrines are basically fixed sites where people regularly defecate. These fixed sites are an indicator of an unsanitary environment. The number of households using tubewells was positively related to cholera hospitalization. It is unclear why this association exists but a speculation is offered. If many households share a tubewell it may decrease access to that tubewell, thus this relationship might indicate that access to tubewell water is important to preventing cholera.

Bari population and population density were positively related to cholera incidence. While it is not completely clear why *bari* population size is related to cholera hospitalization, one conjecture is that the larger the *bari* population the larger the number of human contacts people have. The last variable that was related to cholera hospitalization was household area, a socioeconomic and environmental variable. As described in Chapter 3, it is a socioeconomic indicator because people with smaller households are usually poorer and it is environmental because smaller households represent a condition of crowding. Household area was inversely related to cholera hospitalization. There were two

other socioeconomic indicators, assets and income, which were built into simple logistic regression models. However, neither was found to be related to cholera hospitalization. Conroy (1997) suggests that socioeconomic status in the developing world is a complex issue and that assets and income measure different parts of socioeconomic status. He purports that income is an indicator of purchasing power and consumption and that assets are an indicator of a person's ability to develop options for improving their quality of life (e.g., participating in poverty alleviation programs). A house is part of a family's assets, although it was not included in the original measurement of assets. Household area indicates how much a person is able to invest in their home and this is why the ICDDR,B collects this information regularly. While the variation of assets and income is quite small, this variable has a much larger variation. The inverse relationship between household area and cholera shows that it is an important factor. The author believes that the environmental part of household area, which is a measure of crowding, and the socioeconomic part of this variable, which describes the socioeconomic status of a family, are inseparable yet both important. However, crowding is more likely to occur in poorer households. Poor people are at a big disadvantage in many other parts of their lives in rural Bangladesh. They are forced to eat food that may be unsanitary because it is cheaper and they may not have the ability to invest in proper water and sanitation facilities. Even if an outside organization is paying for the water and sanitation facilities, poorer people are less likely to have these facilities in their *baris* because they have less social power to influence how these resources

are distributed. It is the belief of the author that poorer people are exposed to diseases at higher rates.

There were several variables that help describe the quality of sanitation in each *bari* but which were not statistically related to cholera hospitalization. They include the number of non-septic, ring septic, and concrete septic latrines, the number of other households using a latrine, and the number of latrines per 100 people. It is unclear why these variables were not related to cholera hospitalization while the number of open latrines was related. There were also two variables that help describe the availability of clean water that were not related to cholera hospitalization. They include the number of tubewells in *baris* and the number of tubewells per 100 people. It is also unclear why these water availability variables were not related while the number of households sharing tubewells was related.

The last continuous variable to be measured was the distance to the main river, which was found not to be related to cholera incidence. It was originally thought that the main river might be a more important environmental reservoir than the other aquatic environments within the study area. However, this was not the case. This finding is consistent with the conclusions made from the disease maps. The disease maps showed that cholera was distributed throughout the study area even at the beginning of the yearly epidemics. Thus, it was concluded that the aquatic reservoir exists throughout the study area and not only near the main rivers.

A multiple, logistic regression model was built using many independent

variables because there may be interaction between several different variables related to cholera hospitalization. Because models were devised only for observations for which there were data for all of the variables, the relationships do not refer to the same sample to which the simple regression models refer. Four of the variables that were significant in simple, logistic regression models were also significant in the multiple, logistic regression model. These were the number of open latrines in a *bari*, the household area, the *bari* population, and flood control.

The risk factors for non-cholera watery diarrhea were somewhat different than the risk factors for cholera. Although some of the significant variables were the same as for cholera, the strengths of the associations were different. Four of the binary dependent variables were significantly associated with non-cholera water diarrhea hospitalization. Female participants were only 0.81 times as likely to be hospitalized with non-cholera watery diarrhea as males. In rural Bangladesh males have more freedom of movement than females, thus they are more likely to come into contact with a larger number of people. Contact with more people may lead to increased exposure to non-cholera, watery diarrhea infected people. Also, rural Bangladesh is full of makeshift tea stalls that sell tea and homemade snacks. Although this research project did not include the collection of tea stall use data, the stalls almost exclusively cater to men and are certainly not sanitary. It is also possible that men with non-cholera watery diarrhea were more likely to report to the hospital.

Participants who did not use tubewell water for drinking were 8.49 times more likely to be hospitalized with non-cholera watery diarrhea than those who did use tubewell water. This extremely high association highlights the importance of clean drinking water for avoiding non-cholera watery diarrhea. There was also a relatively high association between not using tubewell water for bathing and non-cholera watery diarrhea hospitalization. Very few people actually bathe with tubewell water, however, it is not a feasible public health option to change this. It is not feasible since it would require a large educational effort to change the custom of bathing in rivers or ponds. Individuals living in flood-controlled areas were 1.42 times more likely to be hospitalized with non-cholera, watery diarrhea than individuals not living in flood-controlled areas. This was not as strong an association as it was with cholera and it is not entirely clear why there is an association. Future work must be conducted to ascertain the reason for this association and to investigate whether it exists in other flood-controlled areas of Bangladesh.

Several variables concerned with water availability and sanitation were not associated with non-cholera hospitalization. The absence of a working tubewell in the participant's *bari* did not lead to a greater hospitalization rate for non-cholera, watery diarrhea. Defecation in places other than latrines was not associated with hospitalization nor were participants who lived in households without latrines or who had latrines with open drainage systems more likely to be hospitalized with non-cholera watery diarrhea. Participants who shared latrines with other households did not have a greater chance of being hospitalized.

The finding that these water and sanitation variables were not associated with watery diarrheal incidence does not mean that they are not important. The reason why so many water and sanitation variables were collected is because previous research has identified them as important. The strongest association of any water and sanitation variable for non-cholera watery diarrhea was found for tubewell water as a drinking source. Thus, this portion of the issue of overall water and sanitation is most important.

Shellfish consumption, breast-feeding, and malnutrition were not associated with non-cholera watery diarrhea incidence possibly because there was little variation in these variables. None of the ordinal-level variables including education for different household members, household material, or knowledge of diarrhea prevention and source was related to non-cholera watery diarrhea.

Simple regression analysis for continuous variables was also used to calculate risk of non-cholera, watery diarrhea. Household area was inversely related to non-cholera, watery diarrheal hospitalization, as it was with cholera. The two other socioeconomic indicators, assets and income, were not related to non-cholera hospitalization, as was also found to be the case with cholera. In accordance with the non-parametric test, people living in a flood-controlled area were more likely to be hospitalized with non-cholera, watery diarrhea than those not living in a flood-controlled area. There was one biological variable associated with non-cholera, watery diarrhea that was not associated with cholera. The mid-arm circumference was related to non-cholera, watery diarrhea hospitalization at the 95 percent confidence level. A mid-arm circumference of less than 120

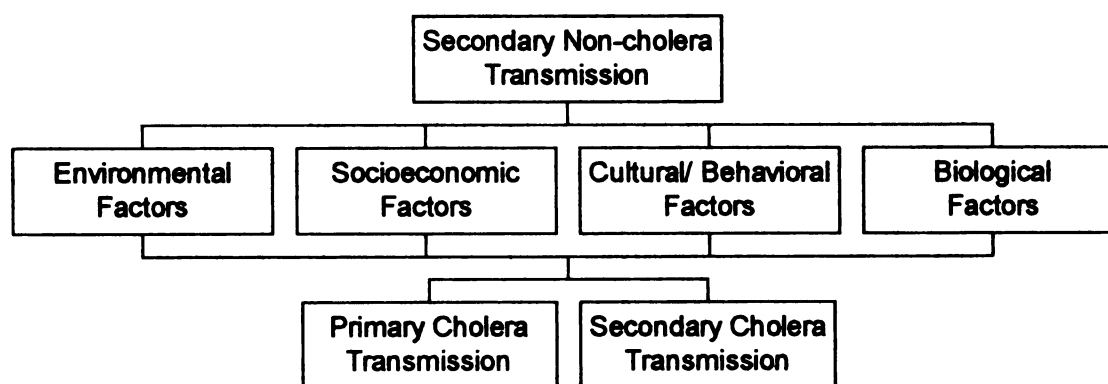
millimeters is considered by the ICDDR,B to indicate malnutrition in children under five years old, in this study population. When stratifying this variable as above 120 and below 120 there was no association. However, there is a relationship with the raw data values. There were not very many observations for this variable (37) and this may explain the absence of an association using the non-parametric test. As discussed in the literature review of this dissertation, there is conflicting information about the effect of malnutrition on diarrheal incidence. More research still needs to be conducted to uncover the answer to this difficult question.

Three variables were significant in a multiple, logistic regression model for non-cholera water diarrhea using variables that were at least moderately significant in the simple regression models. They include the household area, flood control, and tubewell density. Household area was negatively related to non-cholera hospitalization. The smaller the household, the more likely it was that an individual would be hospitalized. As with cholera, people living in flood controlled areas were more likely to be hospitalized with non-cholera, watery diarrhea. Tubewell density was highly significant when built into a multiple, logistic regression model but was only moderately significant in a simple regression model. This indicates that there was interaction with some other variable. As tubewell density increased, non-cholera, watery diarrhea hospitalization decreased. This relationship highlights the importance of clean water availability as a protective barrier to reducing non-cholera hospitalization.

5.3 The disease ecology of cholera and non-cholera watery diarrheal disease

Understanding the disease ecology of cholera and non-cholera watery diarrhea in rural Bangladesh requires an understanding of the multivariate processes that cause humans to be infected with etiological agents as well as an understanding of the spatial and temporal patterns of the diseases. Figure 5.1 is the conceptual model that this study uses to understand the ecology of the two diseases.

Figure 5.1 Conceptual model for understanding the ecology of cholera and non-cholera diarrhea.



Environmental, socioeconomic, cultural/behavioral, and biological factors control whether the disease agents are transmitted to people. Non-cholera agents are only transmitted through secondary fecal-oral transmission. Cholera is transmitted both by primary transmission when people are infected directly by the aquatic reservoir and through secondary transmission when people are infected through fecal-oral transmission. The study could not differentiate between

primary and secondary cholera transmission because the symptoms of cholera victims are exactly the same, no matter how a person is infected. Because primary and secondary transmission cannot be differentiated, understanding this disease ecology of cholera requires a pluralistic methodological approach. Thus, the diseases were mapped and the spatial patterns were analyzed and the temporal patterns were compared. This investigation, in conjunction with Colwell's microbiological study, provides evidence that primary cholera transmission is important.

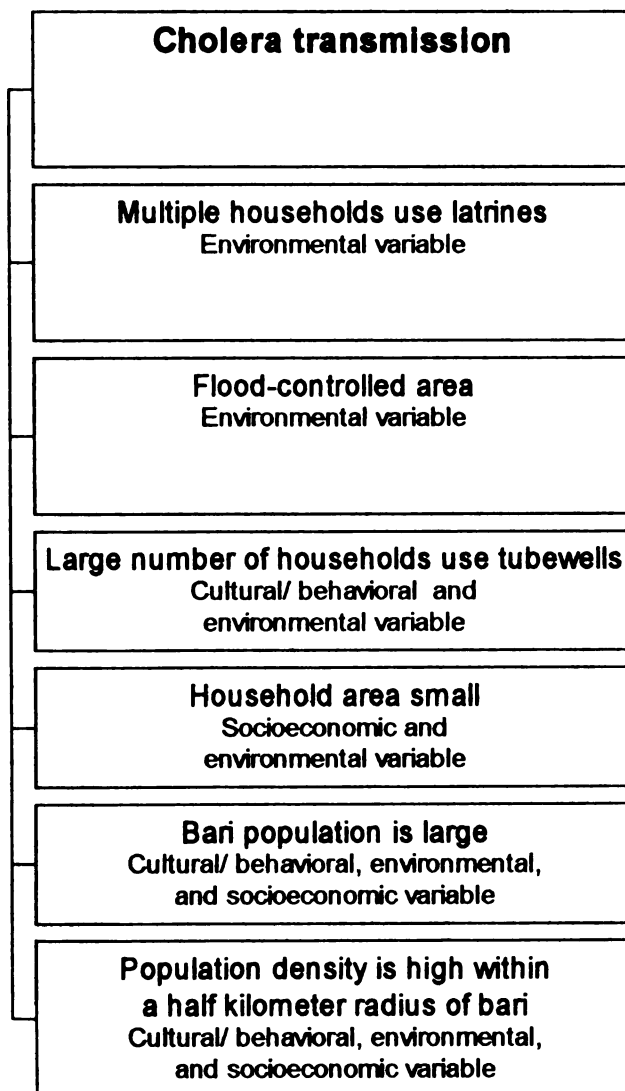
Disease ecology is actually about people interacting with their environment and how this interaction affects their contracting disease. The risk factors described above were found to be statistically associated with hospitalization with the diseases. An understanding of the ecology of disease requires not only a recitation of these statistical associations but also an understanding of the people and their lifestyles. Chapter 1 began to describe the setting in which the study participants live, and the results of the survey highlighted certain information that is thought to be important in the ecology of the diseases. The following section will attempt to describe the ecology of watery diarrheal disease using data collected in this study, information highlighted in the literature that was cited in this dissertation, and by providing anecdotal information about the study area. First, the ecology of cholera is described and then the ecology of non-cholera diarrhea is discussed.

5.3.1 *The disease ecology of cholera*

It is apparent on arrival in rural Bangladesh that the people are always in close contact with the aquatic environment. The aquatic environment is an important source of income for fishers and farmers and it provides the most important system of transportation for people living in the study area. Another readily apparent characteristic of the study area is that there are many people living in a small area and that all land seems to be used for some economic activity. By developing-world standards, it is also clear that almost everyone living in this study area is extremely poor. Figure 5.2 displays the statistically significant risk factors that were found to be important in cholera transmission. Only two variables that describe characteristics of water and sanitation infrastructure or use were related to cholera transmission. Others describe the number of people living in a *bari*, the population density near a *bari*, and the size of a housing structure. The last variable related to cholera transmission is flood control. Secondary cholera transmission is caused by fecal-oral transmission due to the lack of clean water and good sanitation. Thus, it is no surprise that two water and sanitation related variables are associated with cholera. All of the variables not related to water and sanitation have to do with the environmental circumstances in which people are living. Several of these variables show that people living in crowded areas get cholera more often. The last variable that was related to cholera was flood-control. People living inside a flood-controlled area are living in an environment that has been significantly altered by humans. This alteration certainly changes the way people interact with their environment in

these areas. For example, the agricultural system in the flood-controlled area is more reliant on irrigation. It is unclear why there is an association between flood-control and cholera but it may have something to do with how people are interacting with the aquatic environment in this area.

Figure 5.2 Variables involved in cholera transmission

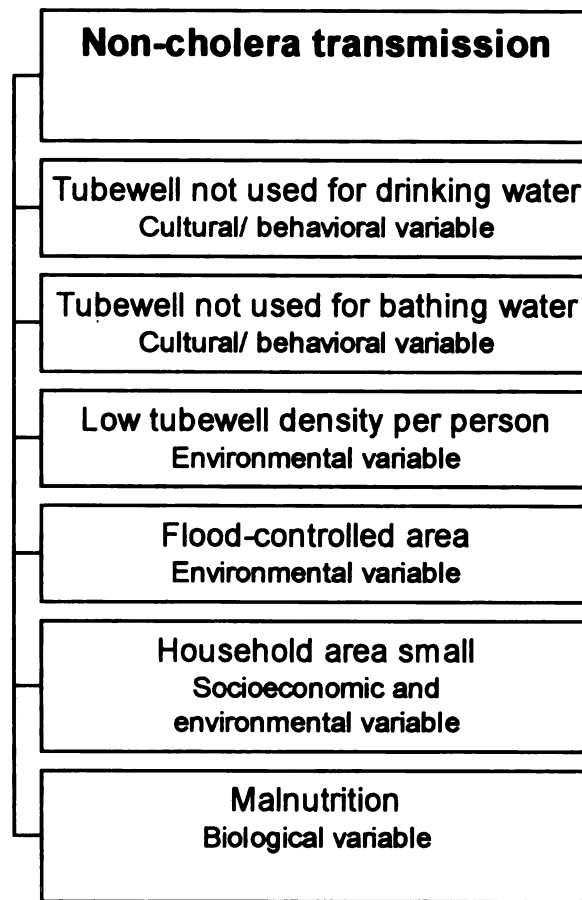


5.3.2 The disease ecology of non-cholera watery diarrheal disease

Non-cholera transmission is exclusively secondary via the fecal-oral route. Fecal-oral transmission means that people are infected when they ingest something that has been contaminated with fecal material. The study area is littered with latrines that hang over water bodies, which are used for bathing, washing cloths, cooking water, and occasionally for drinking water. In such a densely populated area, it is safe to say that the surface water is not fit for drinking. Figure 5.3 displays the factors important to non-cholera watery diarrheal transmission. Three of these variables are associated with tubewell water use. Because there is no water treatment facility in the area, tubewells are the only clean source of water. Other variables associated with non-cholera watery diarrheal transmission include the household area, malnutrition and flood-control. There are many types of variables that predispose people to secondary diarrheal transmission. However, if clean water and sanitary latrines were used then secondary transmission would be much less of a problem.

5.4 Implications for health policy

It is clear that sanitation and water availability and use are extremely important in the effort to reduce secondary cholera and non-cholera, watery diarrhea transmission. While this may seem obvious to many outsiders, health policy makers in Bangladesh and international aid organizations continue to debate whether the appropriate tubewell coverage threshold has been achieved in rural Bangladesh. The water use and availability variables were more

Figure 5.3 Variables involved in non-cholera diarrheal transmission

important for non-cholera watery diarrhea than for cholera but nevertheless they were important for both. With the exception of UNICEF, there has been very little effort to provide septic latrines to the people of rural Bangladesh even though only 10 percent of the study area population had concrete septic latrines. Another debate among health policy makers concerns how to increase latrine coverage. The status quo has been that latrines are usually provided at the expense of the family or community. Since diarrhea is a poor person's disease, however, the people who need proper sanitation most are those who are least

likely to be able to afford it. This research project found significant relationships between sanitation-related variables and cholera but not for non-cholera diarrhea. It is important to note, however, that the sanitation situation in the entire study area was very poor, so comparisons to ideal sanitation conditions could not be made.

One of the socioeconomic status indicators was related to both cholera and non-cholera watery diarrhea and the author suspects that, if compared with a more affluent population, there would be more relationships between socioeconomic variables and the diseases. Socioeconomic status is probably the single most important indirect cause of both of these diseases because poverty is the root cause of many of the other variables, such as lack of sanitation and clean water. The educational level, income, assets, and living environment of the study population are abysmal. The poverty, however, will no doubt continue and these diseases will most likely continue as well. A stronger national and international policy directed at poverty alleviation in rural Bangladesh is necessary to tackle such a difficult problem.

A relationship was found between malnutrition and non-cholera watery diarrhea but not for cholera. There is contradictory information in the health literature concerning the affect of malnutrition on diarrhea. It is obvious, however, that malnutrition is already a health policy concern and thus is already on the health-care agenda.

Flood-control was related to both types of diarrhea but it is not understood why. Since the Bangladesh Flood Action Plan will continue to build and maintain

embankments into the distant future it is very important to investigate whether there is a pattern to this relationship throughout the country and to investigate why the relationship exists. This will no doubt require a multi-disciplinary effort including ecologists, hydrologists, engineers, epidemiologists, and medical geographers.

Health policy makers can use the findings about the spatial and temporal patterns of watery diarrhea to help identify important research issues. Severe, non-cholera, watery diarrhea can be addressed by working on sanitation efforts as well as socioeconomic issues. Cholera, however, is a much more difficult problem. Secondary transmission will decline if water and sanitation, socioeconomic status, and behavioral issues are addressed. Thus, if more money is invested in water and sanitation, secondary transmission will decline. However, primary transmission requires much more research. A large study is presently being conducted (by Rita Colwell and Bradley Sack at the ICDDR,B) to understand the ecology of *Vibrio cholerae* as it relates to the physical environment. This is a five-year project concerned with developing a better understanding of primary cholera transmission. The project will include a spatial component. The GIS database created in conjunction with this study is being used for their project to identify communities at risk for cholera. Satellite imagery will also be used to extract environmental information about this study area. Cholera incidence rates have not declined in the past 30 years because the issue of primary transmission was not properly studied. The author suggests that health policy makers continue to put resources into this type of environmental

project to further our understanding of primary transmission.

5.5 Implications for research

Since the late 1950s, cholera death rates have decreased from approximately 50 percent to almost zero in the Matlab study area. However, cholera incidence has not decreased at all. The reason for the failure of disease prevention is that cholera is an extremely complex disease that is difficult to understand. Analyzing the risk of contracting watery diarrheal disease in Bangladesh requires a conceptual framework that addresses the complexities of biological, socioeconomic, cultural/ behavioral, and environmental factors over time and space. This research project was guided by a medical geographic theoretical approach called disease ecology, which maintains that disease results from a dynamic complex of variables that coincide in time and space. Hunter (1974) argued that geography analyzes human-environmental interactions through time and over space and that studies of disease, "must co-jointly involve pathogen, host, and [a broadly defined] environment" (page 1). The author contends that diarrheal disease will never be fully understood without a holistic approach such as disease ecology.

Mayer (1986) suggested that disease ecologists should differentiate between biological, socioeconomic, behavioral, and environmental variables. Biological variables are those that describe the biological characteristics of the host. The reason that cholera death rates have decreased markedly in the past 30 years is that biological variables are studied in detail and the results of these

studies have improved treatment. Oral rehydration solution (ORS) was developed to counteract severe dehydration, which is what kills cholera victims. The author contends that biological variables are overemphasized in health research in a way that reduces our understanding of the socioeconomic, cultural/behavioral, and environmental variables responsible for diarrheal transmission.

Several of the risk factors found in this research effort have been found in other studies that were discussed in the literature review. In the case of clean water and sanitation, the rural infrastructure for these services remains primitive. Why this situation exists is an extremely difficult question to answer but is probably one of the most important concepts for understanding this disease. By any account, Bangladesh is dismally poor and the government has few resources to allot to this health effort. Most of the tubewells and septic latrines in the study area have been paid for by humanitarian organizations such as UNICEF. However, resources allotted to solve this problem are not even close to sufficient. Understanding the political and economic context is necessary to explain the disease ecology of a particular disease. The Bangladesh government has been implementing the multi-billion-dollar Flood Action Plan with loans and aid from the World Bank, the Asian Development Bank, and many foreign governments. One must understand the politics of international aid to understand why an investment in flood-control was deemed more important than water and sanitation. This study attempts to provide a holistic understanding of the disease ecology of watery diarrhea in rural Bangladesh by using a pluralistic methodology. Future research will expand on the holistic nature of this study by

including political and economic information.

APPENDICES

APPENDIX 1

Appendix 1: Description of independent variable measurement methods.

Chapter 3 summarized each of the independent variables that are hypothesized to be potential risk factors for watery diarrhea. This appendix describes how each of the independent variables was measured and/or calculated in detail. The discussion begins with a description of categorical variables with two classes, followed by the categorical variables with more than two classes, and finally the continuous variables.

Summary of categorical independent variables with two classes.

Variable	Variable Type	Description
Gender	Cultural/behavioral and biological	Male or female
Source of drinking water	Cultural/behavioral	Tubewell or other
Source of cooking water	Cultural/behavioral	Tubewell or other
Source of bathing water	Cultural/behavioral	Tubewell or other
Source of washing water	Cultural/behavioral	Tubewell or other
Working tubewell in bari	Environmental	Yes or no
Adult male defecation	Cultural/behavioral	Latrine or other
Adult female defecation	Cultural/behavioral	Latrine or other
Male child defecation	Cultural/behavioral	Latrine or other
Female child defecation	Cultural/behavioral	Latrine or other
Presence of latrine in household	Environmental	Yes or no
Type of latrine drainage	Environmental	Septic or not
# of households using a latrine	Environmental	Single or multiple
Consumption of shellfish	Cultural/behavioral	Yes or no
Flood controlled area	Environmental	Yes or no
Breast feeding status of children<5	Biological	Yes or no
Nutritional status of children < 5	Biological	Malnourished or not

- Gender of participant (Cultural/behavioral and biological). For cholera and non-cholera watery diarrhea the gender of the participant was taken from therapy sheets which are part of the hospital records. Therapy sheets are forms that doctors fill in when treating a patient. For the control group, the gender was determined from demographic surveillance system records. The

gender was determined from demographic surveillance system records. The gender is either male or female.

- Source of drinking water (Cultural/behavioral). The questionnaire determined whether or not tubewell water was a participant's regular source of drinking water.
- Source of cooking water (Cultural/behavioral). The questionnaire determined whether or not tubewell water was a participant's regular source for cooking water.
- Source of bathing water (Cultural/behavioral). The questionnaire determined whether or not tubewell water was a participant's regular source for bathing water.
- Source of washing water (Cultural/behavioral). The questionnaire determined whether or not tubewell water was a participant's regular source for washing water.
- Working tubewell in *bari* (Environmental). The questionnaire determined whether or not there was a working tubewell in each *bari*.
- Adult male defecation (Cultural/behavioral). The questionnaire determined whether or not the adult males in the participant's family regularly defecate in a latrine.
- Adult female defecation (Cultural/behavioral). The questionnaire determined whether or not the adult females in the participant's family regularly defecate in a latrine.
- Male child defecation (Cultural/behavioral). The questionnaire determined whether or not the male children in the participant's family regularly defecate in a latrine.

- **Female child defecation (Cultural/behavioral).** The questionnaire determined whether or not the female children in the participant's family regularly defecate in a latrine.
- **Presence of latrine in household (Environmental).** The household-level latrine and tubewell survey results were used to determine whether there was a latrine in each household.
- **Type of latrine drainage (Environmental).** The household-level latrine and tubewell survey results were used to determine whether household latrines were septic or not.
- **Consumption of shellfish (Cultural/behavioral).** The questionnaire determined whether or not participants consume shellfish. The questionnaire asked whether or not people consume shellfish and if so how many times per month. However, the number of times per month that people consumed shellfish varied little. Thus, this information was analyzed as a binary variable. People either consumed shellfish or did not.
- **Flood controlled area (Environmental).** In the mid-1980s, a major flood control program was implemented in part of Matlab. An enclosed embankment (polder) protects part of the study area from flooding, while the area outside the embankment remains unprotected. This study determined whether each *bari* is inside or outside the embankment using the GIS.
- **Breast feeding status of children under 5 (Biological).** ICDDR,B community health workers regularly record the breast feeding status of all children under five years old. Children who had been breast fed for the previous month before being hospitalized were classified as breast fed. If there had been no breast-feeding for the month prior to hospitalization, then they were classified as not breast fed. The breast-feeding status of controls was determined by

considering whether the individual had been breast fed the month before hospitalization of the control's corresponding age-matched case.

- **Nutritional status of children under 5 (Biological).** If a participant had a mid-arm circumference of 120 millimeters or below, then the individual was considered malnourished. If it was above 120 millimeters then the individual was considered not malnourished.

Summary of categorical independent variables with more than two classes.

Variable	Variable Type	Description
Years of education: adult (>15) participant	Socioeconomic	More than six; one to six; none
Years of education: mother	Socioeconomic	More than six; one to six; none
Years of education: father	Socioeconomic	More than six; one to six; none
Knowledge of prevention of diarrhea	Cultural/behavioral	Full; good; partial; none
Knowledge of source of diarrhea	Cultural/behavioral	Good; partial; none
Household construction material	Socioeconomic	Brick,/tin; bamboo/tin; jute/ tin; straw/stick/ bamboo

- **Years of education: participant (Socioeconomic).** The number of years of education of the adult (>15) participant was collected in the questionnaire and classified into the three levels shown in the table.
- **Years of education: mother (Socioeconomic).** The number of years of education of the participant's mother was collected in the questionnaire and classified into the three levels shown in the table.
- **Years of education: father (Socioeconomic).** The number of years of education of the father was collected in the questionnaire and classified into the three levels shown in the table.
- **Knowledge of prevention and source of diarrhea (Cultural/behavioral).** Data about the participant's perceptions of diarrheal transmission were collected in the questionnaire.

- **Household Material (Socioeconomic).** The community health workers regularly collect data on the household construction material.

Summary of continuous independent variables.

Variable	Variable Type	Description
Number of open latrines	Environmental	Count
Number of non-septic latrines	Environmental	Count
Number of ring septic latrines	Environmental	Count
Number of concrete septic latrines	Environmental	Count
Number of other households using latrines	Cultural/behavioral and environmental	Count
Latrines per person (excluding open)	Environmental	Latrines per 100 people
Number of tubewells in bari	Environmental	Count
Number of households sharing a common tubewell in bari	Cultural/behavioral and environmental	Count
Available tubewells per person	Environmental	Tubewells per 100 people
Household area (sq. ft.)	Socioeconomic and environmental	Square feet
Bari population	Cultural/behavioral, environmental, and socioeconomic	Count
Population density around baris	Cultural/behavioral, environmental, and socioeconomic	Persons within half kilometer radius
Total household assets	Socioeconomic	Taka
Annual income	Socioeconomic	Taka
Mid-arm circumference (children under 5 years old)	Biological	Millimeters
Distance from main river	Environmental	Meters

- **Number of open latrines (Environmental).** The household-level latrine and tubewell survey results were used to determine the number of open latrines in study *baris*.
- **Number of non-septic latrines (Environmental).** The household-level latrine and tubewell survey results were used to determine the number of non-septic latrines in study *baris*.
- **Number of ring septic latrines (Environmental).** The household-level latrine and tubewell survey results were used to determine the number of ring latrines with septic tanks in study *baris*.

- **Number of concrete septic latrines (Environmental).** The household-level latrine and tubewell survey results were used to determine the number of concrete septic latrines in study *baris*.
- **Number of other households using latrines (Cultural/ behavioral and environmental).** The household-level latrine and tubewell survey results were used to determine the number of households sharing latrines.
- **Latrines per person excluding open (Environmental).** The number of latrines per 100 people was calculated. The household-level latrine and tubewell survey results were used to determine the number of all latrines except for open latrines (numerator). The number of people was determined from demographic surveillance system records (denominator). This ratio was then multiplied by 100. Since the three types of latrines included in the numerator are closed, they represent increased sanitation.
- **Number of tubewells in *bari* (Environmental).** The household-level latrine and tubewell survey results were used to determine the number of tubewells in study *baris*.
- **Number of households sharing a common tubewell in *bari* (Cultural/ behavioral and environmental).** The household-level latrine and tubewell survey results were used to determine the number of households sharing tubewells.
- **Tubewells per person (Environmental).** The number of tubewells per 100 people was calculated. The household-level latrine and tubewell survey results were used to determine the number of tubewells (numerator). The number of people was determined from demographic surveillance system records (denominator). This ratio was then multiplied by 100.

- Household area (square feet) (Socioeconomic and environmental). The community health workers regularly collect data on the household area in square feet.
- *Bari* population (Cultural/ behavioral, environmental, and socioeconomic). The *bari* population was determined from demographic surveillance system records.
- Population density around *baris* (Cultural/ behavioral, environmental, and socioeconomic). The GIS database and the *bari* populations derived from the demographic surveillance system records were used to calculate the total number of people living within a half kilometer radius of each *bari*.
- Total assets (Socioeconomic). The total assets were calculated by adding the value of all household land, livestock, and household items that were collected in the questionnaire. One of the questionnaire enumerators went to the Matlab market to determine the price of the following items used in the calculations.
 - a) Quilt = 200 taka
 - b) Bicycle = 2000 taka
 - c) Radio = 500 taka
 - d) Lamp = 20 taka
 - e) Lantern = 50 taka
 - f) Watch = 500 taka
 - g) Boat = 1000 taka
 - h) Land = 300 taka per decimal
 - i) Cow = 5000 taka
 - j) Goat = 1000 taka
 - k) Chicken = 50 taka
- Annual income (Socioeconomic). The total participant family's annual cash income was collected in the questionnaire.
- Mid-arm circumference for children under five (Biological). ICDDR,B community health workers regularly record the mid-arm circumference of all

children under five years old. For children with watery diarrhea, the mid-arm circumference in millimeters was recorded the month before hospitalization. The mid-arm circumference of controls was determined the month before hospitalization of the control's corresponding age-matched case.

- Distance from main rivers (Environmental). Using the GIS database the distance of each *bari* from the closest main river (Meghna or Dhonogoda) was calculated.

APPENDIX 2

Appendix 2: English translation of questionnaire and consent form.

1) CID _____

2) RID _____

3) Bari ID _____

4) What source of water do you regularly use for drinking? _____

1 = river	2 = canal	3 = tank
4 = ditch	5 = tubewell	6 = other (specify)
9 = unknown		

5) What source of water do you regularly use for cooking? _____

1 = river	2 = canal	3 = tank
4 = ditch	5 = tubewell	6 = other (specify)
9 = unknown		

6) What source of water do you regularly use for bathing? _____

1 = river	2 = canal	3 = tank
4 = ditch	5 = tubewell	6 = other (specify)
9 = unknown		

7) What water source do you regularly use for washing cooking utensils? _____

1 = river	2 = canal	3 = tank
4 = ditch	5 = tubewell	6 = other (specify)
9 = unknown		

8) Is there a tubewell in your bari? (1 = yes; 2 = no) _____

9) Is the tubewell in working condition? (1 = yes; 2 = no)

10) With how many households do you share the tubewell ? _____

11) If you do not have a tubewell in your bari do you use tubewell water from another bari (note bari identification number)? _____

12) How often do you use tubewell water for drinking? _____

1 = always	2 = usually	3 = sometimes
4 = seldom	5 = never	

13) How often do you use river water for drinking? _____

1 = always	2 = usually	3 = sometimes
4 = seldom	5 = never	

- 14) How often do you use canal water for drinking? _____
 1 = always 2 = usually 3 = sometimes
 4 = seldom 5 = never
- 15) How often do you use tank water for drinking? _____
 1 = always 2 = usually 3 = sometimes
 4 = seldom 5 = never
- 16) How often do you use tubewell water for cooking? _____
 1 = always 2 = usually 3 = sometimes
 4 = seldom 5 = never
- 17) How often do you use river water for cooking? _____
 1 = always 2 = usually 3 = sometimes
 4 = seldom 5 = never
- 18) How often do you use canal water for cooking? _____
 1 = always 2 = usually 3 = sometimes
 4 = seldom 5 = never
- 19) How often do you use tank water for cooking? _____
 1 = always 2 = usually 3 = sometimes
 4 = seldom 5 = never
- 20) How often do you use tubewell water for bathing? _____
 1 = always 2 = usually 3 = sometimes
 4 = seldom 5 = never
- 21) How often do you use river water for bathing? _____
 1 = always 2 = usually 3 = sometimes
 4 = seldom 5 = never
- 22) How often do you use canal water for bathing? _____
 1 = always 2 = usually 3 = sometimes
 4 = seldom 5 = never
- 23) How often do you use tank water for bathing? _____
 1 = always 2 = usually 3 = sometimes
 4 = seldom 5 = never
- 24) Where do the adult males of your family regularly defecate? _____
 1 = latrine 2 = fixed site that is not a latrine 3 = field
 4 = courtyard 5 = no fixed site 6 = other (specify)

25) Where do the adult females of your family regularly defecate? _____

- 1 = latrine 2 = fixed site that is not a latrine 3 = field
4 = courtyard 5 = no fixed site 6 = other (specify)

26) Where do the male children of your family regularly defecate? _____

- 1 = latrine 2 = fixed site that is not a latrine 3 = field
4 = courtyard 5 = no fixed site 6 = other (specify)

27) Where do the female children of your family regularly defecate? _____

- 1 = latrine 2 = fixed site that is not a latrine 3 = field
4 = courtyard 5 = no fixed site 6 = other (specify)

28) Do you have a latrine in your household? (1 = yes; 2 = no) _____

29) What kind of drainage does the latrine have (by observation if possible)? _____

- 1 = open to river 2 = open to pond 3 = open to ditch
4 = open to field 5 = pit without septic 6 = pit with septic

30) Is the latrine shared with another/other household(s)? (1 = yes; 2 = no) _____

31) If yes then what is/are the family number(s) of that/those household(s)? _____

32) How often do the adult male members of your family defecate in a latrine? _____

- 1 = always 2 = usually 3 = sometimes
4 = seldom 5 = never

33) How often do the adult female members of your family defecate in a latrine? _____

- 1 = always 2 = usually 3 = sometimes
4 = seldom 5 = never

34) How often do the children of your family defecate in a latrine? _____

- 1 = always 2 = usually 3 = sometimes
4 = seldom 5 = never

35) Does your family consume shellfish? (1 = yes; 2 = no) _____

36) If yes, then how often (times per month)? _____

37) For how many years has the study participant been educated? _____

38) In what type of educational institution has the participant been educated? _____

- 0 = unknown 1 = secular
2 = madrasha 3 = maktab

39) For how many years has the study participant's mother been educated?

40) For how many years has the study participant's father been educated?

41) What is the occupation of the participant? _____

- | | |
|---------------------------|-------------------------------|
| 01 = landowner/ worker | 02 = landowner/ does not work |
| 03 = rent land/share crop | 04 = catches fish |
| 05 = sell fish | 06 = rent fishing equipment |
| 07 = agricultural labor | 08 = domestic labor |
| 09 = mill worker | 10 = unskilled labor |
| 11 = skilled labor | 12 = boatman |
| 13 = cottage industry | 14 = unskilled service |
| 15 = skilled service | 16 = businessman |
| 17 = beggar | 18 = student |
| 19 = disabled | 20 = unemployed |
| 21 = housewife | 22 = unknown |
| 23 = other (specify) | |

42) What is the occupation of the participant's father? _____

- | | |
|---------------------------|-------------------------------|
| 01 = landowner/ worker | 02 = landowner/ does not work |
| 03 = rent land/share crop | 04 = catches fish |
| 05 = sell fish | 06 = rent fishing equipment |
| 07 = agricultural labor | 08 = domestic labor |
| 09 = mill worker | 10 = unskilled labor |
| 11 = skilled labor | 12 = boatman |
| 13 = cottage industry | 14 = unskilled service |
| 15 = skilled service | 16 = businessman |
| 17 = beggar | 18 = student |
| 19 = disabled | 20 = unemployed |
| 21 = housewife | 22 = unknown |
| 23 = other (specify) | |

43) What is the occupation of the participant's mother? _____

- | | |
|---------------------------|-------------------------------|
| 01 = landowner/ worker | 02 = landowner/ does not work |
| 03 = rent land/share crop | 04 = catches fish |
| 05 = sell fish | 06 = rent fishing equipment |
| 07 = agricultural labor | 08 = domestic labor |
| 09 = mill worker | 10 = unskilled labor |
| 11 = skilled labor | 12 = boatman |
| 13 = cottage industry | 14 = unskilled service |
| 15 = skilled service | 16 = businessman |
| 17 = beggar | 18 = student |
| 19 = disabled | 20 = unemployed |
| 21 = housewife | 22 = unknown |
| 23 = other (specify) | |

44) What do you think causes diarrhea? _____

- 1 = microorganisms 2 = unknown 3 = other (specify)

45) What can you do to prevent diarrhea? _____

- 1 = wash hands
2 = drink tubewell water
3 = bath in clean water source
4 = other (specify)

46) What is the source of diarrhea? _____

- 1 = water
2 = fish
3 = food
4 = other (specify)

47) How many of each of the following household articles do you own?

- | | |
|-----------------------|---------------------------------------|
| a) quilt _____ | e) hurricane (kerosene lantern) _____ |
| b) bicycle _____ | f) watch _____ |
| c) radio _____ | g) remittance _____ |
| d) lamp (quiet) _____ | h) other (specify) _____ |

48) How many boats do you own? _____

49) How much land do you own? (in decimals) _____

50) How much of your farm land is (insert each of the following)? (in decimals)

- a) self cultivated _____
b) rented out _____
c) share cropped _____
d) other (specify) _____

51) How many cows do you own? _____

52) How many goats do you own? _____

53) How many chickens do you own? _____

54) What is your cash income? (annual) _____

55) If the participant migrated out of the study area, in what month and year did he/she migrate? _____ (This question should be asked of neighbor or family member. Please specify who answered questions 55 and 56. _____)

56) If they migrated out of the study area then why?

CONSENT FORM

The International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B) is conducting a study on watery diarrhoea. We are trying to determine which factors are involved in the occurrence of the disease in your community.

For that purpose we need to ask you several questions related to your environment, customs and your health status. To collect information on these matters, we would ask you a few questions through a questionnaire and the process will take about half an hour. We are inviting you to participate in this study. You may refrain from answering any question if you wish.

By interviewing you we expect to learn more about diarrhoeal disease and find new ways for its prevention.

The information that you would give us will be kept confidential and none except the principal investigator will know the information. You and your family members would continue to get the best service from the Matlab Cholera Hospital even if you do not participate in this study.

If you agree to participate, please sign your name below, or give your left thumb impression.

Signature of the Principal
Investigator

Signature or left
thumb impression of
The interviewee

Date _____

Date _____

APPENDIX 3

Bengali questionnaire and consent form.

প্রশ্নপত্র

১) CID _____

২) RID _____

৩) Bari ID _____

৪) আপনি খাওয়ার পানি সবসময় কোথা থেকে যোগাড় করে থাকেন? _____

- | | | |
|------------|---------------|-------------------------------|
| ১ = নদী | ২ = খাল | ৩ = পুকুর |
| ৪ = ডোবা | ৫ = টিউবওয়েল | ৬ = অন্য যায়গা (উল্লেখ করেন) |
| ৯ = জানিনা | | |

৫) রান্না-বান্নার জন্য সবসময় কোন যায়গার পানি আপনি ব্যবহার করে থাকেন? _____

- | | | |
|------------|---------------|-------------------------------|
| ১ = নদী | ২ = খাল | ৩ = পুকুর |
| ৪ = ডোবা | ৫ = টিউবওয়েল | ৬ = অন্য যায়গা (উল্লেখ করেন) |
| ৯ = জানিনা | | |

৬) গোসল করার জন্য সবসময় কোন যায়গার পানি আপনি ব্যবহার করে থাকেন? _____

- | | | |
|------------|---------------|-------------------------------|
| ১ = নদী | ২ = খাল | ৩ = পুকুর |
| ৪ = ডোবা | ৫ = টিউবওয়েল | ৬ = অন্য যায়গা (উল্লেখ করেন) |
| ৯ = জানিনা | | |

৭) রান্না-বান্নার বাসন-কোসন ধোয়ার জন্য সবসময় আপনি কোন যায়গার পানি ব্যবহার করে থাকেন? _____

- | | | |
|------------|---------------|-------------------------------|
| ১ = নদী | ২ = খাল | ৩ = পুকুর |
| ৪ = ডোবা | ৫ = টিউবওয়েল | ৬ = অন্য যায়গা (উল্লেখ করেন) |
| ৯ = জানিনা | | |

৮) আপনার বাড়ীতে কি কোন টিউবওয়েল আছে? (১ = হ্যাঁ; ২ = না) _____

৯) টিউবওয়েলটি দিয়ে কি পানি তোলা যায়? (১ = হ্যাঁ; ২ = না) _____

১০) আর কোন কোন বাড়ীর লোকজন টিউবওয়েলটি ব্যবহার করেন (FID দের লিষ্ট লিখুন)? _____

১১) আপনার বাড়ীতে যদি টিউবওয়েল না থাকে তবে আপনি কি অন্য বাড়ীর টিউবওয়েল থেকে পানি এনে ব্যবহার করে থাকেন (BID উল্লেখ করেন) ?

১২) আপনার বাড়ীর বয়স্ক পুরুষরা প্রত্যেক দিন কোন যায়গায় পায়খানা করেন ?

১ = লেট্রিন ২ = নির্দিষ্ট একটি যায়গায় (যেটি লেট্রিন না)
৩ = মাঠে ৪ = উঠানে ৫ = কোন ঠিক নাই
৬ = অন্য যায়গায় (উল্লেখ করেন)

১৩) আপনার বাড়ীর বয়স্ক মেয়েরা প্রত্যেক দিন কোন যায়গায় পায়খানা করেন?

১ = লেট্রিন ২ = নির্দিষ্ট একটি যায়গায় (যেটি লেট্রিন না)
৩ = মাঠে ৪ = উঠানে ৫ = কোন ঠিক নাই
৬ = অন্য যায়গায় (উল্লেখ করেন)

১৪) আপনার বাড়ীর বাচ্চা ছেলেরা প্রত্যেক দিন কোন যায়গায় পায়খানা করে ?

১ = লেট্রিন ২ = নির্দিষ্ট একটি যায়গায় (যেটি লেট্রিন না)
৩ = মাঠে ৪ = উঠানে ৫ = কোন ঠিক নাই
৬ = অন্য যায়গায় (উল্লেখ করেন)

১৫) আপনার বাড়ীর বাচ্চা মেয়েরা প্রত্যেক দিন কোন যায়গায় পায়খানা করে ?

১ = লেট্রিন ২ = নির্দিষ্ট একটি যায়গায় (যেটি লেট্রিন না)
৩ = মাঠে ৪ = উঠানে ৫ = কোন ঠিক নাই
৬ = অন্য যায়গায় (উল্লেখ করেন)

১৬) আপনার বাড়ীতে কি কোন লেট্রিন আছে ? (১=হ্যাঁ; ২=না)

১৭) লেট্রিনের ময়লা কোথায় গিয়ে পড়ে (সম্ভব হলে নিজে গিয়ে দেখুন)?

১ = নদীতে ২ = পুকুরে ৩ = গর্তে
৪ = মাঠে ৫ = ঢাকনা ছাড়া পিটে ৬ = ঢাকনা দেওয়া পিটে

১৮) অন্য/অন্যান্য বাড়ীর লোকজন কি এই/একই লেট্রিন ব্যবহার করে থাকে? (১ = হ্যাঁ; ২ = না)

১৯) যদি 'হাঁ' হয় তবে ঐ বাড়ীর/ঐ সব বাড়ীর কতজন লোক এই/একই লেট্রিন ব্যবহার করে থাকে ? _____

২০) আপনার পরিবারের লোকজন কি কাঁকড়া/চিংড়ী মাছ খায়?
(১=হাঁ; ২=না) _____

২১) যদি 'হাঁ' হয় তবে, মাসে কতবার খায় ? _____

২২) এই গবেষণায় যিনি অংশ গ্রহন করছেন তিনি কতটুকু পড়ালেখা করেছেন? _____

২৩) কোথায় তিনি পড়ালেখা করেছেন? _____

০ = জানিনা ১ = স্কুলে
২ = মাদ্রাসায় ৩ = মস্তবে

২৪) এই গবেষণায় যিনি অংশ গ্রহন করছেন তাঁর মা কতটুকু পড়ালেখা করেছেন ? _____

২৫) এই গবেষণায় যিনি অংশ গ্রহন করছেন তাঁর বাবা কতটুকু পড়ালেখা করেছেন ? _____

২৬) উত্তরদাতার পেশা কি ? _____

০১ = জমির মালিক/শ্রমিক	০২ = জমির মালিক/কাজ করেন না
০৩ = বর্গা চাষী	০৪ = জেলে
০৫ = মাছ ব্যবসায়ী	০৬ = মাছ ধরার জিনিষপত্র ভাড়া দেয়
০৭ = কৃষি মজুর	০৮ = গৃহ শ্রমিক
০৯ = মিলের শ্রমিক	১০ = অদক্ষ শ্রমিক
১১ = দক্ষ শ্রমিক	১২ = মাঝি
১৩ = কুটির শিল্প	১৪ = অদক্ষ চাকুরী
১৫ = দক্ষ চাকুরী	১৬ = ব্যবসায়ী
১৭ = ভিক্ষুক	১৮ = ছাত্র
১৯ = অক্ষম	২০ = বেকার
২১ = গৃহবধু	২২ = জানিনা
২৩ = অন্য পেশা(উল্লেখ করেন)	

২৭) উত্তরদাতার বাবার পেশা কি ?

- | | |
|-------------------------|------------------------------------|
| ০১ = জমির মালিক/শ্রমিক | ০২ = জমির মালিক/কাজ করেন না |
| ০৩ = বর্গা চাষী | ০৪ = জেলে |
| ০৫ = মাছ ব্যবসায়ী | ০৬ = মাছ ধরার জিনিষপত্র ভাড়া দেয় |
| ০৭ = কৃষি মজুর | ০৮ = গৃহ শ্রমিক |
| ০৯ = মিলের শ্রমিক | ১০ = অদক্ষ শ্রমিক |
| ১১ = দক্ষ শ্রমিক | ১২ = মাঝি |
| ১৩ = কুটির শিল্প | ১৪ = অদক্ষ চাকুরী |
| ১৫ = দক্ষ চাকুরী | ১৬ = ব্যবসায়ী |
| ১৭ = ডিক্কুক | ১৮ = ছাত্র |
| ১৯ = অক্ষম | ২০ = বেকার |
| ২১ = গৃহ বধু | ২২ = জানিনা |
| ২৩ = অন্য (উল্লেখ করেন) | |

২৮) উত্তরদাতার মায়ের পেশা কি ?

- | | |
|-----------------------------|------------------------------------|
| ০১ = জমির মালিক/শ্রমিক | ০২ = জমির মালিক/কাজ করেন না |
| ০৩ = বর্গা চাষী | ০৪ = জেলে |
| ০৫ = মাছ ব্যবসায়ী | ০৬ = মাছ ধরার জিনিষপত্র ভাড়া দেয় |
| ০৭ = কৃষি মজুর | ০৮ = গৃহ শ্রমিক |
| ০৯ = মিলের শ্রমিক | ১০ = অদক্ষ শ্রমিক |
| ১১ = দক্ষ শ্রমিক | ১২ = মাঝি |
| ১৩ = কুটির শিল্প | ১৪ = অদক্ষ চাকুরী |
| ১৫ = দক্ষ চাকুরী | ১৬ = ব্যবসায়ী |
| ১৭ = ডিক্কুক | ১৮ = ছাত্র |
| ১৯ = অক্ষম | ২০ = বেকার |
| ২১ = গৃহ বধু | ২২ = জানিনা |
| ২৩ = অন্য পেশা(উল্লেখ করেন) | |

২৯) আপনার মতে কি কারনে ডায়রিয়া রোগ হয় ? _____

- ১ = এক রকম জীবাণুর কারনে ২ = জানিনা
৩ = অন্য কারন (উল্লেখ করেন)

৩০) ডায়রিয়া রোগ যাতে না হয় সেজন্য আপনার কি করা উচিত ? _____

- ১ = সব সময় হাত ধোয়া উচিত ২ = টিউবওয়েলের পানি খাওয়া উচিত
৩ = পরিষ্কার পানিতে গোসল করা উচিত
৪ = অন্যভাবে সাবধান হওয়া উচিত (উল্লেখ করেন)

৩১) বলতে পারেন কিসের মাধ্যমে ডায়রিয়া রোগ হতে পারে? _____

- ১ = পানি থেকে ২ = মাছ থেকে
৩ = খাবার জিনিষ থেকে ৪ = অন্য জিনিষ থেকে

৩২) খানায় আপনার নিজের কি কি জিনিষপত্র আছে? _____

- ১ = কসল ২ = হারিকেন (কেরোসিন)
 ৩ = সাইকেল ৪ = ষড়ি
 ৫ = রেডিও ৬ = টাকা পয়সা (বিদেশ থেকে পাঠানো)
 ৭ = বাতি (কুপি) ৮ = অন্য জিনিষপত্র (উল্লেখ করেন)

৩৩) আপনার নিজের কয়টি নৌকা আছে? _____

৩৪) আপনার নিজস্ব কতটুকু জমি-জমা আছে? (ডেসিমেনে) _____

৩৫) আপনি কিভাবে আপনার নিজের জমি-জমা চাষাবাদ করেন? _____

- ১ = নিজে চাষ করেন ২ = ভাড়া দেন
 ৩ = বর্গা দিয়েছেন ৪ = জানিনা

৩৬) আপনার কয়টি গরু আছে? _____

৩৭) আপনার কয়টি ছাগল আছে? _____

৩৮) আপনার কয়টি মোরগ-মুরগী আছে? _____

৩৯) আপনি নগদ কত রুজী/আয় করে থাকেন? (বছরে) _____

৪০) যে এলাকায় এই গবেষণা কাজ চলছে উত্তরদাতা যদি সেখান থেকে অন্য যায়গায় চলে গিয়ে থাকেন তবে, তিনি কোন মাসে এবং কোন বছর সেখানে চলে গেছেন? _____ (এই প্রশ্ন প্রতিবেশীকে বা পরিবারের কোন সদস্যকে জিজ্ঞেস করেন। যিনি ৪০ ও ৪১ নং প্রশ্নের উত্তর দিচ্ছেন তার পরিচয় দয়া করে উল্লেখ করবেন _____)

৪১) তারা যদি এই গবেষণা এলাকা থেকে অন্য যায়গায় চলে গিয়ে থাকেন তবে, কি জন্য/কারণে সেখানে চলে গেছেন? _____

সম্মতিপত্র

আন্তর্জাতিক উদরাময় গবেষণা কেন্দ্র, বাংলাদেশ, পানির মত পাতলা পায়খানার (ডায়রিয়া) উপর একটি গবেষণা পরিচালনা করিতে যাইতেছে। আমরা খুজিয়া বাহির করিতে চেষ্টা করিতেছি আপনার সমাজে এই রোগের কারণ কি কি ?

এই উদ্দেশ্যে আপনার পরিবেশ, সামাজিক প্রথা ও চাল-চলন এবং আপনার স্বাস্থ্য সম্পর্কিত কিছু তথ্য আমাদের জানা প্রয়োজন। তথ্যগুলি জানার জন্য একটি প্রশ্নমালার মাধ্যমে আপনাকে কিছু প্রশ্ন করিতে চাই এবং এইজন্য আশ্বস্তার মত সময় লাগিবে। এই গবেষণায় অংশগ্রহন করিবার জন্য আপনাকে আমরা আমন্ত্রন জানাইতেছি। আপনি ইচ্ছা করিলে যে কোন প্রশ্নের উত্তর দিতে অস্বীকার করিতে পারিবেন।

আমরা আশা করি প্রশ্নগুলির মাধ্যমে আমরা ডায়রিয়া রোগ সম্পর্কে আরো অনেক তথ্য জানিতে পারিব এবং এই রোগ প্রতিরোধ করার নতুন উপায় খুজিয়া পাইব।

আপনি যে সকল তথ্য আমাদের দিবেন সেগুলি গোপন রাখা হইবে এবং প্রধান গবেষক ছাড়া আর কেহই তা জানিতে পারিবেন না। এই গবেষণায় আপনি অংশগ্রহন না করিলেও মতলব কলেরা হাসপাতালে আপনি ও আপনার পরিবারের সকল সদস্য সর্বোত্তম চিকিৎসা সেবা পাইবেন।

যদি আপনি এই গবেষণায় অংশগ্রহন করিতে রাজী থাকেন তবে দয়া করিয়া নিম্নে আপনার দস্তখত অথবা বৃদ্ধাঙ্গুলির ছাপ দিন।

গবেষকের স্বাক্ষর
তারিখ: _____

উত্তরদাতার স্বাক্ষর বা
বাম বৃদ্ধাঙ্গুলির ছাপ ও নাম :
তারিখ: _____

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