Outbreak of *E. coli* O157 Infections at a Summer Camp Facility —Virginia, 2008

Final Report

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Abstract

Background: *Escherichia coli* O157:H7 (*E. coli* O157) accounts for 73,000 infections annually in the United States. Children are more likely to experience severe complications, such as hemolytic uremic syndrome. In July 2008, the Virginia Department of Health investigated an *E. coli* O157 outbreak at a summer camp facility to identify the source and prevent additional illness.
Methods: We conducted a retrospective cohort study, environmental inspections, and laboratory analysis of stool specimens, leftover food, and environmental samples. A case was defined as illness in a person visiting the summer camp facility July 20–26, 2008, with either a laboratory-confirmed Shiga toxin-producing *E. coli* (STEC) infection or diarrhea and one or more symptoms of fever, vomiting, nausea, or abdominal cramps.
Results: During the outbreak period, 1,599 persons attended the camp facility. Of 538 survey responders, 54 (10%) met the case definition; 32 had laboratory-confirmed STEC. Ill persons had a median age of 13 years (range: 10–66 years) and were identified from four of five campsites. Participants in a traditional campfire meal where raw ground beef was cooked by campers were 13.1 times (95% Confidence interval (CI): 1.8–95.2) as likely to become ill as nonparticipants. Persons who reported that the meat was pink or red after cooking were 4.4 times as likely to become ill compared to those who reported that the meat was gray or brown (95% confidence interval: 2.4–8.1). The average reported cooking time among ill persons was significantly shorter with a median of 18 minutes (range 5–40 minutes) compared to well persons who had a median cooking time of 30 minutes (range 8–120 minutes). From a multivariate regression analysis of all variables significant or borderline significant in the univariate analysis, two variables remained significant after controlling for all variables in the model: color of meat or juice after cooking and cooking time. Those who reported either pink or red meat or juice after cooking were 3.9 times as likely to become ill compared to those who reported gray or brown meat and clear juice (95% CI 1.3–11.8). Also, those who reported cooking the ground beef dish for less than or equal to 20 minutes were 8.2 times as likely to become ill compared to those who reported cooking the dish for more than 20 minutes (95% CI 1.1–60.5). The campsite with no ill persons received ground beef in pre-portioned patties, compared with bulk form for other campsites. *E. coli* O157 cultured from leftover ground beef was indistinguishable from 25 stool specimens tested by pulsed-field gel electrophoresis. *E. coli* O157 was not detected in water or swabs of commonly used surfaces.
Conclusions: Consuming undercooked, contaminated ground beef at the summer camp facility likely caused the outbreak. Future illness can be prevented by cooking foods thoroughly and modifying campfire foods to include irradiated raw ground beef products or precooked or ready-to-eat meat products.
Keywords: Shiga toxin-producing *Escherichia coli*, *Escherichia coli*, disease outbreaks

Background
On Sunday, July 27, 2008 the on-call epidemiologist at the Virginia Department of Health's (VDH) Division of Surveillance and Investigation (DSI) received a telephone call from an emergency department physician working at a Fairfax County hospital. The physician reported that within the past two days he had examined three boys with bloody diarrhea and a recent history of attending a large summer camp facility, which was determined to be located within the Central Shenandoah Health District (CSHD).

Staff members at the Fairfax County Health Department (FCHD) and CSHD were notified of this report and the local health districts began collecting additional information. By Monday, July 28, FCHD learned that one boy had *Escherichia coli* O157:H7 (*E. coli* O157) detected in his stool specimen and bacterial culture tests were pending on the other two children's specimens. The reported onset of diarrhea for one of the boys was July 27. FCHD staff learned that the three boys, aged 10–12 years, had attended the same camp facility during the same camp session during July 20–26. In response to this finding, on July 28, 2008 multiple Epidemiologists and Environmental Health Specialists from CSHD and DSI made a site visit to the camp facility as part of the outbreak investigation.

The camp facility is located in Rockbridge County, Virginia and spans over 4,000 acres. It has been in operation for over 40 years and serves primarily male residents from the District of Columbia metropolitan area, Virginia, and Maryland. The camp facility is divided into six main camps (Camps 1–6, Figure 1) that are located around a 450-acre lake. General characteristics of each camp are presented in Table 1. Camps 1, 3, and 5 are dedicated to campers aged eleven years and older; Camps 2 and 4 are primarily for younger campers aged nine or ten years. Campers arrive and stay at the respective camps in groups and are accompanied by group leaders and other adult chaperones. Camp 6, a high adventure camp for those aged thirteen years or older, allows campers and their adult chaperones an opportunity to hike and perform other activities throughout the camp facility and adjoining property.

The dining options available to attendees vary by camp. Depending on the camp, attendees at Camps 1–5 can eat foods in a dining hall, eat foods that are cooked in a dining hall and transported to a commissary for ultimate consumption at the campsite (i.e., "heater stack cooking"), or eat foods that are prepared and cooked by the attendee at the campsite (i.e., "patrol cooking"). In addition, an aluminum "foil dinner" is held weekly at Camps 1–5 whereby all attendees are given the opportunity to prepare and cook raw ground beef and vegetables over a campfire at the campsite. During the week of July 20–26, the "foil dinner" was held on July 22. Camp 6 attendees prepare dehydrated meals for consumption while camping. Camp 6 does not offer a "foil dinner" but does have regularly-scheduled cookouts where ground beef is served. The source and ground beef product used during the "foil dinner" or cookout varied by camp. Attendees at Camps 1, 3, 4, and 5 received ground beef product in a brick form; attendees at Camps 2 and 6 received a different ground beef product that was in a patty form.

All camps are open for week-long sessions for a total of six weeks during July through mid–August. The week of July 20–26 marked the fourth week of camp for the season. Staff members, aged fourteen years or older, are typically employed for the entire camp season. Each camp averages approximately 100–200 campers, 50–100 adults, and 40 staff members per week. During the week

of July 20–26, the total census at the camp facility for Camps 1–5, including staff, campers, and leaders or volunteers, was 1,599 persons.

Methods

The public health investigation consisted of environmental health, epidemiologic, and laboratory components. Each of these components is described below.

Environmental Health Investigation

Camp inspections

The purpose of the environmental health investigation was to gather information about the facility's general sanitation, foods, drinking and recreational water resources, and overall camp activities for attendees present during the July 20–26 camp session. This information was used to assess exposures that might be linked to illness, develop a survey, and make recommendations to camp management to control the outbreak and prevent additional illness. The information was gathered through campsite inspections that included direct observation at the campsites and conversations with camp facility management and staff and Food Service Provider employees. In addition, environmental health information was also obtained via the analysis of specimens collected from multiple sampling locations at the camp facility.

Regarding the drinking water supply at the facility, each of the six camps located within the camp facility has its own drinking water supply via drilled wells and elevated or underground storage tanks. The camp facility's water system is regulated by VDH Office of Drinking Water (ODW). As such, quarterly bacteriologic testing of the water supply by a Commonwealth of Virginia-approved laboratory is required. During this outbreak investigation, recent routine water quality test results were reviewed and additional water samples were collected by ODW staff and tested at the Division of Consolidated Laboratory Services (DCLS) in Richmond, Virginia.

Epidemiologic Investigation

The epidemiologic investigation was divided into the following main components: 1) illness surveillance among assigned groups of campers, their group leaders and other adult supervisors; 2) additional case finding through interviews with camp facility management and staff, and healthcare provider notification; and 3) retrospective cohort study for case description and risk characterization. Each of these components is described below.

> 1) Illness surveillance among camp groups: The purpose of the illness surveillance among the camp groups was to determine the number of persons from each group that attended the camp during July 20–26 and to identify which groups had attendees who were reporting *any* gastrointestinal illness (i.e., diarrhea, vomiting, abdominal cramps, or fever) on or after July 20. A list of the group leaders was provided by camp facility management. Local health department staff contacted the leaders in their respective jurisdictions for this information.
>
> 2) Additional case finding: Additional case finding was accomplished in multiple ways. First, CSHD interviewed staff members to identify any gastrointestinal illness among these persons. Second, several local health departments in northern Virginia released information regarding the outbreak to local healthcare providers in the community via blast fax. Third, a state-wide electronic notification was also distributed to members of the hospital and

healthcare association to raise awareness about this investigation and to request that healthcare providers report any potentially-related cases to their local health department. Fourth, a notification was posted on the Centers for Disease Control and Prevention (CDC) Epi-X website which is a secure, web-based communication network used for the exchange of epidemic information among members of the public health community in the U.S. Fifth, investigators from the District of Columbia Department of Health (DCDOH) and the Maryland Department of Health and Mental Hygiene (MDHMH) were actively involved in the investigation and were performing case finding in their respective jurisdictions.

3) Retrospective cohort study for case description and risk characterization: The purpose of the cohort study was to describe all cases of illness, to compare ill and well persons, and to identify risk factors associated with illness. This portion of the investigation initially involved open-ended interviews with patients or their parents to identify potential exposures. Several health departments located in northern Virginia performed these open-ended interviews, with FCHD performing the bulk of these interviews during the initial portion of the investigation.

Based on initial information obtained during open-ended patient interviews, a more comprehensive survey (Appendix 1) was developed. This survey was designed to capture demographic information, information about illness, information about foods and drinks consumed while at the camp facility based on menus provided by the Food Service Provider (see Results, Environmental Investigation, Foods at the Camp Facility), and information about other camp activities that might be associated with illness (e.g., swimming, animal contact, cooking practices). This survey was administered electronically using SurveyMonkey® (Portland, OR). Because evidence suggested that this cluster of illness was caused by *E. coli* O157, the exposure time period of interest was ten days prior to illness onset (i.e., maximum of one incubation period). However, because all initial ill persons had the camp facility in common, the food histories addressed in the survey were limited to food exposures while at the camp facility.

The survey was available online during August 1–August 25, 2008. If an individual did not have computer access, the survey was administered either over the telephone or, in the case of camp facility staff, in person using a paper version of the survey. DSI staff entered data from all paper versions of the survey. If a person initiated more than one survey response, the most complete survey response was used in the analysis; if the most complete survey response could not be determined (i.e., many questions were answered for multiple surveys), then the first survey response was used in the analysis.

E. coli O157 *Case Definition*

For the purposes of case identification and epidemiologic analyses, a case was defined as illness in a person who attended the camp facility during July 20–26 and had either 1) a laboratory-confirmed Shiga toxin-producing *E. coli* (STEC) or *E. coli* O157 infection; or 2) reported diarrhea, defined as three or more loose stools in a 24-hour period, and at least one additional sign or symptom of self-reported fever, vomiting, nausea, or abdominal cramps, with onset of symptoms occurring during July 20–August 5. Diagnostic laboratory tests of stool specimens that were considered for the laboratory-confirmed criteria were enzyme immunoassay (EIA) for Shiga toxin or bacterial culture.

Data analysis and statistics

A summary of the progression of the epidemiologic analysis is presented in Figure 2. All camp facility attendees (e.g., campers, staff, group leaders and adult chaperones, and those reporting "Other" when defining their role at the facility) who were present at the camp during July 20–26 and who either responded to the survey (n=538) or for whom laboratory information was available (n=22) were initially eligible for inclusion in the cohort study (total n=560).

Persons were excluded from the cohort analysis based on the following criteria:

1) Persons who arrived at the camp facility on or after July 27 (n=11) were not eligible because the exposure period of interest was the camp session during July 20–26;
2) Persons who had laboratory-confirmed illnesses other than STEC infections (n=2) were not eligible because of possible misclassification of illness;
3) Persons attending camps other than Camps 1–5 or who were missing the name of the camp (n=30) were not eligible. Attendees at Camps 1–5 were considered the persons at risk for illness. If these data were not available, then the person was excluded to avoid possible misclassification of exposures. Camp 6 attendees were excluded because their food, water, and overall camp exposures were significantly different from those in Camps 1–5.

Thus, a total of 517 persons were included in the initial cohort analysis. As information about specific populations at risk were uncovered in the analysis, subsets of the cohort were further analyzed (i.e., participants in the "foil dinner" and persons attending camps that had received the brick form of the ground beef for this dinner, See Results, Environmental Investigation, Aluminum "Foil Dinner" and Foods at the Camp Facility).

Data were cleaned extensively prior to analysis. If values were missing for a particular question or were inconsistent with other answers, an attempt was made to reclassify answers. For example, some persons reported not participating in the "foil dinner," but did report eating ground beef at the foil dinner. Thus, participation in the "foil dinner" was reclassified to "Yes."

Some variables were recoded during the analysis. For example, ground beef dishes cooked during the "foil dinner" were collapsed into similar categories based on the ultimate form of the cooked ground beef and the respondents' descriptions of the dishes. Continuous variables for age and reported cooking time were recoded as categorical variables and as dichotomous variables for the multivariate analysis. The reported characteristics of cooked ground beef, color of meat and color of meat juice, were combined for the multivariate analysis (see below).

Data were analyzed using Microsoft Excel 2003 and SAS 9.1 (SAS Institute Inc., Cary, NC). An epidemic curve was constructed to determine the magnitude and timing of the outbreak based on the reported onset date for the first symptom. The incubation period was calculated as the difference between the onset date of the ill person's first symptom and the reported time of ground beef consumption during the "foil dinner." Illness duration was calculated as the difference between the onset date and time of the first symptom and the date and time of the last gastrointestinal-related symptom.

To evaluate survey response rates and potential response bias, Chi-square tests comparing observed and expected rates of responses by camp for Camps 1–5 were performed. Descriptive and

univariate analysis were performed to calculate illness attack rates (AR), relative risk (RR) or the association between a specific exposure and illness, 95% confidence intervals (CI), and ***P*** values for a given exposure. To assess statistical significance using an alpha of .05, the following two-sided tests were used: Wilcoxon signed-rank tests for continuous variables with nonnormal distributions, Chi-square tests for univariate analysis, and Fisher's exact tests for univariate analysis with cell sizes less than or equal to 10. For the analysis, only individuals who answered "Yes" or "No" when asked about a particular exposure were considered; individuals who answered "Don't know" for a particular exposure or who did not answer a question were excluded. Because skip patterns were included in the survey design to minimize the number of nonapplicable questions for each respondent, a respondent did not necessarily have access to all questions within the survey.

A multivariate Poisson regression analysis was conducted among the "foil dinner" participants who had received the brick form of the ground beef product. The purpose of this analysis was to identify main risk factors associated with illness after controlling for other variables. Variables that were statistically significant (i.e., ***P*** value less than .05) or borderline significant (i.e., ***P*** value less than or equal to .10) in the univariate analysis were included in the model. The full model contained the cooking method (i.e., dichotomous variable with cooking in a container versus in aluminum foil or directly on the grill), the role of the attendee (i.e., dichotomous variable with camper versus noncamper), whether foods were tasted while cooking (i.e., dichotomous variable with "Yes" versus "No"), reported color of the ground beef meat and meat juice after cooking (i.e., dichotomous variable with pink or red meat or pink or red meat juice versus gray or brown meat and clear juice), reported cooking time (i.e., dichotomous variable using a cutoff of less than or equal to 20 minutes based on the median reported time among ill persons), and age of attendee (i.e., dichotomous variable using a cutoff of less than or equal to 13 years based on the median age of ill persons). Specific type of ground beef dish could not be included in the model because the model failed to converge because of small sample sizes when this variable was included. A backward, stepwise elimination process was done to remove the least influential, nonsignificant variables from the full model.

Interagency Notification

On July 29, DSI staff notified the Virginia Department of Agriculture and Consumer Services (VDACS) and the Food Safety Inspection Service (FSIS) personnel at the United States Department of Agriculture (USDA) about the outbreak investigation. DSI staff provided epidemiologic data and information about food items collected during the investigation to VDACS and FSIS during the investigation.

Because groups of campers from the Mid-Atlantic region also visited the camp facility, DSI notified MDHMH and DCDOH of the investigation on Wednesday, July 30. As the permanent residences of the camp attendees were determined, other local or state public health departments were notified and asked if the survey could be distributed via their respective group leaders. DSI also notified all health district directors and local epidemiologists within the Commonwealth of Virginia about the outbreak investigation. Local and state health departments were updated as new information developed.

Laboratory Investigation
Specimens collected from patients, leftover food, drinking and recreational water sources, and other locations during the environmental health assessments were tested at various private laboratories (i.e., hospital or commercial laboratories) or public health laboratories in Virginia and Maryland.

Ill individuals who sought medical care typically submitted stool specimens to their health care provider or were encouraged to submit specimens through their local health department. Private laboratories tested specimens for bacterial agents by culture or EIA, and depending on the laboratory, also tested for non-bacterial agents. At the state public health laboratories, stool specimens were tested for bacterial agents by EIA, culture, or polymerase chain reaction (PCR); samples might also have been tested for norovirus by reverse-transcription PCR (RT-PCR). If a bacterial agent was identified in the specimen, local health departments and private laboratories forwarded the specimens or bacterial isolate to DCLS in Virginia or MDHMH Laboratories Administration in Maryland. These laboratories performed pulsed field gel electrophoresis (PFGE) analysis for molecular characterization of the identified isolates.

During the investigation, VDH staff obtained an opened package of frozen raw ground beef from Camp 1 and submitted it for bacterial culture to DCLS. Investigators from USDA also collected several unopened boxes of ground beef from the camp facility that were subsequently tested by culture at their laboratory.

Environmental specimens, including drinking water, recreational lake water, and swabs of surfaces of commonly used equipment (i.e., hose spigots, bathroom door handles, and drinking fountain), were collected and submitted to DCLS for *E. coli* testing.

All available *E. coli* O157 isolates from stool, leftover food, or environmental specimens received by state public health laboratories underwent additional characterization using PFGE analysis to determine the genetic composition of each isolate.

Results
Environmental Investigation
VDH Environmental Health Specialists made multiple visits to the camp facility to collect information about overall sanitation at the facility, food, and water resources. During these visits, environmental specimens were also collected for laboratory testing (see Results, Laboratory Investigation).

Camp Inspections
Each camp, with the exception of Camp 6, had multiple campsites organized into subcampsites that typically accommodated eight campers. Campers slept in tents situated on wooden platforms within the subcampsite. Each campsite contained an open fire pit, a tarp-covered dining area with picnic tables, and a pit latrine with adjacent water station that were housed under a common roof. The latrine consisted of a vault under a concrete deck with two enclosed toilet rooms that contain a porcelain nonwatered toilet. The water station supplied cold water through overhead drip ports for hand and face washing, and tooth brushing; camp attendees provided their own soap and products for personal hygiene. The water station also included a water fountain for drinking and a water spigot that supplied water for cooking purposes and latrine cleaning; dish soap and sanitizer for

cleaning dishes and the latrine were provided by the camp facility. The latrine and water stations were constructed in 2008. In addition, each camp had a first aid station with one nurse on site.

At the camp facility, three different dining methods were available to camp attendees depending on the camp and the attendee's cooking and eating preferences. Camps 1, 2, and 4 had a dining hall where breakfast, lunch, and dinner meals were prepared by Food Service Provider staff and served cafeteria style. Camps 3 and 5 provided two dining options of "heater stack" or "patrol cooking." Prior to arrival at the facility or immediately upon arrival, attendees would select which method they would use for the camp session. With the "heater stack" option, foods are prepared and cooked at the full dining facilities by the Food Service Provider staff and are then transported to one of the commissary sites. Campers pick up the foods from the commissary and take them back to the campsite to eat. Campers and their supervisors might reheat food at the campsite if desired. With "patrol cooking," Food Service Provider staff plan the menus. All raw food ingredients, including recipe information, are picked up from the commissary by the attendees prior to the start of each meal. These raw ingredients are prepared and distributed in such a way that they can serve six to ten people (i.e., in batches). At their respective campsite, camp attendees prepare their own meals on the open campfire, consume the meals, and clean their dishes and cooking equipment. According to the camp facility guidelines, camp attendees are provided a set of cooking and cleaning equipment (e.g., pots, pans, utensils, and wash buckets). Food thermometers, while not listed in the guide, were observed during some campsite inspections. The camp facility Director reported that a thermometer is issued at the beginning of the week and is returned at the end of the week. Thermometers were reported to be calibrated weekly.

In general, staff members ate at separate dining halls designated specifically for them. Chefs, who were provided to the camp facility via the Food Service Provider, prepared meals for staff. These meals were typically different from those served to other camp attendees.

A general description of each of the six camps is presented below and summarized in Table 1.

1) Camp 1 contained 20 campsites that are used by campers aged 11–17 years and their adult supervisors. The camp had its own water supply and a designated swimming area. During July 20–26, campers and adult supervisors from Camp 1 ate all meals prepared at the dining hall except for the "foil dinner" on July 22.

2) Camp 2 contained 12 campsites that are used by campers aged 9–10 years and their adult supervisors. The camp had its own water supply and a designated swimming area.. During July 20–26, campers and adult supervisors from Camp 2 ate all meals prepared at the dining hall except for the "foil dinner" on July 22.

3) Camp 3 contained 12 campsites that are used by campers aged 11–17 years and their adult supervisors. The camp had its own water supply and a designated swimming area. Camp attendees select the type of dining method they prefer (i.e., "patrol cooking" or "heater stack" method).

4) Camp 4 contained 10 campsites that are used by campers aged 9–10 years and their adult supervisors. The camp had its own water supply and a designated swimming area.

During July 20–26, campers and adult supervisors from Camp 1 ate all meals prepared at the dining hall except for the "foil dinner" on July 22.

5) Camp 5 contained 12 campsites that are used by campers aged 11–17 years and their adult supervisors. This camp was similar in all aspects to that of Camp 3 described previously.

Environmental Health Assessments
Environmental health assessments comprised the following three areas: general campsite sanitation, food resources, and water resources. The environmental investigation focused on camps from which illnesses were reported. Thus, Camp 2 and Camp 6, which had no reports of illness, were deemed lower risk during the investigation.

General Sanitation
During the inspections of Camps 1, 3, 4, and 5, Environmental Health Specialists noted that the construction of the latrines and wash stations did not prevent rodent or insect entry and that the hose attached to the water basin did not have a back-flow prevention device. With reports of additional illness among attendees at Camp 1 who attended the subsequent July 27–August 2 camp session, environmental samples were collected from campsite latrines locations (i.e., door handles, handwashing faucet, drinking fountain, and hose spigot). At Camp 3, Environmental Health Specialists noted that although dishes were not supposed to be washed in the latrine area, a plate was observed in the sink trough. At Camp 5, campsite water containers were found to be unclean and uncapped in some campsites. Also, facility-provided cooking equipment for the campsite were reportedly not taken back to the commissary to be washed, rinsed, and sanitized after each camp group. When inspecting the cooking utensils supplied to the campers, investigators did not observe any food thermometers.

Foods at the Summer Camp Facility
Food service for the entire camp facility is contracted out to one company. The company is located in Gaithersburg, Virginia and will be referred to in this report as the Food Service Provider. The six managers at the camp facility employed by this Food Service Provider were certified as National Restaurant Association ServSafe Managers. Combined, these managers had over 150 years of lifetime experience in the food service industry. All food items served at the camp facility were provided by one of two food distributor companies, Food Distributor 1 or Food Distributor 2.

In general, food deliveries to the camp facility were arranged by the Food Service Provider and typically occurred on Mondays, Wednesdays, and Fridays to the main dining halls between 8:00 – 10:00 A.M. Deliveries were relatively frequent because of the limited kitchen and food storage space at the facility dining halls and commissaries. Most of the food products arrived frozen. Because of the frequent deliveries, foods were typically prepared and consumed relatively quickly. Unused foods distributed to the actual campsites could not be returned to employees of the Food Service Provider; if leftover food items were present, they would be discarded. Menus of foods served at the camp facility were supplied to VDH by the Food Service Provider managers.

In addition to foods supplied through the Food Service Provider, other food and drink options were available to camp attendees. Snack foods and bottled or canned drinks could be purchased from a

general store. Also, camp facility management reported numerous groups that purchased foods at local supermarkets to supplement foods provided by the Food Service Provider. These foods could be used for either personal consumption or during group meals. Usually these supplemental foods were purchased at the beginning of the camp session. Camp facility management required that these foods be refrigerated if they were perishable. Finally, persons could leave the camp facility to eat at restaurants in nearby towns.

Aluminum "Foil Dinner"

During the initial visit to the facility on July 28, investigators learned of an aluminum "foil dinner" that occurred on Tuesday July 22. This meal, a weekly camp facility tradition, is offered to all camp attendees at Camps 1–5, regardless of their dining method selection for the week. The meal gives attendees, especially the campers, an opportunity to prepare and cook a dinner over a campfire. From the dining hall or commissary, attendees would pick up raw, thawed ground beef, vegetables including potatoes, onions, and carrots, seasonings, and aluminum foil. These items would be transported back to the campsite. There, camp attendees would prepare the ingredients and wrap them in aluminum foil. The foil packets would be cooked over the campfire. Packets could be prepared for an individual attendee, but were more commonly prepared for a small group of attendees. Attendees could also supplement the provided ingredients with additional ingredients to create their own customized dinners. Based on survey responses, the actual dinner meal prepared within a camp varied by campsite or group. For example, dishes such as hamburgers, tacos, burritos, Salisbury steak, foil dinner (i.e., beef and vegetables wrapped in aluminum foil but not further specified) and stews were reported; some persons specifically reported not eating ground beef during this meal. Instead of cooking the ingredients in the foil packets, cooking containers, such as pots, pans, and Dutch ovens, were also available for attendees. When dishes were cooked in these containers, the dishes would typically serve a larger number of attendees and perhaps an entire group, depending on the size of the group.

Documents provided by camp facility management for incoming camp attendees describe the "foil dinner." The descriptions contained a menu and cooking instructions which were to be read three times before preparing the "foil dinner" meals. Adult supervisors and some staff were present at the meal to provide assistance and supervise attendees while cooking. According to camp management and interviewed camp attendees, younger campers were provided more assistance during preparation and cooking of the "foil dinner" than older campers. Based on survey responses, the majority of staff members (n=117, 81%) did not participate in the "foil dinner."

During the investigation, investigators learned that two different raw, thawed ground beef products were available to attendees for the "foil dinner." The distribution process of each of these products was identified through a traceback investigation conducted by FSIS and VDACS. The results of this investigation are presented in Figure 3. The first ground beef product was in a solid, rectangular form or "brick." Each brick measured approximately 14 inches in length, 3 inches in width, and 7/8 of an inch in thickness; each brick weighed approximately one pound. The traceback investigation determined that the product originated at the Food Supplier located in Wichita, Kansas; the product was further processed by the Food Producer, located in Azusa, California. The product was then sent to an initial distribution center located in Fogelsville, Pennsylvania operated by Food Distributor 1. The product was then shipped to a second distribution center, Food Distributor 2, which is located in Harrisonburg, Virginia. The product was then transported to the camp facility

where it was received and used as an end-product by the Food Service Provider. This ground beef product was not normally distributed by the Food Supplier; however, a special arrangement with the Food Supplier, Food Producer, and Food Service Provider had been established for this particular product. The brick form of the ground beef was available to attendees at Camps 1, 3, 4, and 5 for the "foil dinner" on July 22.

During the visit to the camp facility on July 28, investigators located a sample of this raw ground beef product in the brick form in the freezer at Camp 1. This product was leftover from the previous camp session (July 20–26). Although the packaging (box and internal plastic bag) were open, approximately 17 one-pound bricks remained. This product was collected by VDH, placed in a cooler, and transported to DCLS for testing.

The second ground beef product was a pre-seasoned, pre-pattied, raw frozen hamburger that was portioned as five patties per pound. The initial components of the distribution chain (Figure 3) are not described in detail because epidemiologic data did not warrant a detailed traceback investigation for this product. However, the ground beef product was delivered to Food Distributor 2 and was also received by the Food Service Provider at the camp facility. This product was available to attendees at Camp 2 for the July 22 "foil dinner" and was also available to attendees at Camp 6 for the weekly cookout meal. The executive chef for Camp 2 and Camp 6, a Food Service Provider employee, reported that this alternative product was preferred because the pre-portioned patties were easier to serve and required less manipulation than the brick product.

Kitchen Inspection and Interviews among Food Service Provider Workers
Because of numerous reports of illness among attendees of Camp 1, an inspection of the Camp 1 kitchen was conducted on Monday, July 28, by the Environmental Health Supervisor and Environmental Health Specialists from CSHD. Health department staff observed the food handling preparation, storage, and serving areas at the dining hall and kitchen and conducted interviews with the kitchen manager and other Food Service Provider staff. During this inspection, internal food temperatures of chicken breasts declared ready to be served by the Food Service Provider manager were measured. The temperatures were found to be below the accepted minimum internal temperature requirement of 165°F for poultry. Based on observations during the environmental health assessment of a commissary kitchen, Food Service Provider employees appeared to be unsure how to thaw additional frozen chicken product quickly. At the time of the observation, there was only 30 minutes before the chicken product was going to be picked up by attendees who were performing the "patrol cooking." In addition, a new oven was believed to be improperly calibrated.

Discussions with the kitchen manager and the camp's Food Service Provider director revealed that providing underthawed foods to attendees selecting the "patrol cooking" method was a habitual process. It was reported that this practice was done, in part, to offset the hot Virginia weather. Staff explained that partially thawed products, including meat products such as pork chops and chicken, would continue to thaw while being transported back to the campsite by those selecting the "patrol cooking" dining option. This transport time was approximately five to seven minutes in duration. Kitchen staff explained that other factors, including menu selection, delivery schedules, lack of refrigeration, storage, and thawing space, and lack of adequate time to completely thaw food items, contributed to this underthawing practice.

Twenty-two in-person interviews with Food Service Provider employees were conducted by CSHD staff. None of these employees reported gastrointestinal symptoms before July 20 or during the week of July 20–26. Information about symptoms among these employees that might have been present after July 26 was not available.

Drinking and Recreational Water Resources
Drinking water samples collected in April 2008 and on July 21, 2008 were reviewed and all the recommended levels of coliform bacteria were not exceeded in any of the samples tested. During on-site inspections of the wells during the investigation, no violations or abnormalities were noted. Although routine drinking water samples from the distribution system had been collected recently, additional drinking water samples from each of the six wells were collected by ODW staff on July 30. When the additional four cases of diarrheal illness were reported among Camp 1 attendees present at the camp facility during the week of July 27–August 2, ODW staff returned to the camp facility on August 5 to collect drinking water samples from drinking water distribution points for Camps 1, 2, 3, and 4,. On August 6, CSHD Environmental Health staff collected water samples from two drinking fountains and a food preparation sink at Camp 1. Results from water testing from these sites showed that the recommended levels of coliform bacteria were not exceeded in any of the samples.

Recreational Lake Water Testing
The camp facility includes a 450-acre lake that provides swimming, boating, and fishing opportunities for camp attendees. As part of the investigation, Environmental Health Specialists reviewed lake water quality results of samples collected by camp facility management from five designated swimming areas and from the lake inlet, middle of the lake, and the lake outlet. Furthermore, ODW returned to the camp facility on July 30 to collect eight quality-assurance samples from similar sampling sites across the lake. Because all samples had coliform levels within an acceptable range set by VDH, investigators concluded that the lake water was not likely to be the source of exposure for the outbreak.

Epidemiologic Investigation
Illness surveillance among groups
A total of 70 groups that attended Camps 1–5 during July 20–July 26 were identified. Groups ranged in size from 4–70 members. Groups were from Virginia (n= 46, 66%), Maryland (n=22, 31%), and the District of Columbia (n=2, 3%). Based on information from the group leaders, these 70 groups accounted for 1,000 campers and 399 group leaders and adult supervisors. When considering the additional 200 staff members, the total number of persons attending the camp facility during that week was 1,599.

Group leaders reported that the groups had stayed at one of the following camps: Camp 1 (n=14 groups, 20%), Camp 2 (n=11 groups, 16%), Camp 3 (n=14 groups, 20%), Camp 4 (n=19 groups, 27%), and Camp 5 (n=12 groups, 17%). Among the 70 group leaders surveyed, 22 (31%) reported being aware of at least one or more persons with *any* symptom of gastrointestinal illness that began on or after July 20.

Additional Case Finding
Limited illness among staff members was described by camp facility management and staff during the initial visit to the camp facility. Eight staff members had reported varying illnesses to camp medical staff on July 23. Reported illness included cold-like symptoms and gastrointestinal symptoms, such as nausea, vomiting, and diarrhea. Three staff members who complained of gastrointestinal symptoms had used anti-diarrheal medications. Reported illnesses among staff members had subsided within 24–48 hours according to management. The majority of reported illnesses occurred among staff members responsible for the aquatic program, although a couple of staff members worked at the facility's general store. Management reported being unaware of any additional illness among staff members.

No additional cases were identified in Virginia either through blast faxes or electronic notifications among persons attending any of the camps during July 20–July 26.

In addition to illness among persons who attended camp during July 20–July 26, two campers from Camp 1 who attended the subsequent camp session during July 27–August 2 had laboratory-confirmed *E. coli* O157 infections (See Results, Laboratory Investigation). Two additional campers from Camp 1 who also attended the July 27–August 2 camp session, reported recent onset of diarrhea; however, laboratory testing of stool specimens was not available for these persons. Dates of illness onset for these four campers ranged from July 31–August 3. Because of the small number of ill persons reported during the week of July 27–August 2, an analytic study involving these camp attendees was not pursued.

Retrospective Cohort Study
A total of 577 survey responses were completed. Thirty-two individuals initiated two or more separate survey responses. After addressing multiple entries from these individuals, a total of 538 respondents were identified for an overall survey response rate of 33.6%. Response rates to the survey did vary significantly by camp (Table 1, Chi-square ***P*** value <.01) with attendees from Camp 5 and Camp 3 having the highest response rates of 44.0% and 38.9%, respectively. When considering all respondents (n=538) and persons for whom laboratory data were available (n=22), a total of 560 persons had data available for review.

Forty-three persons were excluded from the cohort analysis based on the exclusion criteria. Eleven persons were excluded from the analysis because they arrived at the camp facility on or after July 27. Two persons for whom laboratory testing of stool specimens revealed non-STEC infections (i.e., detectable norovirus (n=1) or *Salmonella* (n=1)) were excluded from the cohort. In addition, 30 persons who did attend Camps 1–5 during the camp session were excluded. Six of these persons reported attending Camp 6. Twenty-four persons who had missing values for the camp that was attended or who did not report being assigned to one of the camps were also excluded. Thus, the overall cohort used in the initial analysis consisted of 517 persons.

Of these 517 cohort members, 110 (21.3%) reporting having *any* gastrointestinal illness (i.e., diarrhea, abdominal cramps, vomiting, or nausea), that began on or after July 20. However, when considering the *E. coli* O157 case definition, 54 persons met the case definition, resulting in an overall attack rate of 10.4%. Those persons who met the case definition will be hereafter referred to as ill persons.

The clinical characteristics among the ill persons are presented in Table 2. Diarrhea (100.0%), stomach cramps (97.4%) and nausea (81.1%) were commonly reported symptoms among 39 ill persons for whom complete clinical data were available. The median duration of illness was 3.5 days (range 12 hours–7 days, n=25). Among all 54 ill persons, 32 (59.3%) had laboratory-confirmed STEC infections. A total of 41 ill persons sought healthcare for their illness and 9 (16.7%) required hospital admission for medical care and treatment. Two (3.7%) ill persons were diagnosed with hemolytic uremic syndrome.

The epidemic curve of the outbreak is presented in Figure 4. Dates of illness onset were available for 53 (98.1%) ill persons. The first dates of illness onset available for non-laboratory confirmed infections and laboratory-confirmed infections were July 20 and July 22, respectively. These two persons with the earliest onset dates were campers who arrived at the camp facility 1 to 9 days before illness began, attended Camp 5, and selected the "patrol cooking" method as their dining option. The epidemic curve shows that the outbreak peaked on July 26 and its shape is suggestive of a point-source outbreak. When considering the foil dinner as the main exposure for cohort members, the median incubation period was 3.7 days (range 4 hours–8.2 days, n=24); two persons had onset dates prior to the "foil dinner" and were not included in the calculation.

The attack rates and characteristics of the 54 ill persons and the 463 well persons are presented in Table 3. Briefly, the majority of ill and well attendees were non-Hispanic, white males. Ill and well attendees did not differ significantly by sex, race, or ethnicity. The median age of ill persons was 13 years (range 10–66 years) and was significantly younger than well persons (median age 17 years, range 8–83 years; Wilcoxon signed-rank test, $P < .01$). When evaluating the age of attendees by age categories, the attack rate of illness was highest among the younger campers, particularly those aged 11–13 years (20.7%) and those aged ten years or younger (14.3%). Persons aged 18 years or older had the lowest attack rate (2.0%).

Persons attending any of the five camps included campers, group leaders or adult supervisors, staff, and persons who reported not being assigned to the aforementioned categories (e.g., "Other" category). The overwhelming majority (n=50, 92.6%) of ill persons were campers and only three (5.6%) group leaders or adult supervisors and one (1.9%) staff member met the case definition. Ill persons reported attending each of the five camps; however, the attack rate was highest (20.4%) among Camp 5 attendees compared to the other four camps (Chi-square, $P < .01$). No ill persons reported attending or working at Camp 2.

Ill and well persons were also compared by the reported dining method during the July 20–July 26 camp session. Persons who reported only the "patrol cooking" dining method had the highest (19.2%) attack rate. Persons who reported using the dining hall or "heater stack cooking" methods had the lowest (4.7%) attack rate. Furthermore, persons reporting *any* "patrol cooking" during the week had a higher attack rate (11.9%) compared to those who did not report *any* "patrol cooking" (4.7%, Chi-square $P < .01$). Of note, some persons reported selecting multiple dining options during the camp session week (i.e., "patrol cooking" and either dining hall or "heater stack cooking"). These multiple dining method responses conflict with camp facility management reporting that only one dining method could be selected for the entire camp session.

Exposure and Illness Associations
Ill and well cohort members were also compared by the types of exposures they encountered at the facility. Five hundred three (97.3%) of the 517 cohort members had survey responses available for this univariate analysis. Exposures included recreational and drinking water use, animal contact, personal hygiene, cooking behavior (i.e., thermometer use, utensil cleaning), and 245 different food items served at the camps based on the dining methods selected and menus provided during the investigation. Exposures found to be significantly associated with illness are presented in Table 4. Persons who reported cleaning their own cooking utensils were 2.4 times as likely to become ill as those not reporting this exposure (95% CI 1.3–4.6, ***P*** <.01). Persons reporting participation in the "foil dinner" were 13.1 times as likely to become ill as those not participating in the dinner (95% CI 1.8–95.2, ***P*** <.01). After assigning the type of ground beef served at the "foil dinner" based on the camp that was attended, 100.0% of the ill persons were at camp that had been provided with the brick form of the ground beef and none (0.0%) of the ill persons were at a camp that had been provided with the patty form of the ground beef (RR not calculable, ***P*** <.01). Also of note, reported washing of hands after using the bathroom and reported washing hands prior to cooking were not statistically significantly associated with illness when comparing those who reported "Always" versus those reporting "Sometimes" or "Never" to these exposures. Reported use of a thermometer was not significantly associated with illness; ten (3.7%) persons reporting using a thermometer while cooking and 262 (96.3%) reported not using a thermometer while cooking.

In addition to the previously mentioned exposures, multiple food items available to those selecting patrol cooking or those selecting dining hall-prepared foods (i.e., dining hall or "heater stack cooking" dining methods) were statistically significant in the univariate analysis. However, when these food items were controlled (i.e., stratified) by participation in the "foil dinner," these items were no longer statistically significant.

Persons who attended camps that received the brick form of the ground beef and who participated in the "foil dinner" (n=310) were further analyzed for exposures during the "foil dinner," specifically for the method of cooking, dishes cooked, and reported cooking time. The results of this analysis are presented in Table 5. Those reporting cooking the ground beef dish in a container (i.e., pot, pan, Dutch oven, or other container) were 2.3 times as likely to become ill (95% CI 1.2–4.3, ***P*** <0.01) compared to those cooking in aluminum foil or directly on the grill. The attack rate did not vary significantly based on the type of ground beef dish cooked. However, those who reported cooking burritos, tacos, stew, or spaghetti had a higher attack rate (29.4%) compared to those who reported cooking hamburger, meatloaf, or Salisbury steak (attack rate = 11.3%) or those who reported cooking the foil dinner (i.e., beef and vegetables, attack rate = 5.9%).

The reported cooking time and characteristics of the cooked ground beef were also evaluated. The median cooking time for the ground beef dishes was statistically lower among ill persons (17.5 minutes, range 5–40 minutes) compared to well persons (30 minutes, range 7.5–120 minutes, ***P*** <.01). When the time of reported cooking was collapsed into categories of cooking time, the attack rate of illness was highest among those reporting cooking the dish less than ten minutes (60.0%). No illnesses occurred among those persons who reported cooking the ground beef dish 45 minutes or longer. The analysis did not identify any statistically significant differences in the cooking time by method of cooking (i.e., container compared to aluminum foil or directly on the fire, ***P*** =.97) or by the ground beef dish cooked (***P*** =.43). When considering characteristics of the cooked ground beef, persons who reported that the ground beef or the juice from the ground beef was pink or red

after cooking were 4.4 times and 3.1 times as likely to become ill compared to those who reported brown or gray meat color or clear meat juice, respectively. Persons who reported ever eating undercooked beef were 2.9 times as likely to become ill compared to those who reported not ever eating undercooked beef (95% CI 1.4–6.3, P =.02).

Ill and well persons who received the brick form of the ground beef product for the "foil dinner" were also compared based on the ground beef dishes cooked during the dinner and the method of cooking. Table 6 presents these data. There were no statistically significant differences in ill and well persons who cooked the particular ground beef dishes after controlling for the method of cooking.

From the multivariate regression analysis, the following two variables remained significant in the final model after controlling for other variables: reported color of meat and juice after cooking and reported cooking time. Those who reported pink or red meat or pink or red juice after cooking were 3.9 times as likely to become ill compared to those who reported gray or brown meat and clear juice (95% CI 1.3–11.8, P =.02). Also, those who reported cooking the ground beef dish for less than or equal to 20 minutes were 8.2 times as likely to become ill compared to those who reported cooking the dish for more than 20 minutes (95% CI 1.1–60.5, P =.04).

Of note, after the survey had been made available to the cohort, DSI staff learned that some menu items referred to in the survey for both "patrol cooking" and "dining hall" options were incorrect. Specifically, food items listed in the survey questions were either not always offered on the same day that was listed in the survey question, or the actual items were not available to camp attendees during the week of July 20–26.

Public Health Interventions during the Investigation

Once the existence of an outbreak of diarrheal illness associated with the camp facility was identified, health department staff alerted camp management, visited the camp facility to identify potential sources, and recommended interventions to prevent additional illness. Of note, however, is that when VDH was notified of the potential outbreak, most of the camp attendees, with the exception of staff, had returned home and a new cohort of camp attendees had already arrived. This turnover might have complicated identifying the likely sources of infection because camp attendees could not be directly observed or interviewed in person. As a result, multiple general interventions were recommended to the camp facility management throughout the investigation as information on the likely pathogen and potential sources of infection were identified.

Based on the possibility that raw ground beef was a potential source for the outbreak, camp management was advised on July 28 by health department staff not to serve any ground beef from boxes with the same lot number as the ground beef specimens that had been collected and sent to DCLS for testing. An environmental health staff member placed an embargo on this ground beef. Camp management verbally agreed not to serve this ground beef. VDH and camp management also agreed that cooked ground beef could be used for the "foil dinner" meal for the remaining two camp sessions. However, camp management decided to cancel the "foil dinner" planned for Tuesday, July 29 for the entire facility.

After CSHD Environmental Health staff observed raw meat (e.g., chicken) being sent from the commissaries to the camp sites frozen or partially frozen, the CSHD Environmental Health Supervisor ordered a directive on July 31 that Food Service Provider management completely thaw these items before sending these foods to the campers.

Health department staff asked camp management and medical personnel to continue monitoring for additional gastrointestinal illness among all persons at the campsite. Camp management was instructed to alert VDH of any additional persons that became ill and to collect stool specimens for testing from these ill persons. Additional recommendations focused on maintaining proper hand hygiene among attendees. In addition, a “FAQ” or Frequently-Asked Questions document (Appendix 2) was provided to group leaders on July 30. A VDH press release (Appendix 3) of the outbreak investigation was delivered on July 31; subsequent press releases and VDH website updates were also provided. These updates informed camp attendees of the outbreak so that they could seek appropriate health care if they developed symptoms, and also served to educate attendees about how to minimize the risk of secondary transmission to others.

On Friday, August 1, VDH held a press conference to notify the public regarding the *E. coli* outbreak at the camp facility. Information about the investigation, including information about *E. coli* O157 and related public health issues, was provided. Attendees of the camp who had developed gastrointestinal illness were encouraged to seek medical care and to contact their local health department. Other media interviews were conducted during the course of the investigation to provide updates. In addition, information was provided on the VDH website regarding *E. coli* O157, including methods to prevent illness.

On August 3, MDHMH notified VDH that a camper who had attended Camp 1 during the week of July 27–August 2 had been hospitalized with bloody diarrhea. This information was relayed to camp management and on August 3 management canceled the final session of camp (August 3–August 9), thereby closing the facility for the season.

Also on August 3, laboratory results from the ground beef product collected from Camp 1 and tested at DCLS confirmed the presence of *E. coli* O157. VDH staff reported these results to staff at FSIS and to management of the Food Service Provider. In response, the Food Service Provider issued a system wide food safety alert to all of their clients. The alert advised units to review their inventory for the specified ground beef product lot number from the Food Processor Company. If any product with the specified lot number were found in inventory, the advisory recommended not using the product for consumption and to either hold the product until further notice or dispose of it.

On August 7, Food Producer recalled 153,630 pounds of frozen ground beef products because of possible contamination with *E. coli* O157 (Appendix 4). As a result of the recall, USDA (FSIS) started food safety assessments at the ground beef production plant. This action resulted in increased frequency of reviews and sampling of the product at the factory by inspectors. Extensive contamination at the production plant was not discovered. FSIS did not identify the possible cause or mechanism of contamination for the particular ground beef that was served at the camp facility. To date, no additional ground beef samples collected from the plant have been confirmed to be contaminated with *E. coli* O157.

Because other reports of sporadic Shiga toxin-producing *E. coli* (STEC) infections were reported to VDH during the investigation, local public health department staff were asked to be attentive to other gastrointestinal outbreaks, especially at institutions (e.g., universities, nursing homes, hospitals, government centers) that might have received ground beef products from the same Food Producer. Furthermore, on August 11, the Virginia Health Commissioner sent a notification (Appendix 5) to emergency, family practice, and pediatric physicians and members of the Virginia Hospital and Healthcare Association to raise awareness of *E. coli* enteritis for patients presenting with diarrhea, especially those with bloody diarrhea.

Laboratory Investigation

Laboratory results were available for 38 cohort members from the District of Columbia, Maryland, and Virginia. Six (15.8%) attendees who had specimens tested did not have detectable STEC, E. coli O157, or viral pathogens in their stool specimens. Thirty-two (84.2%) attendees had laboratory-confirmed STEC or *E. coli* O157 infections. Three of these infections were actually coinfections with other species of bacteria: one person had a specimen with detectable *Campylobacter sp.* and *E. coli* O157 present and two persons had specimens with detectable *Clostridium difficile* and *E. coli* O157. Thirty-one (96.9%) of 32 *E. coli* O157 isolates were tested by PFGE. Twenty-five (80.6%) of these 31 specimens had indistinguishable *E. coli* O157 outbreak strains (i.e., matching primary (EXHX01.0047) and secondary enzyme (EXHA26.0015) patterns); four (12.9%) had indistinguishable secondary enzyme (EXHA26.0015) patterns; two (6.5%) had unique PFGE patterns (i.e., primary enzyme pattern code EXHX01.4505 and secondary enzyme pattern code EXHA26.2812; and primary enzyme pattern code EXHX01.4506 and secondary enzyme pattern code EXHA26.2813, respectively)

All environmental specimens collected from the facility that were tested contained acceptable levels of coliform (*E. coli*) bacteria. Specifically, acceptable levels were detected in specimens from the well water systems, drinking fountains, lake water samples, and commonly used surfaces (e.g., latrine door handles, water station faucets, hose spigots, preparation sink, and drinking fountains) at Camp 1.

Laboratory testing on the leftover raw ground beef product in the brick form resulted in a total of 46 separate STEC isolates. Forty-four (95.7%) of the 46 isolates were indistinguishable from the *E. coli* O157 outbreak strain (i.e., primary enzyme pattern code EXHX01.0047, secondary enzyme pattern code EXHA26.0015). Two (4.3%) other PFGE patterns were detected in the ground beef samples; each pattern was found in one isolate (primary enzyme pattern code EXHX01.00154 and secondary enzyme pattern code EXHA26.0556; and primary enzyme pattern code EXHX01.2616, and secondary enzyme pattern code EXHA26.0015).

Because *E. coli* O157was detected in the initial ground beef sample, USDA officials subsequently went to the camp facility to collect unopened boxes of raw ground beef. A box that was produced four minutes after the box of ground beef that had detectable *E. coli* O157 was obtained. However, this box was not accepted for testing at the USDA laboratory. The reason for denying testing involved improper chain of custody procedures. As a result, two additional boxes from the facility were collected; these boxes contained product that was produced several weeks after the product with detectable *E. coli* O157. Neither of these additional raw ground beef products collected from the camp facility and tested at the USDA laboratory had detectable *E. coli* O157 present.

Overall, six different PFGE patterns were found in the ground beef samples and ill persons' stool samples submitted for testing. However, the majority of isolates tested by PFGE (i.e., n = 14 isolates from stool specimens and n = 44 isolates from ground beef product) had two indistinguishable PFGE patterns and were thus identified as the *E. coli* O157 outbreak strain. Three other PFGE patterns were found only with ill persons; one other PFGE pattern was found only with the ground beef samples.

In addition, laboratory-confirmed illness was documented in persons not included in the cohort analysis. One attendee of the July 20–26 session for whom camp information or survey information was not available had an *E. coli* O157 infection; PFGE analysis revealed an indistinguishable PFGE pattern as the *E. coli* O157 outbreak strain. Two attendees of the July 20–26 session were found to have non-STEC infections: one person had a specimen with detectable norovirus present, and one person had a specimen with detectable *Salmonella sp.* present. Also, two symptomatic campers who attended Camp 1 during the following week (July 27–August 2) and had stool specimens collected were determined to have laboratory-confirmed *E. coli* O157 infections. PFGE testing of these two specimens revealed an indistinguishable PFGE pattern as that identified from specimens collected from ill persons present at the camp during July 20–26 and from the ground beef product collected on July 20.

Discussion

The results of this investigation demonstrate that the *E. coli* O157 outbreak was most likely caused by the consumption of undercooked, contaminated ground beef at the camp facility. Specifically, persons who participated in the "foil dinner" on July 22 and particularly those who received the brick form of the ground beef product were most likely to become ill. While color of meat or meat juices after cooking is not a reliable indicator of meat doneness (USDA 2003), ill attendees who participated in this dinner and received the brick form of ground beef were more likely to report that the cooked ground beef was pink or red in color or contained pink or red meat juice. These results are consistent with ill attendees reporting a shorter median cooking time for the ground beef dish compared to well attendees. *E. coli* O157 was detected in leftover ground beef product collected from Camp 1. Additional boxes of this product were also available to and served at Camps 3, 4, and 5 during the "foil dinner." PFGE results from stool specimens collected from ill persons demonstrated that the *E. coli* O157 outbreak strain was indistinguishable from that in the Camp 1 ground beef product. Furthermore, illness was not reported among attendees receiving the patty form of the ground beef product.

E. coli are bacteria that normally live in the intestines of humans and animals such as cows. Most strains of *E. coli* bacteria do not cause illness. However, STEC infections can cause serious illness in humans. *E. coli* O157 is the most common type of STEC. A person can become infected with STEC after consuming food or drinks contaminated with the bacteria. The most common cause of STEC infection is consumption of undercooked contaminated ground beef; however, other sources have included consumption of unpasteurized milk and juice, contaminated produce (e.g., sprouts, lettuce, spinach), and ingestion of bacteria through swimming in feces-contaminated water. Furthermore, infected food handlers can contaminate food if they do not wash their hands after going to the bathroom. Zoonotic transmission from animals to humans via the fecal-oral route after contact with contaminated surfaces or animals (e.g., at agricultural fairs, petting zoos, farm visits)

can also occur. A similar outbreak of *E. coli* in a camp-type setting in Virginia has been previously described (Frost, 1995). During that outbreak in 1994, consumption of rare ground beef while at the camp was determined to be the main risk factor associated with illness.

The actual form of the ground beef might have also played a role in *E. coli* exposure and subsequent development of illness. For example, the one-pound bricks likely resulted in more handling by the attendees preparing the meal because these brick products would require more manipulation for cutting, slicing, or chopping up the ground beef. Also, for those who made hamburgers, for example, the brick form of the ground beef would be more difficult to obtain uniform portion sizes compared to the pre-portioned patties. As a result, appropriate cooking time, cooking temperature, and "evenness" of cooking for the hamburgers made from the brick form of the ground beef products would have varied depending on the thickness of the meat.

The results of this investigation emphasize the overall importance of adequate cooking time and internal cooking temperature. Despite contamination with *E. coli*, ground beef products that are cooked thoroughly and appropriately (i.e., reaching an internal temperature of 155° Fahrenheit for 15 seconds, FDA 2005) are considered safe for consumption. While thermometers were provided to camp attendees, they were not observed at all camp sites and the majority of persons responding to the survey reported not using them. Thus, it is likely that both the cooking time and internal temperatures necessary to kill *E. coli* were not sufficient.

The method of cooking ground beef dishes and the ground beef dishes that were prepared were also of interest in the investigation and epidemiologic analysis. While the method of cooking (i.e., in a container such as a pot or pan, or in aluminum foil or directly on the grill) the ground beef dishes during the "foil dinner" was significantly associated with illness in a univariate analysis, this significant association was no longer evident when considering the specific dishes by cooking method, the reported cooking time by cooking method, or the multivariate analysis. However, there are possible explanations for these results. One explanation is that with the relatively low number of available responses for these variables in the stratified or multivariate analyses, a statistically significant association for cooking method and dishes cooked could not be detected. In fact, the ground beef dishes could not be added to the multivariate analysis without causing the model to fail to converge. Second, the volume of food cooked in the containers compared to the volume of food cooked in the aluminum foil packets or on the grill was not assessed with the survey. It is hypothesized that dishes cooked in containers served a larger number of people compared to dishes cooked in the foil packets. As a result of the larger volume of food to be cooked, it is expected that the time required to thoroughly cook the food would need to be longer; however, the results did not identify a statistically significant difference in reported cooking time by cooking method.

Another possible contributing factor to the outbreak was the serving of partially thawed, raw meat products to the camp attendees. While underthawed food products are not necessarily dangerous in and of themselves, underthawed food products do require special consideration. First, underthawed foods typically have an uneven distribution so that frozen and thawed portions in the same food will lead to uneven heating and cooking. Second, partially thawed foods require longer cooking times than completely thawed foods. Attendees might not have had enough cooking time built into their schedule to account for this additional required cooking time or might not have known to cook these foods longer. Lastly, the *method* to safely thaw foods is important. Because bacteria might become

dormant as a result of freezing, the time and temperature involved in thawing foods properly to ensure that food is kept out of the temperature danger zone (i.e., 41°–135° Fahrenheit) is critical. The 2005 Food and Drug Administration Food Code describes safe methods for thawing food.

Among all 517 cohort members, illness attack rates were highest among those who selected the "patrol cooking" dining option compared to those who did not select "patrol cooking." The reason for this higher attack rate is not known, but might be related to having more opportunities throughout the camp session to handle and prepare their own meals, frequent or increased exposure to underthawed meat products which require longer cooking times, or not consistently using a thermometer while cooking. Attack rates were also highest among the campers, specifically younger campers aged nine–13 years. While younger children are at higher risk for developing complications associated with *E. coli* infections, it is not known for certain why these younger campers were more likely to become ill. The relatively lower attack rate among the group leaders, adult supervisors, and staff might partially explain this finding. Other possible explanations are that adults and staff might have been less likely to eat ground beef dishes compared to younger campers or that younger campers ingested a relatively higher dose of *E. coli* compared to adults or staff. A similar outbreak of *E. coli* at a summer camp in 1994 also identified consumption of undercooked ground beef as the main risk factor associated with illness (Frost, 1995). During that outbreak, 18 (90.0%) of those who became ill were campers and the remaining two (10.0%) persons were counselors.

Based on the available dates of symptom onset among ill persons, not all cases of illness can be attributed to the July 22 "foil dinner." Specifically, the following four persons had illness that could not be attributed to that dinner: two cohort members with illness onset dates on July 20 and July 21 and two noncohort members who attended the facility during July 27–August 2 and who had laboratory-confirmed infections. Possible explanations for illness in these individuals are that the persons with nonlaboratory-confirmed infections had non-*E. coli* infections, that contaminated ground beef product was available and served prior to the July 22 foil dinner to a limited number of persons, that leftover product was served after the July 22 dinner to a limited number of attendees during the following week, or persons became infected via environmental contamination (i.e., via contaminated kitchen surfaces, equipment, or other food items).

Other potential sources of exposure that were considered in this outbreak included environmental contamination and subsequent contact or consumption (i.e., consumption of recreational lake water or drinking water) and exposure from contact with infected persons or animals. The results of the environmental investigation, while not comprehensive of every possible exposure, did not suggest an environmental source. Laboratory testing of recreational lake and drinking water samples did not suggest contamination. Well water quality had not been an issue based on routine water testing and testing that occurred during the investigation. Camp attendees and management did not report consistent exposures to animals, especially those that are likely to harbor STEC and substantially contaminate the environment (e.g., cows). Exposure from contact with infected individuals is not likely given the diffuse nature of the outbreak across multiple camps, the epidemic curve suggestive of a point-source outbreak, and the absence of illness among food handlers or other persons central to camp operations.

Several factors facilitated the public health response to the *E. coli* outbreak and perhaps limited illness among camp attendees. An astute emergency department physician at a hospital in northern Virginia suspected that an outbreak might have occurred at the camp facility. The physician had examined three patients with similar gastrointestinal symptoms and common histories and quickly alerted the health department of these findings. This timely reporting by the physician enabled a rapid response by the local and state health department to start the investigation. A second factor that contributed to the public health response was the cooperation among management staff at the camp facility and the regional council, representatives of the contracted Food Service Provider, and the health departments. Both the Food Service Provider and camp facility management provided requested information to VDH staff in a timely fashion. Camp management provided full access to the camp facility for VDH staff, including access to the kitchens and dining halls. Lastly, initial recommendations provided by VDH staff were heeded, including not serving raw ground beef during the remaining "foil dinners" at the facility.

Recommendations

A number of recommendations were discussed with camp facility management to prevent the occurrence of *E. coli* or other gastrointestinal outbreaks at the camp facility. The following recommendations focused on food safety, particularly for the "foil dinner:"

- Ensure foods, especially raw meat products, are thoroughly thawed by food handlers before providing them to camp attendees for cooking. The 2005 Food and Drug Administration Food Code describes safe methods for thawing food.
- Switch from providing nonirradiated raw animal meats, such as raw ground beef and raw chicken, to using irradiated, raw meat products or pre-cooked or ready-to-eat meat products. Raw animal meats might be contaminated with bacterial pathogens such as *Salmonella*, *Campylobacter* and *E. coli*. Insufficient time or temperature during cooking might lead to consumption of undercooked product and, ultimately, in infection and illness. Examples of safer foods for young, healthy populations include precooked beef crumbles, hot dogs, or soy products, such as veggie burgers and veggie dogs.
- Utilize food thermometers while cooking to verify that internal temperature of foods reaches appropriate temperatures. For ground beef, a minimum cooking temperature of 155°F for 15 seconds is required. Because the color of beef cannot be used as a reliable marker for adequate cooking temperature and times, using a food thermometer while cooking beef and other meats is recommended (USDA 2003).
- For overall operation, follow the 2007 Commonwealth of Virginia Board of Health *Food Regulations,* 12 VAC 5-421.

Additional recommendations provided to the camp facility regarding food safety and education, include the following:

- Collaborate with VDH to provide food safety education to camp attendees, group leaders, and staff.
- Consider the creation of a Food Safety certificate, which would provide a more intense training in food safety than other health-related certificates, such as the cooking and public health certificates.

Limitations
Several limitations were identified during the investigation. A significant limitation during the course of the investigation was the discrepancies in the daily menus for the July 20–26 camp session. A rotating menu was used for camp attendees. The dates that particular meals were served were misunderstood by the investigators. Initially, investigators believed the menus rotated on a Sunday to Saturday schedule. However, it was learned after the survey tool was released that the menus were rotated on a Friday to Thursday schedule. These factors impacted the accuracy of the survey because some foods served were not asked about within the survey and other foods that were not served were included in the survey. As a result, responses about food items consumed on a particular day might not be valid.

Another limitation was the survey methodology. An electronic survey was considered for data collection because illness did not appear to be geographically clustered by camp. As a result, the size of the cohort at the start of the investigation was initially estimated to be approximately 1,700 persons. The majority of these persons had returned home to their permanent residences which included other states or jurisdictions. Given the size and the dispersed nature of the cohort members, conducting individually-administered interviews by telephone would not have been practical or feasible and would have led to a significant delay in data collection. An electronic, web-based survey was selected to enable rapid assessment of the cohort and to minimize time required for data collection, entry, and analysis so that focused control measures could be implemented.

However, given the young age of the majority of cohort members and the length and complexity of the survey instrument (see Appendix 1), the electronic survey might have contributed to the low response rate (34%) and incomplete and inaccurate responses. In addition, VDH staff learned of problems with the survey. These problems included participants' questioning the legitimacy of the survey because of the name of the web link (SurveyMonkey®) and difficulty accessing the survey when certain browsers were used.

Another limitation with the survey was the number of inconsistencies or discrepancies in survey responses. Because an "interviewer" who could clarify these discrepancies was not available, data were cleaned to best address these problems and, as a result, bias from misclassification of exposures is possible. Missing data reduced the power of the statistical analysis. However, the experience of VDH staff was that, even when the survey was administered to camp staff in person, the quality of the responses was also limited. It is simply difficult to accurately ascertain information about clinical symptoms, diagnoses, and specific details about a long list of exposures from a predominantly adolescent population.

The time between the exposure period at the facility and taking the survey was long for some persons. The survey was available for over three weeks because there were reports that some of the group leaders had not disseminated the link to the group members. This long duration and the complex nature of exposures at the facility might have made survey participation and accuracy of survey responses difficult for some individuals. However, even if details were not precisely recalled, the data still showed general patterns of disease risk. For example, although attendees might not have been able to recall the exact cooking time for ground beef dishes, the overall trend for shorter reported cooking time among ill persons and longer reported cooking times among well

persons was noted. Overall, despite concerns regarding the quality of the data from the survey, it is possible that the electronic survey was the best possible option given the circumstances.

Acknowledgments
VDH staff members thank all campers, their parents, the group leaders, adult supervisors, and camp facility staff who participated in this investigation. We also thank persons from the food distribution system, including the Food Service Provider, the Food Distributor 1, the Food Distributor 2, and the Food Service Supplier for their complete cooperation during the investigation. We thank other agencies involved in the investigation, including the United States Department of Agriculture Food Safety Inspection Service (Wu San Chen, Bonnie Kissler, James DeBres, Shannon Ashby), the Virginia Department of Agriculture and Consumer Services (Ryan Davis, Pamela Miles), District of Columbia Department of Health (Dina Passman), Maryland Department of Health and Mental Hygiene (David Blythe, Alvina Chu, Emily Luckman, Marvin Rock), VDH Central Shenandoah Health District (Dana Anfin, Debbie Bundy Carpenter, Cathy Halterman, Doug Larsen, Katie McIvor, Charles Shifflett, Susan Zollman), Fairfax County Health Department (Gloria Addo-Ayensu, Karen Fujii, Debbie Kalunian, Elizabeth Miller-Zuber, Marjorie Pless, Peter Troell, Linda Zabielski), Division of Consolidated Laboratory Services within the Commonwealth of Virginia's Department of General Services (Sherry Giese, Crystal Johnston, Sean Kelly, Jody Lowman, Mary Mismas, Daksha Patel, Dave Peery, Jennifer Sharp, Elise Smith, Francis Tannor, Kelly Tomson, Denise Toney, Allison Wellman), and Virginia Department of Health (Karen Remley, Carl Armstrong, Doug Caldwell, Michael Coletta, Ana Colon, Gary Hagy, Lesliann Helmus, Bob Hicks, AJ Hostetler, Robert Parker, Michelle Peregoy, Tim Powell, Cheryle Rodriquez, James Simmons, Jeremy Smith, and Denise Sockwell).

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Table 1. General characteristics of camps at the summer camp facility.*

Camp	Total Attendees	Percent of Total Attendees	Number of survey respondents	Percent of survey respondents	Age range of campers (years)	Number of campsites	Dining options[†]	Form of ground served at the "foil dinner"
1	463	29.0	140	30.2	11–17	20	Dining hall	Brick
2	183	11.4	57	31.1	9–10	12	Dining hall	Patty
3	293	18.3	114	38.9	11–17	12	Patrol cooking, heater stack	Brick
4	335	21.0	74	22.1	9–10	10	Dining hall	Brick
5	325	20.3	143	44.0	11–17	12	Patrol cooking, heater stack	Brick
6	NA[§]	NA[§]	6	NA[§]	13–17	NA[¶]	Freeze-dried meals	Patty**

* Among 553 survey respondents and nonrespondents with laboratory-confirmation for whom information was available. Nineteen persons reported attending or working at "Other" camp. Total attendees include campers, group leaders, adult supervisors, and staff members.
† As reported to Environmental Health Specialists. The dining hall option consists of foods prepared and consumed at a central dining hall. The patrol cooking dining option consists of the attendee's picking up raw foods at a central commissary and preparing the meal at the campsite. The heater stack dining option consists of picking up foods that are cooked in the central dining hall, but reheating and consuming them at the campsite.
§ Not available (NA).
¶ Not available (NA). Attendees hiked and camped throughout the summer camp facility and adjoining property.
**Ground beef form served at weekly cookouts; an aluminum "foil dinner" is not held for Camp 6.

Table 2. Illness characteristics among persons meeting the *E. coli* case definition (n=54) and for whom clinical information were available among 517 cohort members.*

Clinical Characteristic	Number of ill persons*	Percentage
Diarrhea†	39	100.0
Stomach cramps†	38	97.4
Nausea†	30	81.1
Headache†	19	52.8
Bloody diarrhea†	16	43.2
Vomiting†	11	31.4
Chills†	10	27.8
Fever (self-reported)†	6	16.7
Laboratory-confirmed§	32	59.3
Sought healthcare§	41	75.9
Admitted to a hospital§	9	16.7
Hemolytic uremic syndrome (HUS) §	2	3.7

*A case was defined as illness in a person who attended the summer camp facility during July 20–26, 2008 and had either a laboratory-confirmed *E. coli* infection or who reported diarrhea, defined as three or more loose-stools in a 24-hour period, and at least one additional sign or symptom of self-reported fever, vomiting, nausea, or abdominal cramps, with onset of symptoms occurring during July 20–August 5, 2008.
† Based on persons meeting the case definition who responded to the survey (n=39).
§ Based on all persons meeting the case definition (n=54).

Table 3. Attack rates (AR) and ***P*** values associated with demographic and camp characteristics among 517 cohort members.*

	Ill[†]	% of total cases	Well	Total	AR (%)	*P* value
Sex						
Female	2	3.8	46	48	4.2	.21
Male	51	96.2	411	462	11.0	
Missing	1		6			
Race						
Asian	1	2.6	10	11	9.1	.98
Black	1	2.6	17	18	5.6	
White	35	89.7	407	442	7.9	
Other	2	5.1	24	26	7.7	
Missing	15		5			
Ethnicity						
Hispanic	0	0.0	26	26	0.0	.25
Non-Hispanic	36	100.0	407	443	8.1	
Missing	18		30			
Age						
Median (range) age	13 (10–66)		17 (8–83)			<.01
Age categories						
10 years or younger	8	16.7	48	56	14.3	<.01
11–13 years	23	47.9	88	111	20.7	
14–17 years	13	27.1	109	122	10.7	
18 years or older	4	8.3	198	202	2.0	
Missing	6		20			
Role at camp						
Camper	50	92.6	193	243	20.6	<.01
Troop leader/adult supervisor	3	5.6	128	131	2.3	
Staff	1	1.9	135	136	0.7	
Other	0	0.0	7	7	0.0	
Missing	0		0			
Camp attended						
Camp 1	14	25.9	121	135	10.4	<.01
Camp 2	0	0	55	55	0	
Camp 3	7	13.0	107	114	6.1	
Camp 4	4	7.4	67	71	5.6	
Camp 5	29	53.7	113	142	20.4	
Missing	0		0			
Dining Method						
Patrol cooking only	15	40.5	63	78	19.2	<.01
Dining hall or heater stack cooking	12	32.4	241	253	4.7	
Combination patrol cooking and dining hall or heater stack cooking	10	27.0	122	132	7.6	
Missing	17		24			

[*] Cohort members defined as those attending Camps 1–5 during July 20–26, 2008 who did not have non-*E. coli* laboratory-confirmed infections.

[†]A case was defined as illness in a person who attended the summer camp facility during July 20–26, 2008 and had either a laboratory-confirmed *E. coli* infection or who reported diarrhea, defined as three or more loose-stools in a 24-hour period, and at least one additional sign or symptom of self-reported fever, vomiting, nausea, or abdominal cramps, with onset of symptoms occurring during July 20–August 5, 2008.

Table 4. Attack rate (AR), relative risk (RR), 95% confidence intervals (CI) and ***P*** values of specific activities or food items among cohort members for whom exposure information was available (n=503).*

Exposure	**Ill**†	**% of total cases**	**Well**	**Total**	**AR (%)**	**RR (95% CI)**	***P* value**
Utensil cleaning							
Cleaned one's own cooking utensils	24	64.9	170	194	12.4	2.4 (1.3–4.6)	<.01
Did not clean one's own cooking utensils	13	35.1	241	254	5.1		
Missing	17		52				
Aluminum "Foil Dinner"							
Participated in foil dinner	36	97.3	308	344	10.5	13.1 (1.8–95.2)	<.01
Did not participate in foil dinner	1	2.7	125	126	0.8		
Missing	17		30				
Form of ground beef available at foil dinner							
Brick form	54	100.0	408	462	11.7	NC§	<.01
Patty form	0	0.0	55	55	0.0		
Missing	0		0				

* Cohort members defined as those attending Camps 1–5 during July 20–26, 2008 who did not have non-*E. coli* laboratory-confirmed infections. Information about specific exposures was available only among survey respondents.

†A case was defined as illness in a person who attended the summer camp facility during July 20–26, 2008 and had either a laboratory-confirmed *E. coli* infection or who reported diarrhea, defined as three or more loose-stools in a 24-hour period, and at least one additional sign or symptom of self-reported fever, vomiting, nausea, or abdominal cramps, with onset of symptoms occurring during July 20–August 5, 2008.

§Not calculable (NC) because of 0 in denominator.

Table 5. Attack rates (AR), relative risks (RR), 95% confidence intervals (CI), and ***P*** values associated with exposures among cohort members who reported participating in the "foil dinner" and who reported attendance at the camps that received the brick form of the ground beef (n=310).*

Exposure	Ill[†]	% of total cases	Well	Total	AR (%)	RR (95% CI)	*P* value
Method of cooking ground beef dish							
In container	13	37.1	47	60	21.7	2.3 (1.2–4.3)	<.01
In aluminum foil or directly on grill	22	62.9	214	236	9.3		
Missing	1		13				
Ground beef dishes cooked							
Burrito, taco, stew, or spaghetti	10	29.4	24	34	29.4	--	.07
Hamburger, meatloaf, or Salisbury steak	17	50.0	133	150	11.3	--	
Foil dinner	5	14.7	80	85	5.9	--	
Multiple	1	2.9	9	10	10.0	--	
No ground beef	1	2.9	17	18	5.6	--	
Missing	2		11				
Color of meat after cooking							
Pink or red	13	40.6	24	37	35.1	4.4 (2.4–8.1)	<.01
Brown or gray	19	59.4	219	238	8.0		
Color of meat juice after cooking							
Pink or red	4	25.0	12	16	25.0	3.1 (1.1–8.6)	.05
Clear	12	75.0	139	151	8.0		
Median (range) time spent cooking ground beef dishes	18 (5–40)		30 (8–120)			--	<.01
Categories of time spent cooking ground beef dishes							
Less than 10 minutes	3	15.8	2	5	60.0		.02
10 –less than 30 minutes	8	42.1	86	94	8.5		
30 –less than 45 minutes	8	42.1	58	66	12.1		
45 minutes or more	0	0.0	39	39	0.0		
Reported ever eating undercooked ground beef							
Yes	6	18.8	15	21	28.6	2.9	.02

						(1.4–6.3)	
No	26	81.3	240	266	9.8		

*Cohort members defined as those attending Camps 1–5 during July 20–26, 2008 who did not have non-*E. coli* laboratory confirmed infections. The brick form of the ground beef was provided at Camps 1, 3, 4 and 5.

†A case was defined as illness in a person who attended the summer camp facility during July 20–26, 2008 and had either a laboratory-confirmed *E. coli* infection or who reported diarrhea, defined as three or more loose-stools in a 24-hour period, and at least one additional sign or symptom of self-reported fever, vomiting, nausea, or abdominal cramps, with onset of symptoms occurring during July 20–August 5, 2008.

Table 6. Comparison of attack rates (AR), relative risks (RR), 95% confidence intervals (CI) and ***P*** values by cooking method used for ground beef dishes among cohort members who reported participating in the "foil dinner" and who reported attendance at the camps that received the brick form of the ground beef (n=310).*

	Container			**Aluminum foil or directly on the grill**			**RR (95% CI)**	***P* value**
Ground beef dish	**Ill**[†]	**Well**	**AR (%)**	**Ill**[†]	**Well**	**AR (%)**		
Burrito, taco, stew, spaghetti	8	13	38.1	2	9	18.2	2.1 (0.5–8.2)	.43
Hamburger, meatloaf, Salisbury steak	3	26	10.3	13	102	11.3	0.9 (0.3–3.0)	1.00
Foil dinner	1	1	50.0	4	78	4.9	10.3 (1.9–55.2)	.12
Multiple	0	1	0.0	1	8	11.1	NC[§]	1.00
No ground beef	0	5	0.0	1	11	8.3	NC[§]	1.00
Missing (2 container, 7 foil)								

[*]Cohort members defined as those attending Camps 1–5 during July 20–26, 2008 who did not have non-E. coli laboratory confirmed infections. The brick form of the ground beef was provided at Camps 1, 3, 4 and 5.

[†]A case was defined as illness in a person who attended the summer camp facility during July 20–26, 2008 and had either a laboratory-confirmed *E. coli* infection or who reported diarrhea, defined as three or more loose-stools in a 24-hour period, and at least one additional sign or symptom of self-reported fever, vomiting, nausea, or abdominal cramps, with onset of symptoms occurring during July 20–August 5, 2008.

[§]Not calculable (NC) because of 0 cell.

Figure 1. Map of summer camp facility.

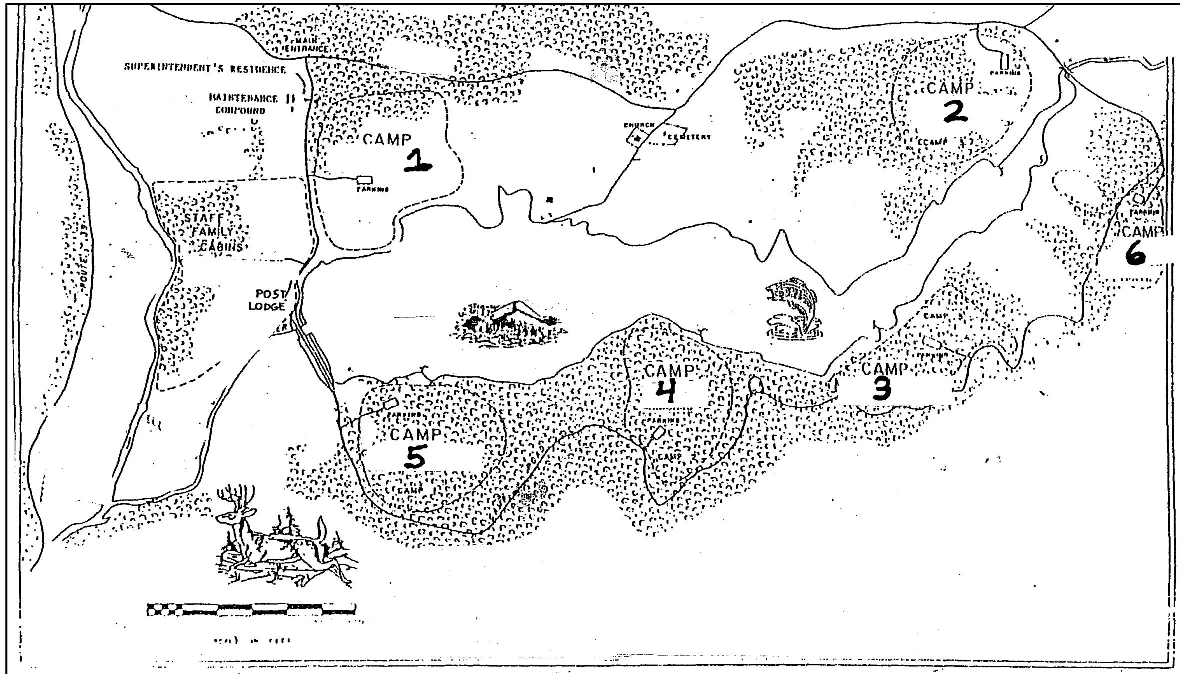


Figure 2. Progression of epidemiologic analysis

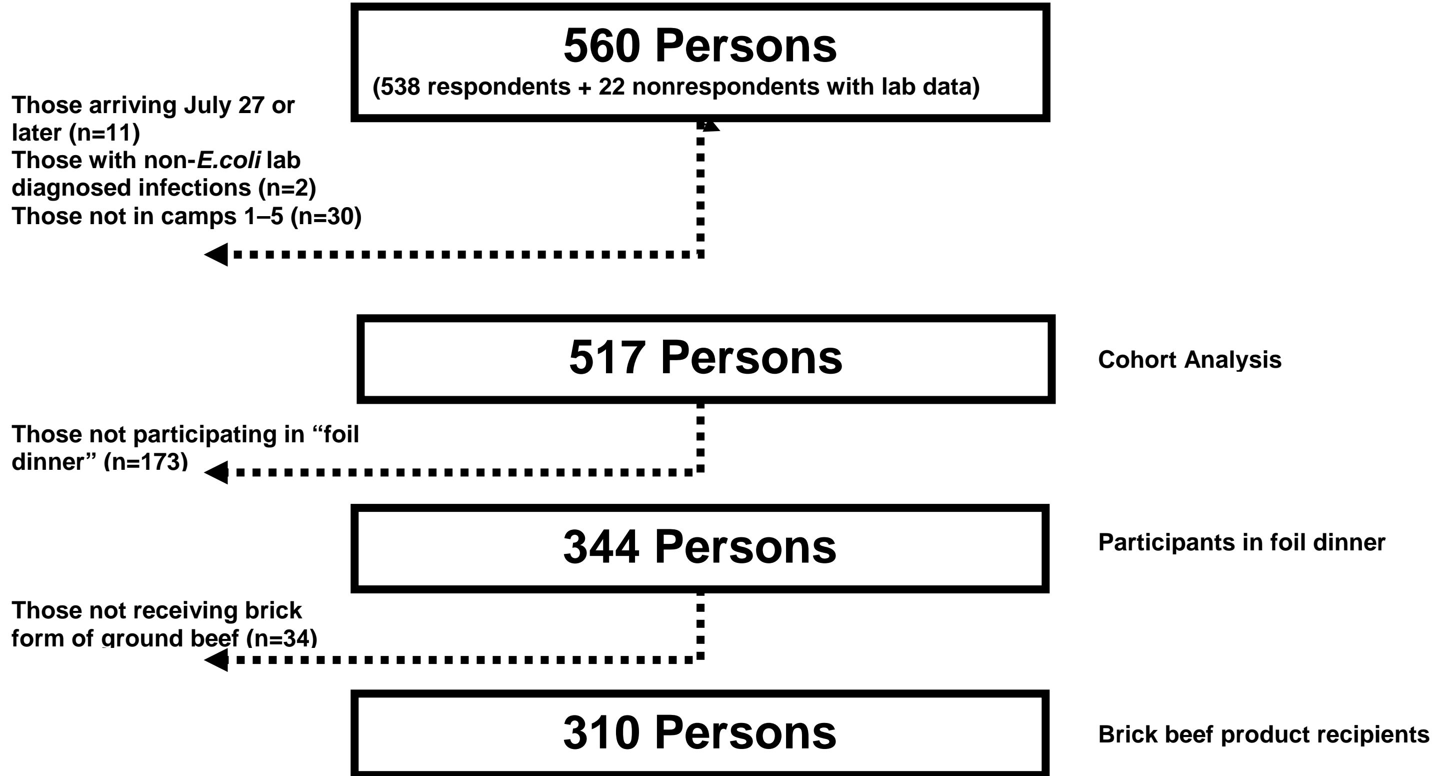


Figure 3. Distribution process for the two ground beef products served at the summer camp facility.

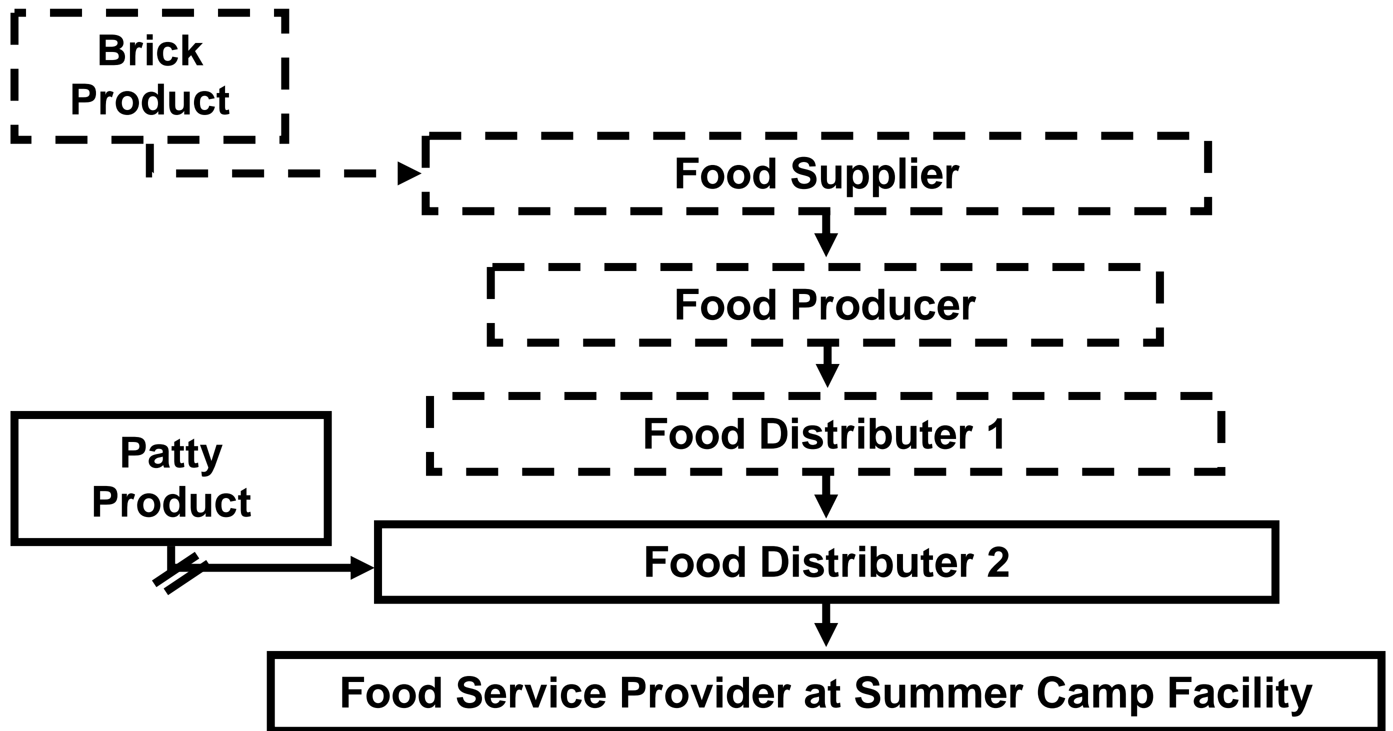
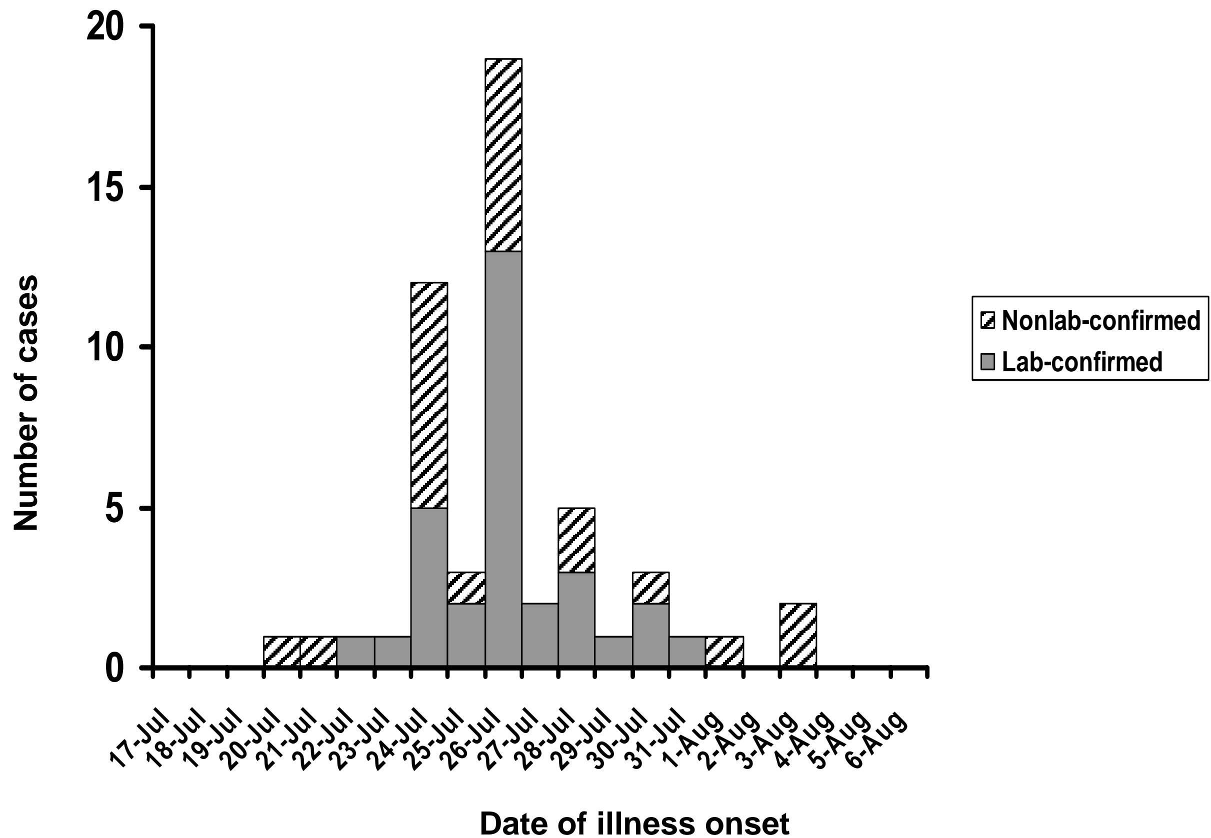


Figure 4. Epidemic curve of the number of laboratory-confirmed and nonlaboratory-confirmed cases of *E. coli* among persons meeting the *E. coli* case definition and for whom date of illness onset were available (n=53).*



*A case was defined as illness in a person who attended the camp during July 20–26, 2008 and had either a laboratory-confirmed *E. coli* infection or who reported diarrhea, defined as three or more loose-stools in a 24-hour period, and at least one additional sign or symptom of self-reported fever, vomiting, nausea, or abdominal cramps, with onset of symptoms occurring during July 20–August 5, 2008.