Nonpoint Pollution From Animal Sources and Shellfish Sanitation

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ABSTRACT

Many of the microorganisms pathogenic to both animals and man are transmitted via the fecal-oral route. Most of these pathogens could conceivably be transmitted through a shellfish vector. Bacteria potentially transmitted from animal to man via shellfish include most of the salmonellae, Yersinia enterocolitica, Yersinia pseudotuberculosis, Escherichia coli O157:H7, Campylobacter jejuni, and Listeria monocytogenes. The protozoa most likely to be transmitted this way are Giardia lamblia and Cryptosporidium spp. Because the enteric viruses are highly species-specific, they are not likely to be transmitted from animals to humans. There are environmental data showing that bacterial pathogens shed by both domestic and wild animals have been isolated from shellfish. However, there is little epidemiological evidence that illness outbreaks have been caused by shellfish harvested from waters polluted by animals. Unfortunately, epidemiological observations are of limited value because most illnesses are probably not recorded. In addition, more than half of the recorded outbreaks are of unknown etiology, and more than half of the shellfish implicated in illness outbreaks cannot be traced to their points of origin. More lenient bacteriological standards should not be established for waters affected only by animal pollution until health effects of the pollution that originates from domestic animals could be eliminated by simple and inexpensive measures.

In May of 1986, a jointly sponsored Shellfish Microbiology Research Workshop was held at the Virginia Institute of Marine Science, to address several major scientific concerns and research needs related to shellfish sanitation. The sponsors of the Workshop included the following agencies and organizations: the Food and Drug Administration, Interstate Shellfish Sanitation Conference, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Environmental Protection Agency, Shellfish Institute of North America and Virginia Institute of Marine Sciences. One of these needs was a determination of human health hazards associated with the consumption of shellfish harvested from nonpoint source polluted areas. The nonpoint source study group agreed that sources containing human waste material (i.e., septic systems, waste discharge from boats) posed the greatest human health risk. Waters containing domestic or wild animal wastes were considered to offer a reduced risk. However, the study group was not able to define the precise relationship between pollution from animal sources and human health risk.

Subsequently, a draft report on the workshop was submitted to the Institute Shellfish Sanitation Conference for deliberation at its fourth annual meeting in August 1986. At this meeting, the Conference requested that the Environmental Protection Agency conduct a literature search concerning animal pathogens which may be transmitted from animals through a shellfish vector to humans. This literature search was written to provide a summary of the current scientific significance of pollution associated with runoff to shellfish-harvest waters from animal sources such as wildlife, waterfowl, and agricultural stock. The materials contained in this report were obtained after an extensive review of the literature for: (i) diseases common to both animals and man (zoonoses) that are known to be transmitted via the fecal-oral route, (ii) environmental studies of waters affected by nonhuman fecal pollution, and (iii) reported shellfishborne illness caused by pathogens that may have originated from nonhuman fecal pollution. Zoonoses listed in this report include only those that have been documented to cause foodborne and/or waterborne illness. Zoonoses transmitted via other routes, such as animal bites or via insect vectors, were not considered as potential shellfishborne pathogens.

BACTERIAL ZOOONES

Several enteric pathogens of the family Enterobacteriaceae are common causes of food-and waterborne illness. Members of the genus Salmonella appear to be the most important representatives of this family that are transmitted from animals to man. The frequency of salmonellosis is relatively high in comparison with other foodborne infections (55), and salmonellosis has been increasing steadily as a public health problem over the last 40 years in this country (82). Most cases of salmonellosis caused by species other than Salmonella typhi or Salmonella paratyphi are of animal origin (68), and it is reasonable to assume that
they could potentially be transmitted from animals to man by shellfish. Reservoirs of *Salmonella* include cattle, swine, sheep, and domestic poultry (1). All serotypes of *Salmonella* are considered pathogenic (68).

The epidemiological data compiled by Rippey and Verber (76) suggest that salmonellae other than *S. typhi* and *S. paratyphi* have been infrequent causes of shellfishborne illness. Only 130 of over 12,000 reported cases of salmonellosis have been attributed to the nontyphoidal salmonellae, and only seven outbreaks involving 30 cases have been reported in the last 22 years. This would seem to indicate that fecal pollution from animal sources has rarely (if ever) caused salmonellosis. However, these data should be interpreted with caution, since they only represent reported cases. It is generally accepted that the true incidence of foodborne illness is under-reported (5), and salmonellosis is no exception. Although approximately 40,000 cases of salmonellosis are reported to the Centers for Disease Control each year, it is estimated that two million cases actually occur. Only outbreaks or sporadic cases that are sufficiently severe to be brought to the attention of health authorities are reported. These cases appear to represent a small proportion of all *Salmonella* infections and may be caused by more virulent strains or by higher doses of the organisms (15). *Shigella* spp. have also been implicated in shellfishborne outbreaks (64). However, these species are specific to man and other primates, and human cases are always considered to be the sources of *Shigella* infections (56).

Two members of the genus *Yersinia*, *Y. enterocolitica* and *Y. pseudotuberculosis*, are potential shellfishborne zoonoses. Both species have caused foodborne as well as waterborne outbreaks (1). None of the reported shellfishborne outbreaks in the United States have been attributed to these organisms. However, both species have the potential for transmission via shellfish. *Y. enterocolitica* has been isolated from mussels (64) and oysters (83), and *Y. pseudotuberculosis* survives in both freshwater and seawater for relatively long periods (63). Reservoirs for *Y. enterocolitica* include most domestic mammals, particularly swine, rodents, and lagomorphs, but not fowl. Reservoirs for *Y. pseudotuberculosis* include a wide variety of domestic mammals and fowl (1). Two recently discovered environmental yersiniae, *Y. kristensenii*, and *Y. frederiksenii*, invade HeLa cells with a low infectivity rate, indicating a moderate virulence potential. However, the significance of these and other new species of *Yersinia* as animal or human pathogens has not been fully established (4).

Pathogenic strains of *Escherichia coli* are usually of human origin. Few cases of enterotoxigenic *E. coli*, enteroinvasive *E. coli*, or enteropathogenic *E. coli* exist that point to direct transfer of pathogenic strains from domestic animals to humans (68); consequently, shellfishborne illness caused by *E. coli* would more likely originate from human fecal pollution than from animal fecal pollution. The recently discovered hemorrhagic colitis strains belonging to the O157:H7 serotype may be the exception. These Verotoxin-producing strains of *E. coli* (VTEC) are usually acquired after ingestion of either raw ground beef or raw milk (57,58). Two recent incidences have shown that these organisms can also be transmitted via water. However, the outbreak that occurred in Cabool, Missouri, during an extremely cold period in December of 1989 was attributed to drinking water contaminated by human sewage that got into the system through breaks in the water lines (35). The other outbreak, which occurred in the village of Tarves, United Kingdom, in the summer of 1990, could have been due to transmission from animal to man. The supply to one of the subsidiary reservoirs that augmented the main reservoir came from a source that both resembled a field-drain system and may have been contaminated by cattle slurry. No further cases of hemorrhagic colitis were reported after the subsidiary reservoir was cut off permanently (24). Although some investigators still question whether VTEC is a zoonosis (85), VTEC have been isolated from calves, and pigs with enteric diseases (79). VTEC have also been isolated from retail pork and lamb (25).

*Edwardsiella*, another genus that has been implicated in shellfishborne illness (76), is closely related to *Escherichia* (68) and is also most likely acquired from human sources, if acquired as a result of pollution. The only other warm-blooded species listed by Acha (1) as a host for *Edwardsiella* is the turkey, *E. tarda*, the only *Edwardsiella* species associated with human disease, has also been isolated from cold-blooded animals, which may serve as a reservoir of human infection (80). Because turtles and other cold-blooded animals are indigenous to any estuarine environment, the organisms they carry should probably be considered as indigenous pathogens rather than as pollutants.

*Enterobacter* spp., especially *E. cloacae*, should also be viewed as potential agents of foodborne diseases. However, more epidemiological information on these organisms is required to allow a reliable assessment of their potential as foodborne pathogens (80).

*Campylobacter jejuni*, another enteric pathogen normally acquired by ingestion, has been transmitted from nonhuman animals to man by both food and water (8). Raw milk was the source of a recent case of severe gastroenteritis in an adult male. The milk was obtained from a cow that was not kept in the state of cleanliness prescribed for dairy herds. The *C. jejuni* isolated from the cow was the same serotype and biotype as the patient isolate (23). This case confirmed the long suspected (8) link between *Campylobacter* of bovine origin and human illness. A 1983 waterborne outbreak of *Campylobacter* gastroenteritis in Florida was traced to contamination of the water system by wild birds; a total of 871 cases were reported (18). Further evidence that birds may have a significant role in the dissemination of campylobacters was cited by Pacha et al. (70), who recovered *C. jejuni* from the cloacal contents of 70 of 89 (79%) mallard ducks. Other reservoirs of *Campylobacter* include sheep, swine, dogs, and domestic poultry (8).

An outbreak that occurred in New Jersey in December of 1980 was the first demonstration that campylobacteriosis can be transmitted by shellfish. The outbreak occurred among participants of a banquet. Raw clams were the only food significantly associated with illness (*P* = 0.000006). It is not known whether the *C. jejuni* that caused this outbreak was of human or animal origin. The shellfish tags had been
removed before sale; therefore, the site of harvesting could not be ascertained (37). Eleven additional outbreaks, each consisting of one known case, have been recorded subsequent to the 1980 outbreak (76). It is possible that C. jejuni has also been responsible for some of the shellfishborne outbreaks that were of unknown etiology, since they are often not detected by standard techniques used for the isolation of human enteropathogens from patients’ stools (8,37).

Although campylobacters have been isolated from seawaters as well as freshwaters, the results of environmental studies suggest that they would be found less frequently in shellfish-harvesting waters than in fresh waters and that pathogenic strains found in those waters would more likely be of human than of animal origin. Knill et al. (48) isolated campylobacters from 37 of 50 (74%) freshwater samples but only from 7 of 34 (20.5%) seawater samples. Bolton et al. (9) isolated Campylobacter spp. from a number of river sites. The highest numbers of CFU were isolated at sites adjacent to or downstream from sewage works. C. jejuni, the species most pathogenic to man, comprised 94% of campylobacters isolated from the site adjacent to the sewage works. There was a gradual decrease in the proportion of C. jejuni isolation at sites downstream from the effluent. The sites affected by surface runoff from adjacent farmland had lower frequencies of isolation and lower counts of campylobacters. These rural sites also had lower proportions of C. jejuni, with C. coli being the most prevalent species.

Listeria monocytogenes, an important pathogen in several domestic animal species, can cause human neonatal sepsis or meningitis. This opportunistic pathogen also infects immunocompromised adults (10,33,36). Recent reports of three outbreaks in which commercial foods were identified as the vehicles have established L. monocytogenes as a foodborne pathogen (14,31,78). There are several reports describing isolations of L. monocytogenes from shellfish-harvesting waters (16,66) and from a variety of seafoods (11,16,28,66,67,86,87). Colburn et al. (16) studied the incidence of Listeria spp. in freshwater tributaries draining into Humboldt-Arata Bay, California, an area that supports an active molluscan shellfishery. They recovered Listeria species and L. monocytogenes in 81 and 62%, respectively, of fresh or low-salinity waters. A given species or L. monocytogenes serogroup appeared to predominate in fresh water when domesticated animals were nearby, whereas greater variation with no species predominance was observed in areas with no direct animal influence. Although Weagant et al. (86), Buchanan et al. (11), and Motes (66) all failed to recover Listeria spp. from oysters, Motes (66) did recover Listeria spp. from the overlying waters. This indicates a potential for oysters, filter feeders that concentrate particulates from the water column, to accumulate Listeria. Estella et al. (28) isolated L. monocytogenes from a large variety of seafoods, including clams. Presently, the only evidence linking human listeriosis to shellfish consumption is indirect. This evidence consists of an epidemiological association between shellfish or raw fish consumption and an outbreak of perinatal listeriosis in New Zealand (52). Listeria monocytogenes can attack or be harbored by at least 37 mammalian species, the most important reservoirs being the ruminants (36). Fecal carriage of L. monocytogenes by seagulls feeding at sewage works has been demonstrated (30). L. monocytogenes is environmentally stable, surviving in feces at ambient temperatures for periods of up to 347 d and for 27 d in 12% NaCl (63).

Several of the zoonoses that have caused food-or waterborne illness are not likely to be found in shellfish-growing waters and should not be considered as potential shellfishborne pathogens. Brucella and Bacillus anthracis have caused both food-and waterborne illness, but the diseases caused by both of these organisms in animals have been virtually eradicated in the United States and other developed countries (1); and the probability of these organisms being deposited in estuaries is remote. These pathogens should not be considered as a potential problem unless a large outbreak occurs in close proximity to an estuary. Leptospira spp. have caused waterborne outbreaks (18); however, those organisms have extremely low tolerance to saline conditions (2) and should not survive in shellfish-growing waters. Clostridium perfringens type A, a common cause of foodborne illness, is another organism highly unlikely to be transmitted from animal to man via shellfish. Illness in animals is caused by C. perfringens types B, C, D, and E (I). Although type A, has been found in the feces of virtually every animal species (51), animals are not believed to play a direct role in the epidemiology of these organisms (1). Furthermore, marine sediments contain very low numbers of C. perfringens spores (59), and large numbers of vegetative cells are necessary for infection to occur (51); this would probably require extreme temperature abuse between harvesting and consumption of the shellfish.

VIRAL ZOOONES

Viruses contributed to water by nonhuman fecal pollution have not been studied extensively (43), and little is known about the spread of viral zoonoses to humans via the fecal-oral route. However, animal viruses are generally counterparts of those found in humans, and many viruses common to both human and nonhuman animals are capable of crossing species barriers and producing disease (49). Therefore, it is conceivable that humans could acquire viral illness from shellfish contaminated with animal viruses.

Although there is currently no evidence that rotaviruses are transmitted via shellfish, rotaviruses should still be considered as potential causes of this type of illness. Long known as a major worldwide cause of diarrhea in infants and children, they have now been associated with occasional outbreaks involving adults (39,45,56,84). Some of these outbreaks have been waterborne (39,56). Rotaviruses have been isolated from a variety of animals, including cattle, sheep, and goats. Cross-species transmission of rotaviruses is recognized; human rotaviruses to various nonhuman species and nonhuman rotaviruses to other animal species, including humans (43). Humans excrete up to 10^10 rotavirus particles per g of feces (21). Whether such high titers of rotavirus are shed by nonhuman animals is
Beavers, muskrats, and water voles all have clear infectivity of cysts from animals for humans is from amphibian and avian sources for mammals. The infectivity of cysts from man fecal contamination were more likely from animals than from higher primates (D. O. Cliver, personal communication).

Enteroviruses and adenoviruses of nonhuman origin appear less likely to be transmitted to humans. Although both of these types of virus are shed in feces, their host ranges are generally restricted to the natural host species. Hepatitis A virus (HAV), a known cause of shellfishborne illness (75,76), is also not likely to be transmitted to humans from animal fecal pollution. Hepatitis A virus apparently produces disease only in primates.

PARASITIC ZOONOSES

Metazoan zoonotic parasites are unlikely to be shellfishborne in this country. Known nematode and trematode species that utilize mollusks as intermediate hosts are problems only in the Far East (1). There are, however, two protozoan parasites, Giardia lambia and Cryptosporidium, that could possibly be acquired by ingestion of contaminated shellfish.

Community-wide outbreaks of waterborne giardiasis have been documented with increasing frequency (17,18). In at least two of the waterborne outbreaks, the sources of fecal contamination were more likely from animals than from man (47,54). Two foodborne outbreaks have also been documented (69,72). It is possible that a number of foodborne outbreaks have occurred but have gone unrecognized because of the long time interval between exposure to Giardia cysts and the onset of symptoms. In the outbreak described by Osterholm et al. (69), the time of onset was typically 7-9 d after ingestion of the contaminated salmon but in some cases nearly a month later. Recognition of this outbreak was probably due to the fact that it occurred among a large number (48%) of employees of the same school.

Giardia spp. infect a wide variety of wild and domestic mammals, amphibians, and birds. The infectivity of cysts from amphibian and avian sources for mammals has not been studied, and neither the species specificity nor the infectivity of Giardia cysts from animals for humans is clear (22,42). Beavers, muskrats, and water voles all have high prevalences of infection (46,70). The prevalence of infection in waterfowl is still unknown (42). Giardia cysts are resistant to destruction in hypotonic solutions, particularly at low temperatures (7,61), but are relatively unstable in 5% NaCl (44) and may not survive well enough in estuarine environments to be a hazard, even though the infectious dose is very low (74).

Cryptosporidium, formerly thought to be an opportunistic pathogen, is now known to be a significant and widespread cause of gastrointestinal illness in man and several animal species, especially calves and lambs (20). Cryptosporidium causes a profuse watery diarrhea that is more copious in immunocompromised individuals than in immunocompetent individuals (3,13). Cross-infection studies indicate that species from mammals are generally infective for other mammals (29). However, preliminary evidence suggests that mammals may be resistant to avian Cryptosporidium, which failed to experimentally infect seven mammalian species (53). Mammalian reservoirs include farm animals, beavers, and muskrats (20). Animals have been implicated as the source of Cryptosporidium in at least one waterborne outbreak. This outbreak, which occurred in England from April to October 1986, was traced to water from a reservoir complex. Cryptosporidium oocysts were found in fecal samples from cattle on farms adjoining the reservoir area, in the deposit from membrane-filtered surface water from the reservoir and streams feeding it, and in the intestinal contents of trout caught in the reservoir. Contamination of the reservoir water most probably happened via surface runoff after heavy rain (77). The stability of the oocysts in estuarine waters has not been reported. However, under highly favorable conditions, oocysts remain infective for relatively long periods of time (29).

ENVIRONMENTAL DATA

Environments in which nonpoint pollution from animal sources could provide sufficient numbers of pathogens to adversely affect the safe harvesting of shellfish include estuaries contaminated with runoff from nearby pastures or from fields fertilized with animal waste and estuaries heavily populated with wildlife, such as muskrats or migrating waterfowl. One example of a shellfish-harvesting area affected by waste from domestic animals is located at the easterly end of Long Island. This area, known as the Peconic River, Reeves Bay, Flanders Bay area was shown to contain excessive numbers of coliform organisms of nonhuman origin during the summer months. Several species of Salmonella were also isolated from these waters, and one species of Salmonella was isolated from oysters taken from a private bed in Flanders Bay. The greatest source of pollution in the area was the numerous duck farms located along the river near its entrance to the bay. These waters received duck farm wastes equivalent to the discharge of raw sewage from a village of more than 20,000 persons (6).

In areas affected by agricultural runoff, factors such as precipitation and spring snow melts have a great influence on drainage water quality (19,34,71), and it is possible for waters normally safe for shellfish harvesting to become unsafe after intense storms or during snow melts. This situation has been observed in Tillamook Bay in northern Oregon. Tillamook Bay is the drainage basin for 120 dairies. In 1980, the total cow population in this region was approximately 19,100. These cows produced 256,360 tons of manure annually. The human population was basically rural with 11,305 permanent residents. Safe harvesting of shellfish from the bay was threatened by high fecal coliform levels during rain events. Studies of the impact of
several sources of pollution indicated a potential for waterborne disease transmitted by shellfish both from animals to man and from man to man, with runoff from the dairies and septic tanks as the sources. There were no sewage plant malfunctions during the study, and nonpoint pollution from seashore in the bay and elk herds and swimmers in the forested streams was not significant (41).

Occasionally, wild animals have been identified as sources of significant numbers of pathogens in aquatic environments. In one recent incident, a *Yersinia pseudotuberculosis* infection acquired by a child was traced and has caused shellfishborne illness on several occasions (63). A survey of a relatively remote shellfish-harvesting area in Mississippi (Graveline Bayou) revealed that some areas that were free from wastes of human or domestic animal origin did not meet the standards for approved shellfish-growing areas, due to high numbers of fecal coliforms. These organisms were derived in part from soils immediately adjacent to the bayous and in part directly from wildlife living immediately adjacent to the bayous. *Salmonella* was also found in unpolluted soils, raccoon feces, and feces from a species of marsh bird (rail) that inhabited the area (73). *Salmonella* species were also isolated from oysters and from algal ponds developed to feed oysters in an experimental semiclosed system oyster farm in Hawaii. Extensive search for the *Salmonella mokola* serotype resulted in the isolation of that serotype from bird droppings collected in the vicinity of the farm, which was located in a Federal Bird Sanctuary that harbored both migratory and native species (62). Sanctuaries for aquatic birds and estuaries with large populations of mammals with aquatic habitats (muskrats, etc.) are probably more likely to contain significant numbers of pathogens than waters polluted by agricultural runoff, since the source of the pollution in these environments is the direct deposit of animal feces into the water.

The environmental stabilities of the bacterial zoonoses that could be transmitted to man via shellfish have been investigated in feces and in waters of various salinities. The data collected before 1984 were summarized by Mitscherlich and Marth (63). Unfortunately, these data were determined under a variety of different conditions (degree of salinity, temperature, etc.) and cannot easily be used either to compare the stabilities of the various pathogens in polluted estuaries or the relative risks of shellfishborne infection by these organisms. Another problem with these data is that most were collected under conditions where there was no predation by protozoa. Recent studies suggest that predation greatly affects survival of bacteria in aquatic environments (50,81). The risk of infection by a particular pathogen may depend as much on the numbers of that species that are being shed into the estuary and the consistency with which it is shed as on its persistence in the environment. This may be the reason that *C. jejuni*, one of the least environmentally stable of the enteric pathogens (63), has frequently been isolated from aquatic environments (9,12,48) and has caused shellfishborne illness on several occasions (37,76).

### SUMMARY AND ASSESSMENT OF HAZARDS

There are a number of bacterial zoonoses that have been transmitted from animals to man by water and/or foods (Table 1). Two of these zoonoses, *Salmonella* and *Campylobacter*, have been acquired by ingestion of raw shellfish (37,76). At least two other bacterial zoonoses (*Y. enterocolitica* and *Y. pseudotuberculosis*) appear to have the potential to cause shellfishborne illness. *Y. enterocolitica* has been isolated from both mussels and oysters (64,83), and *Y. pseudotuberculosis* survives in seawater for relatively long periods (63).

**TABLE 1.** Recognition of the etiologic agents and the origins of the implicated shellfish of recently reported outbreaks of shellfishborne illness.

<table>
<thead>
<tr>
<th>Etiologic agent</th>
<th>No. of outbreaks</th>
<th>% of outbreaks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Known</td>
<td>93</td>
<td>41.5</td>
</tr>
<tr>
<td>Unknown</td>
<td>131</td>
<td>58.5</td>
</tr>
<tr>
<td>Origin of Shellfish</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Known</td>
<td>105</td>
<td>46.9</td>
</tr>
<tr>
<td>Unknown</td>
<td>119</td>
<td>53.1</td>
</tr>
</tbody>
</table>

1. Calculated from the data compiled by Rippey and Verber (64) from January 1983 through August 1987.

There are also some viral and parasitic zoonoses that could possibly be transmitted from animals to man via shellfish. However, the potential for shellfishborne illness caused by these agents is more difficult to assess than that for most bacterial zoonoses. Cross-species transmission of rotaviruses and Norwalk viruses is recognized, but the numbers of these viruses shed by animals and their host ranges are not known (43). *Giardia* cysts shed by animals have caused human illness (47,54), and *Cryptosporidium* cysts from mammals are generally infective for other mammals. However, the ability of these cysts to survive in marine or estuarine waters and the abilities of shellfish to retain them are not known.

Environmental studies have shown that domestic cattle (41), domestic ducks (6), and migratory birds (62) have shed significant numbers of both indicator organisms and salmonellae into shellfish-harvesting waters. Wild birds have also shed *Campylobacter* into drinking water in numbers sufficient to cause an outbreak of gastroenteritis (18). In each of these cases, the presence of pathogens or high numbers of indicator organisms were associated with large populations of animals. Environmental studies have also shown that high concentrations of organisms of fecal origin in waters are related to runoff events such as rainfall and snow melts (19,34,71).

The relatively long list of zoonoses potentially acquired by shellfish ingestion seems to suggest that there is a problem. However, the epidemiological data do not indicate a widespread occurrence of these illnesses. Nontyphoidal species of *Salmonella*, which are considered to be of animal origin, have accounted for only 130 of the
more than 12,000 reported cases of shellfishborne salmonellosis (76). Shellfishborne campylobacteriosis has also been relatively rare with only one multicase outbreak (30) and 11 single case outbreaks (76) recorded in the United States. Furthermore, the symptoms of approximately three-fourths of reported outbreaks of unknown etiology are consistent with those of Norwalk virus (38), an agent that would most likely be the result of human fecal pollution.

Unfortunately, the available epidemiological data are not sufficient to allow any firm conclusions to be drawn with regard to the hazards of nonpoint pollution. One major problem is that the reported outbreaks account for only a small fraction of all shellfishborne illness. Outbreaks are usually only recognized when a large number of people in a group become ill at the same time. Most actual incidents of illness probably appear to be sporadic and are either not reported or reported only to the restaurant where the contaminated shellfish were ingested. It is likely that the reported incidence of shellfishborne illness parallels that of all foodborne diarrheal illness, which has been estimated to be 1 in 25 (at best) or 1 in 100 (at worst) (5).

Other problems are the large percentage of reported incidents of shellfishborne illness that are of unknown etiology and the large percentage of reported incidents in which the origins of the implicated shellfish are unknown (27,38,76). The data incorporated into Table 1 were compiled from the incidents of shellfishborne illness reported by Rippey and Verber (76). The data shown include outbreaks that occurred from the beginning of 1983 through August of 1987. During that period, 131 of the 224 reported incidents (58.5%) were of unknown etiology, and 119 (53.1%) of these outbreaks were caused by shellfish of unknown origin. Without knowledge of the etiologic agents, it is impossible to determine whether specific incidents occurred as the result of human fecal pollution, animal fecal pollution, or infection by indigenous flora. Without knowledge of the beds from which implicated shellfish were harvested, it is impossible to determine whether the infections caused by known agents, such as nontyphoidal Salmonella or Campylobacter, resulted from human or nonhuman pollution.

The data concerning the hazards of nonpoint pollution from animal sources are too equivocal to permit an objective assessment of the problem. Public health officials inclined to believe that animal pollution is a problem can point to the fairly extensive list of zoonoses that have been passed from animals to humans by foods and water as well as to specific food or waterborne outbreaks to reinforce this belief, whereas those with the opinion that animal pollution of shellfish-growing areas is of no consequence can point to the absence of solid epidemiological evidence that shellfishborne zoonoses are occurring. The resolution of this issue will require more effective reporting of incidents of shellfishborne illness to public health authorities, more effective means of tracing implicated shellfish back to the source waters, and research that will provide information relating the presence of significant numbers of pathogens in estuaries to animal species, numbers of animals, and the proximity of these animals to the estuaries.

### RECOMMENDATIONS

Because the relative health risks associated with animal versus human fecal pollution are not known, separate microbiological standards cannot presently be established for shellfish-growing waters contaminated only by nonhuman fecal pollution. Until realistic standards can be established, the application of the currently accepted coliform and fecal coliform standards to these waters should minimize the risk of infection by zoonoses. Even though these standards do not provide completely satisfactory protection against human viruses, they have provided a measurable protection against health hazards due to bacteria (60). These standards should offer even greater protection against bacterial zoonoses, which have higher infective doses than those of the human-specific pathogens, S. typhi and Shigella.

The long-term goal of future research efforts should be to establish realistic standards specifically for waters contaminated by animal pollution. These standards should be sufficiently stringent to protect against infection by zoonoses but not so stringent that waters are shut down unnecessarily. The establishment of such standards will require both microbiological and epidemiological studies.

The first step in establishing these standards would be the identification of specific estuaries where fecal pollution can only be attributed to cattle, migratory birds, seals, or other nonhuman sources. The next step would be to determine, as accurately as possible, the relationships between numbers of various indicator organisms and human health effects using an epidemiological approach. This type of study would provide a direct comparison of illness rates between volunteers given raw shellfish from waters marginally unsafe by the present standards and volunteers given raw shellfish from pristine waters. Once these relationships are established, it should be possible to determine the most appropriate indicator organism and to estimate the number of these organisms consistent with safe harvesting conditions. Analyses of symptomology and stool samples could provide data useful in determining whether viruses or parasites can be transmitted from animals to man through shellfish consumption. The volunteers could be observed for sufficient periods to allow recognition of illness due to organisms, like Giardia, that have long incubation periods.

If the results of the microbiological and epidemiological studies suggest separate standards for human and animal pollution, it would also be valuable to develop a rapid method to determine whether the source of pollution in a given estuary is human or animal. This would make it much easier to decide which indicator standard to use in waters with potential for either human or animal pollution.

Another approach would be to institute pollution prevention measures similar to those currently used by the State of Maryland (Mary Jo Garries, personal communication). These include: (i) installation of electric fences near streams and small [12 in. (30.48 cm)] earthen berms between the fences and the streams, (ii) prohibition of hog running in marshes, (iii) establishment of crops rather than grazing areas adjacent to water, (iv) establishment of a 50-ft (ca. 17.26 m) buffer plus a 12-in. (30.48 cm) berm between fields fertilized with manure and water, (v) storage
of stockpiled manure away from water, and (vi) building of roofed shelters for stockpiled manure. These measures should prevent nearly all of the pollution in shellfish waters that is due to domestic animals.

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LITERATURE CITED


