Prevalence of *Salmonella* spp. in Oysters in the United States


Department of Veterinary Science and Microbiology and Department of Soils, Water and Environmental Sciences, The University of Arizona, Tucson, Arizona; Ohio Agricultural Research and Development Center, Ohio State University, Wooster, Ohio; and College of Veterinary Medicine, North Carolina State University, Raleigh, North Carolina

Received 14 April 2004/Accepted 21 September 2004

Food-borne diseases such as salmonellosis can be attributed, in part, to the consumption of raw oysters. To determine the prevalence of *Salmonella* spp. in oysters, oysters harvested from 36 U.S. bays (12 each from the West, East, and Gulf coasts in the summer of 2002, and 12 bays, four per coast, in the winter of 2002–2003) were tested. *Salmonella* was isolated from oysters from each coast of the United States, and 7.4% of all oysters tested contained *Salmonella*. Isolation tended to be bay specific, with some bays having a high prevalence of *Salmonella*, while other bays had none. Differences in the percentage of oysters from which *Salmonella* was isolated were observed between the summer and winter months, with winter numbers much lower probably due to a variety of weather-related events. The vast majority (78/101) of *Salmonella* isolates from oysters were *Salmonella enterica* serovar Newport, a major human pathogen, confirming the human health hazard of raw oyster consumption. Contrary to previous findings, no relationship was found between the isolation of fecal coliforms and *Salmonella* from oysters, indicating a necessity for specific monitoring for *Salmonella* and other pathogens rather than the current reliance on fecal coliform testing.

Shellfish are known carriers of viral and bacterial pathogens (1, 4). In particular, the consumption of raw oysters has been linked to outbreaks of hepatitis A and viral gastroenteritis (1). The accumulation of pathogenic bacteria and viruses within the oysters make them a hazard for human consumption. Muniai-Mujika et al. (20) performed a study in which *Escherichia coli*, *Clostridium perfringens*, and somatic coliphages were isolated from 24% of shellfish, human adenovirus from 47% of shellfish, and enteroviruses from 19% of shellfish. In addition to these contaminants, oysters have also been responsible for disease outbreaks as a result of contamination with other infectious agents such as enterotoxigenic *E. coli*, *Vibrio cholerae*, *Vibrio parahaemolyticus*, *Campylobacter jejuni*, noroviruses, *Staphylococcus aureus*, hepatitis A virus, and *Salmonella* (4, 7, 9, 11, 13, 15, 19–21, 24, 26, 28, 29). Seafood and shellfish accounted for 7.42% of all food poisoning related deaths from *Salmonella* infections between 1990 and 1998 (14).

The incidence of *Salmonella* infections has risen dramatically since the 1980s with a loss of productivity in billions of dollars annually (14), and many cases are linked to seafood (6), particularly to the consumption of shellfish (14). An estimated 1.4 million annual cases of salmonellosis in the United States result in approximately 500 fatalities yearly (www.cdc.gov/ncidod/dbmd/diseaseinfo/salmonellosis_t.htm). Salmonellosis is characterized by fever, abdominal cramps, and diarrhea.

Heinitz et al. (14) tested seafood and shellfish around the world for the presence of *Salmonella* spp. and found that U.S. shellfish, particularly oysters, had a 1.2% prevalence of *Salmonella* in domestic shellfish (14). Wilson and Moore (29) conducted a study that showed that 8% of 433 shellfish contained *Salmonella*. Harvesting areas have become more populated in recent years, with more human sewage discharged into coastal waters resulting in an increase in pathogens in these waters, and thus a higher incidence of food-borne disease from shellfish (18). Oysters are filter feeders; as water flows through them, they ingest and concentrate all particulate matter in the water, including pathogenic bacteria and viruses (18).

Since the 1970s, the Food and Drug Administration (FDA) has required the shellfish industry to use fecal coliforms as indicators of contamination within harvesting waters and oysters (14, 15, 19–21). Hood et al. (15) concluded that fecal coliforms were a sufficient indicator of other bacterial pathogens, as *Salmonella* spp. were not present in the absence of fecal coliforms. However, these results are inconsistent with the studies of Heinitz et al. (14), which indicated that *Salmonella* could be present in oysters that did not contain fecal coliforms. The FDA requires that each U.S. state test harvesting waters six times per year for the presence of fecal coliforms. If fecal coliforms are detected above the most probable number (MPN) of 230/g of oyster or 230/ml of water sample, then the waters are closed to harvesting (1, 5, 27). There are no current requirements for U.S. states to test harvesting waters for the presence of human pathogens, such as *Salmonella* spp.

To determine the prevalence of *Salmonella* in oysters and their relationship to oyster fecal coliforms, oysters harvested from 36 bays (12 per coast from the West, East, and Gulf coasts during the summer of 2002, and 12 bays, four per coast, in the winter of 2002–2003) were tested.

**MATERIALS AND METHODS**

**Collection and shipment of oysters.** Bays from which oysters were to be harvested were identified on the West, East, and Gulf coasts of the United States and were restricted to those from which licensed shippers, from the Interstate...
TABLE 1. Percentage of Salmonella- and fecal coliform-positive oysters per bay in summer 2002

<table>
<thead>
<tr>
<th>West Coast bay (state)</th>
<th>% Oysters positive</th>
<th>East Coast bay (state)</th>
<th>% Oysters positive</th>
<th>Gulf Coast bay (state)</th>
<th>% Oysters positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>1W (OR)</td>
<td>19.4 (20)</td>
<td>1E (ME)</td>
<td>27.8 (45)</td>
<td>1G (FL)</td>
<td>0</td>
</tr>
<tr>
<td>2W (OR)</td>
<td>2.8 (21)</td>
<td>2E (ME)</td>
<td>72</td>
<td>2G (FL)</td>
<td>5.5 (85)</td>
</tr>
<tr>
<td>3W (WA)</td>
<td>11.1 (0)</td>
<td>3E (VA)</td>
<td>42</td>
<td>3G (FL)</td>
<td>16.7 (0)</td>
</tr>
<tr>
<td>4W (WA)</td>
<td>0 (22)</td>
<td>4E (NY)</td>
<td>38</td>
<td>4G (FL)</td>
<td>77.8 (6)</td>
</tr>
<tr>
<td>5W (WA)</td>
<td>16.7 (0)</td>
<td>5E (NY)</td>
<td>19</td>
<td>5G (LA)</td>
<td>0</td>
</tr>
<tr>
<td>6W (WA)</td>
<td>36.1 (5)</td>
<td>6E (ME)</td>
<td>41.7 (12.8)</td>
<td>6G (LA)</td>
<td>0</td>
</tr>
<tr>
<td>7W (CA)</td>
<td>0 (5)</td>
<td>7E (DE)</td>
<td>23</td>
<td>7G (LA)</td>
<td>0</td>
</tr>
<tr>
<td>8W (AK)</td>
<td>0 (39)</td>
<td>8E (DE)</td>
<td>93</td>
<td>8G (FL)</td>
<td>5.5 (78)</td>
</tr>
<tr>
<td>9W (AK)</td>
<td>0 (39)</td>
<td>9E (NY)</td>
<td>0</td>
<td>9G (FL)</td>
<td>0</td>
</tr>
<tr>
<td>10W (OR)</td>
<td>0 (15)</td>
<td>10E (SC)</td>
<td>95</td>
<td>10G (MS)</td>
<td>0</td>
</tr>
<tr>
<td>11W (AK)</td>
<td>0 (19)</td>
<td>11E (NY)</td>
<td>24.6 (0)</td>
<td>11G (LA)</td>
<td>0</td>
</tr>
<tr>
<td>12W (AK)</td>
<td>0 (8)</td>
<td>12E (NJ)</td>
<td>63</td>
<td>12G (LA)</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>7.1 (16.1)</td>
<td>Total</td>
<td>6.0 (44.0)</td>
<td>Total</td>
<td>8.8 (70.1)</td>
</tr>
</tbody>
</table>

a Sal., Salmonella. Salmonella is expressed as the percentage of oysters positive in the bay.
b Coli., fecal coliforms. Fecal coliforms are expressed as the percentage of oysters above the MPN.

RESULTS

Previous reports have suggested that oysters harvested and sold in the United States may be contaminated with potentially pathogenic Salmonella spp. (27). To assess the frequency of contamination, market oysters harvested from a total of 36 bays, 12 bays per coast (East, West, and Gulf coasts), were chosen randomly and 36 oysters from each bay were tested for the presence of Salmonella spp. by enrichment and culture on bismuth sulfite agar (Table 1). Ninety-three of 1,296 oysters examined were positive for Salmonella spp.

Salmonella spp. were isolated from oysters harvested on each coast; however, oyster contamination was not uniform. The prevalence of Salmonella isolation from the oysters was bay specific but not coast specific (Table 1). Salmonella spp. were detected in 5 of 12 West Coast bays: 2 of 3 in Oregon and 3 of 4 in Washington. Salmonella spp. were not recovered from oysters in any of the Alaskan bays. Salmonella-positive oysters were only obtained from 3 of 12 East Coast bays: 2 of 3 in Maine and the single New Jersey bay (12E), while none of 4 New York bays had detectable Salmonella contamination. The four Gulf Coast bays which contained Salmonella-positive oysters were located in Florida (4/6). Salmonella was not detected in oysters from the five Louisiana bays sampled.

Detection of fecal coliforms. Fecal coliforms were detected by using standard methodology (27). Ten-fold serial dilutions (1:10, 1:100, and 1:1,000) from the 3-mL aliquot of oyster homogenate were inoculated into five tubes of lauryl sulfate tryptose lactose broth (Difco) and incubated at 37°C for 24 h. Positive samples, determined by gas production in the tubes, were transferred to Brilliant Green lactose bile broth (Difco) for 48 h at 37°C to confirm the presence of coliforms. Positive samples were analyzed using the MPN method (27), providing an estimate of the number of fecal coliforms present per 100 g of oyster meat.

Salmonella confirmation by PCR. Putative isolates were definitively identified as Salmonella spp. by PCR with the primers SHIMA-L (5'-CGTGCTCTGGA AACGGTGAG-3') and SHIMA-R (5'-CGTGCTGTAAATAGGAATATCTTC A-3'), which amplify a 123-bp Salmonella-specific product from the himA gene (3). PCR amplification was performed on whole cells in a Bio-Rad I-Cycler (Bio-Rad, Hercules, Calif.) by using a reaction mixture of 50 mM Tris-HCl, pH 8.9, 50 mM KCl, and 2.5 mM MgCl₂, containing 200 μM dNTPs (Sigma, St. Louis, Mo.), 0.5 μM each aforementioned primer (QIAGEN, Valencia, Calif.), and 2.5 U of Taq DNA polymerase (Biolase, Celmente, Calif.). PCR conditions were as previously published (3), with a 65°C annealing temperature to provide specificity for Salmonella spp. Amplified PCR products were separated in a 1.8% Low EEO agarose (Fisher, Pittsburgh, Pa.) by using a reaction mixture of 50 mM Tris-HCl, pH 8.9, 50 mM KCl, and 2.5 mM MgCl₂, containing 200 μM dNTPs (Sigma, St. Louis, Mo.), 0.5 μM each aforementioned primer (QIAGEN, Valencia, Calif.), and 2.5 U of Taq DNA polymerase (Biolase, Celmente, Calif.). PCR conditions were as previously published (3), with a 65°C annealing temperature to provide specificity for Salmonella spp. Amplified PCR products were separated in a 1.8% Low EEO agarose (Fisher, Pittsburgh, Pa.) by using a reaction mixture of 50 mM Tris-HCl, pH 8.9, 50 mM KCl, and 2.5 mM MgCl₂, containing 200 μM dNTPs (Sigma, St. Louis, Mo.).
contamination with *Salmonella* was bay specific, the percentage of *Salmonella*-positive oysters within individual contaminated bays varied considerably from 2.8% in bay 2W (Oregon) and 12E (New Jersey) to 77.8% in bay 4G in Florida.

Twelve bays, four from each coastline, were randomly selected from those initially sampled during the summer of 2002, and a second set of oysters were examined from each of the bays approximately 6 months after the initial sampling. The average proportion of oysters harvested from the 12 bays during the summer that were contaminated with *Salmonella* spp. (13.4%) was higher than the average proportion of *Salmonella*-positive oysters harvested in the winter (1.6%) (Table 2). The difference between summer and winter samples was particularly marked in the four Gulf Coast bays, all of which were located in Florida. Three of the four bays showed *Salmonella*-contaminated oysters in summer, with an average percent *Salmonella*-positive oysters of 25% and a high of 77.8% of oysters in bay 4G. However, in winter, all four Florida bays were free of *Salmonella*-positive oysters. *Salmonella* spp. were detected in oysters harvested from a similar number of bays in the summer and winter months, on both the West and East coasts, but the proportion of positive oysters in individual samples was higher in samples harvested during the summer. These results suggest a decrease in *Salmonella* contamination in winter. However, this result is tempered by the detection of *Salmonella* in oysters from two bays, 4W and 2E, in the winter, where no *Salmonella* contamination was detected in the summer months.

*Salmonella enterica* serovar Newport was the predominant serotype isolated from oysters. To determine whether the *Salmonella* spp. isolated from oysters were major human pathogens, all *Salmonella* spp. isolated during this study were serotyped by the National Veterinary Services Laboratories of the U.S. Department of Agriculture Animal and Plant Health Inspection Services. The serotype breakdown of the 101 isolates was as follows: 78 serovar Newport, 6 serovar Typhimurium (Copenhagen), 9 serovar Arizona (21:G,Z51), 2 serovar Agona, and one each of serovars Adelaide, Arizona (65:K-Z), Bardo, Hartford, Poona, and Reading. The majority of *Salmonella* isolates on all three coasts in both summer and winter were serovar Newport. A greater variety of *Salmonella* serotypes were isolated from oysters harvested on the West Coast, with five other strains isolated. However, with the exception of one serovar Bardo isolate, only serovar Newport was observed on the Gulf Coast.

### Comparative presence of fecal coliforms and *Salmonella* spp.

Fecal coliforms or total coliform assessments of water samples are currently used by shellfish sanitation agencies to determine the sanitary suitability of specific locations for shellfish harvesting (6, 8–11, 17, 23). For each oyster tested in this study for *Salmonella* spp., the MPN of fecal coliforms was determined and contrasted with the presence of *Salmonella* spp. (Table 1 and Table 2). The percentage of oysters within a bay that exceeded the MPN 230/g limit imposed by the FDA was compared to the percentage of *Salmonella*-positive oysters on all coasts, during either season, and no consistent trend could be found between the presence of fecal coliforms over the FDA imposed limit of MPN 230/g and that of *Salmonella* spp. Therefore, in this study, fecal coliform presence was not a viable predictor of *Salmonella* presence.

In the summer on the West Coast (Table 1), fecal coliforms were detected in oysters harvested from 10 bays, but *Salmonella* spp. were detected in oysters harvested in only five bays. Oysters harvested from two bays contained only *Salmonella* spp., while oysters harvested from seven bays contained only fecal coliforms. Only bay 1W (Oregon) had an equal occurrence of oysters contaminated with both fecal coliforms and *Salmonella* spp. On the East Coast (summer) (Table 1), fecal coliforms were detected in oysters harvested in 11 bays, some with a high percentage of *Salmonella*-positive oysters. Bays 5E (Delaware) and 10E (South Carolina) had over 90% of oysters coliform positive and 2E (Maine) and 12E (New Jersey) were over 50%. *Salmonella* was detected in oysters from three bays. Bay 6E (Maine) had 42% of oysters positive for *Salmonella* and only 12% positive for fecal coliforms, whereas the other two bays containing *Salmonella* had high fecal coliform occurrence. On the Gulf Coast (summer) (Table 1), fecal coliforms were identified in ≥75% of the oysters harvested from nine bays and 100% of the oysters harvested from five bays. However, oysters positive for *Salmonella* were harvested from only four bays. In one Florida bay, 8G, 5.5% of oysters examined had *Salmonella* spp., but no fecal coliforms were detected. In addition, *Salmonella* spp. were detected in 77.1% of oysters harvested in bay 4G (Florida) but only 5% of these oysters contained fecal coliforms at levels above the FDA limit. Oysters harvested from 10 of the 12 bays tested during winter had oysters with fecal coliform contamination (Table 2). However, *Salmonella* spp. were detected in oysters harvested from one of the two bays from which no fecal coliforms were detected.

### Table 2. Percentage of *Salmonella*- and fecal coliform-positive oysters per bay in winter 2002-2003

<table>
<thead>
<tr>
<th>West Coast bay (state)</th>
<th>% Positive oysters</th>
<th>East Coast bay (state)</th>
<th>% Positive oysters</th>
<th>Gulf Coast bay (state)</th>
<th>% Positive oysters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1W (OR) 8.3 61</td>
<td>1E (ME) 0 11</td>
<td>0 17</td>
<td>0 27.8</td>
<td>Total 3.5 58.3</td>
<td>0 17</td>
</tr>
<tr>
<td>2W (OR) 2.8 0</td>
<td>2E (ME) 2.8 83</td>
<td>2.8 83</td>
<td>2G (FL) 0 17</td>
<td>Total 1.6 59.7</td>
<td>0 17</td>
</tr>
<tr>
<td>3W (WA) 0 86</td>
<td>3E (VA) 0 0</td>
<td>0 0</td>
<td>3G (FL) 0 55</td>
<td>Total 0.8 16.1</td>
<td>0 17</td>
</tr>
<tr>
<td>4W (WA) 2.8 86</td>
<td>4E (NY) 0 0</td>
<td>0 0</td>
<td>4G (FL) 0 58</td>
<td>Total 2.8 84.0</td>
<td>0 17</td>
</tr>
<tr>
<td>Total</td>
<td>3.5 58.3</td>
<td>Total</td>
<td>0.7 27.8</td>
<td>Total</td>
<td>0 65.0</td>
</tr>
</tbody>
</table>

*a* *Salmonella.* *Salmonella* is expressed as the percentage of oysters positive in the bay.

*b* Fecal coliforms. Fecal coliforms are expressed as the percentage of oysters above the MPN.
DISCUSSION

Nontyphoidal Salmonella spp. are common food-associated pathogens, and Salmonella infections account for a large proportion of deaths associated with food-related illness (6, 18). Potential pathogenic serotypes of Salmonella were isolated from oysters harvested on all three U.S. coasts. The oysters sampled were harvested from waters approved for shellfish harvesting, intended for consumers, and sold by shellfish vendors. Although shellfish sanitation agencies work diligently to ensure oysters and other shellfish are harvested from sanitary waters, pathogens that pose a risk to human health are still being detected in oysters sold for human consumption.

The prevalence of Salmonella contamination in oysters appears to be bay specific but not coast specific. Despite the fact that there were bays on each coast that contained contaminated oysters, some with a higher prevalence of contamination, the majority of bays on each coast did not have contaminated oysters.

There was a difference between summer and winter contamination levels of fecal coliforms as well as Salmonella spp. When comparing the same bays from summer to winter, the summer percentage of oysters positive for Salmonella was 13.4%, while the winter proportion was 1.6%. Martinez-Urtaza et al. (18) also noted an increase in Salmonella isolation during summer, furthering the possibility that weather has an effect on the presence of Salmonella spp. Multiple weather-related factors may be responsible for the lower isolation of Salmonella during the winter. For example, in the Gulf Coast, where Salmonella prevalence was high in summer but no Salmonella was isolated in winter, several hurricanes occurred shortly before the summer harvesting. In addition, winter is the dry season in Florida, where less rainfall and runoff occurs which may potentially reduce the fecal coliform load of these bays. Differences in Salmonella isolation between summer and winter may be due to the temperature of the water, with colder waters reducing the presence of bacteria while warmer waters may allow increased bacterial survival (22). In addition, in the summer there is a significant amount of runoff from the mountain snow which contains contaminants and accumulates contaminants as it runs off into the bays (18). Animals are also more active during the summer months, and their increased defecation into streams that feed oyster bays may result in higher fecal, as well as Salmonella, contamination rates, since many animals harbor Salmonella in their intestines (8). A large number of Salmonella serotypes have been detected in cattle. Runoff from agricultural crops may also contribute to the increase of Salmonella contamination in summer, since most crops are irrigated with recycled water, which may contain fecal and Salmonella contaminants, as stated by the United States geological survey (http://water.usgs.gov/pubs/pp/pp1655 .html). It has been documented that alfalfa sprouts also contain Salmonella spp., including serovar Newport (16, 26). If Salmonella is present when the crops are irrigated, the runoff goes into local streams. This would be a common occurrence on all coasts, crops such as alfalfa, wheat, grapes, and apples are abundant on the West Coast, tobacco on the East Coast, and citrus in the Gulf Coast.

All serotypes that were isolated from the oysters have been associated with human disease (www.cdc.gov/ncidod/dbmd/phlsdata/salmtab2001/SalmonellaAnnualSummary2001.pdf). Serovar Newport was the predominant Salmonella isolate from oysters, with 78 of 101 (77.2%) Salmonella isolates being of this serotype. Serovar Newport is emerging as an important human pathogen that has been extensively associated with cattle (8, 10). Serovar Newport also has a wide range of hosts such as cattle, swine, water fowl, and poultry, as well as marine life, which may contribute to the contamination of water sources in which oysters are harvested (8, 10, 14, 25).

Serovar Newport is an emerging Salmonella serotype associated with human salmonellosis. In 2001, serovar Newport was the third highest cause of Salmonella-associated human gastroenteritis, behind serovars Typhimurium and Enteritidis, and linked to nearly 10% of human cases of Salmonella infection (www.cdc.gov/ncidod/dbmd/phlsdata/salmtab /2001/SalmonellaAnnualSummary2001.pdf). The incidence of serovar Newport infections has increased probably as a result of multiple reservoirs for serovar Newport (8, 11, 16, 19, 22, 26) and the emergence of multidrug-resistant strains (12). The ability of serovar Newport to attach to cells from a number of different host species may be a function of the fimbriae produced by this organism (2, 7), allowing for many carriers.

One purpose of this study was to determine if the currently accepted method of fecal coliform testing was a sufficient way to examine the contamination rate of market oysters as previously proposed (15, 20). Our present study contradicts the previous work, which found no evidence of Salmonella spp. when fecal coliforms were not present (20). Our results may reflect an increasing incidence of Salmonella spp. in harvesting waters over the past decade, due to encroachment of human and animal habitation (18) on these waters. Consistent with this interpretation, our study showed a higher prevalence of Salmonella, with a national prevalence of 7.4% of oysters positive for the presence of Salmonella, than did Heinitz et al. (14), who reported just 1.2% of domestic U.S. oysters contaminated with Salmonella. While this increase seems significant, it is difficult to compare between studies because of differences in sampling strategies. However, in light of the apparent increase in prevalence of Salmonella in oysters, there is a need to update testing techniques for Salmonella in shellfish. The guidelines for oysters set forth in the Sanitation of Shellfish Growing Areas (National Shellfish Sanitation Program 1992) (5) state that the water should be tested for coliforms every three months and that the actual oyster meat be tested only every 10 years. This represents an unacceptable testing regimen for filter feeders such as oysters that concentrate all microorganisms ingested, and it ignores the apparently changing relationships between fecal coliforms and other pathogens, as indicated by Wilson and Moore (29) and our study. It is worth noting, that the waters from which the oysters in this study were harvested were not tested for coliforms or Salmonella spp., but it is likely that oyster concentrates are reflective of the contamination of the water.

The results of our study indicated that there was no correlation between fecal coliform numbers and Salmonella isolation. Some bays in which there was a high prevalence of Salmonella, as in 4G (Florida) with 77.8% of the oysters positive for Salmonella, there was a low prevalence of oysters with coliform MPN over the FDA limit. There were three bays, two in the summer and one in the winter, that only had Salmonella...
present, and coliforms were not detected. There were many bays that had both present, sometimes with high coliform and low Salmonella contamination or vice versa. In addition, many bays with high numbers of coliform-positive oysters had no Salmonella, such as 1G in Florida. Thus, monitoring of bacterial contamination of oysters solely based on coliform testing or water sampling testing is not justified and in fact is likely to overlook Salmonella-contaminated oysters. The testing of the oyster meat specifically for Salmonella spp. on a regular basis throughout the year, in each bay open for harvesting, would appear to be the only mechanism to remedy this oversight.

In conclusion, both fecal coliforms and Salmonella spp. were isolated from oysters harvested and intended for human consumption. The current use of the MPN procedure to quantify the presence of fecal coliforms does not seem to be effectively eliminating the risk of infection with Salmonella when consuming oysters. A number of alternative indicators have been examined as potential replacements for fecal and total coliform monitoring. Isolation and characterization by DNA fingerprinting, using evolving molecular technology, is being increasingly examined as an adjunct for surface water monitoring. Reliance on a single indicator may be overly optimistic and the combination of a profile of indicators may prove more useful for surface water monitoring and the classification of shellfish growing areas as either open or closed for shellfish harvesting.

ACKNOWLEDGMENTS

We thank Brian Raphael, Tanya Houghton, Michelle Lee, Kristin Little, Lori Nelson, and Naoko Wada for help with the shucking of the oysters and Amber Scott for performing the fecal coliform analyses.

This work was supported by NRC/GRP/USDA Epidemiologic Approaches to Food Safety award 2001-35212-10876.

REFERENCES


PREVALENCE OF SALMONELLA SPP. IN OYSTERS 897