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***Vibrio vulnificus* epidemiology and risk factors for mortality in the United States, 2000–2022**

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Abstract

Background: *Vibrio vulnificus* is a foodborne and waterborne pathogen causing substantial morbidity and mortality; however, its epidemiology remains poorly understood. To inform prevention and control efforts, we characterized U.S. *V. vulnificus* epidemiology and identified risk factors for mortality.

Methods: For all culture-confirmed *V. vulnificus* cases reported to the Cholera and Other *Vibrio* Illness Surveillance (COVIS) system from 2000 to 2022, patient characteristics and medical outcomes were described by foodborne vs. non-foodborne transmission routes. Risk factors for mortality were identified using multivariate logistic regression.

Results: Two thousand nine hundred and eighty-nine *V. vulnificus* cases were reported from 2000 to 2022, including 656 (22%) foodborne and 1,619 (54%) non-foodborne cases. Five-year case total increased 70% from 2000–2004 ($n = 487$) to 2018–2022 ($n = 827$). Most patients were male, older and White, with reported underlying health conditions; 2,493 (83%) patients were hospitalized and 692 (23%) died. Number of deaths (260 vs. 200) and fatality rate (40% vs. 12%) were higher among foodborne vs. non-foodborne cases. Mortality was associated with history of liver disease/alcoholism (odds ratio (OR) = 6.5, $p < 0.001$), age 45–59 (OR = 11.3, $p = 0.001$), foodborne transmission (OR = 1.3, $p = 0.006$), and Black (OR = 1.8, $p = 0.03$) or Asian (OR = 2.5, $p = 0.009$) race. Antibiotic use was protective (OR = 0.33, $p = 0.001$). Liver disease associated

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Disclosure statement

No potential conflict of interest was reported by the author(s).

Ethical approval

This activity was reviewed by CDC, deemed not research, and was conducted consistent with applicable federal law and CDC policy (see e.g. 45 C.F.R. part 46, 21 C.F.R. part 56; 42 U.S.C. §241(d); 5 U.S.C. §552a; 44 U.S.C. §3501 et seq.).

with diabetes had lower mortality than other forms of liver disease (interaction OR = 0.5, $p = 0.04$).

Conclusions: *V. vulnificus* infections confer a substantial and increasing public health burden in the United States. Non-foodborne transmission caused 2.5 times more cases, and foodborne transmission caused 30% more deaths and had >3 times higher fatality rate. Identifying risk factors for mortality can inform public health and medical interventions.

Keywords

Vibrio vulnificus; vibriosis; epidemiology; foodborne illness; wound exposure

Introduction

Vibrio bacteria, found in marine and coastal waters globally, are pathogens of increasing concern [1]. One key species, *Vibrio vulnificus*, can cause severe and life-threatening infection through foodborne and waterborne transmission [2]. More than 150 *V. vulnificus* infections are reported to the U.S. Centers for Disease Control and Prevention (CDC) every year, and approximately 20% of these are fatal [2,3].

Cases peak during summer months and typically occur in men over 45 years old with underlying health problems, particularly liver disease or other immunocompromising conditions [4–7]. Illness onset usually occurs within 24 hours, and disease progression is rapid and frequently severe. Manifestations can include septicemia, cellulitis and necrotizing skin and soft tissue infection. Septic infections can quickly progress to death without medical intervention. Antibiotics significantly improve clinical prognosis, but many surviving patients require surgical intervention, such as debridement or amputations, leaving them with permanent morbidities [8]. *V. vulnificus* patients are hospitalized for an average of 45 days, and direct medical expenses are estimated at \$4.6 million per case [9,10].

V. vulnificus bacteria are found in widespread coastal environments [5]. Bacteria can proliferate in waters warmer than 55 °F/13 °C and thrive above 68 °F/20 °C [5,11]. The primary sources of infection are wound exposure to salty or brackish water (often occurring during recreational activities), seafood consumption (particularly molluscan shellfish), and exposure to marine life or seafood drippings [5,11]. While most infections are associated with non-foodborne exposures, *V. vulnificus* is reported to be responsible for >95% of seafood-related deaths in the United States, and the fatality rate among foodborne cases is the highest reported for any enteric pathogen [4,5,11,12]. Despite the severity of this illness, many aspects of *V. vulnificus* infection remain understudied. Previous publications had small sample sizes, were limited to a singular route of infection, or used older surveillance data.

The Cholera and Other *Vibrio* Illness Surveillance (COVIS) system is coordinated by CDC to track U.S. *Vibrio* infections [13]. All 50 states collect and report data to COVIS, including details of the patient's illness, medical history and relevant exposures during the week before illness onset. To inform prevention and control efforts, this analysis aimed to describe *V. vulnificus* epidemiology and identify risk factors for mortality.

Methods

Data for all culture-confirmed *V. vulnificus* cases reported to COVIS from 2000 to 2022 were analyzed using Stata 18 (StataCorp LLC, College Station, TX). For each case, the likely transmission route was characterized as confirmed or likely foodborne, confirmed or likely non-foodborne, or unknown. Detailed methods are described elsewhere [14]; briefly, classification was conducted on an individual basis from patient exposure category (seafood consumption or skin contact with bodies of water, marine life or seafood drippings) and specimen collection site (gastrointestinal, blood/other sterile site, skin/soft tissue, or other non-sterile site). For this analysis, classification of ‘confirmed’ and ‘likely’ transmission routes were combined into a single foodborne or non-foodborne category.

Descriptive statistics were calculated overall and by transmission route for case demographic characteristics, pre-existing medical conditions, reported exposures, medical outcomes, and region of residence (Pacific, Gulf Coast, Atlantic, Noncoastal). Cases were plotted over time by transmission route and sub-region using the ggplot2 package in R 4.4.0 (R Foundation for Statistical Computing, Vienna, Austria) with sub-regions defined as Pacific (AK/HI/WA/OR/CA); Gulf Coast (TX/LA/MS/AL/FL); Southeast (NC/SC/GA); Mid-Atlantic (NY/NJ/DE/MD/DC/VA), Northeast (ME/VT/NH/MA/CT/RI) and Noncoastal (all others). Choropleth maps were created in ArcMap 10.6.1 software (ESRI, Redlands, CA) using the ESRI U.S. States layer package, and charts were developed to explore patterns of mortality by age, sex, transmission type and key underlying conditions.

To identify correlates of mortality, bivariate comparisons were conducted for all demographic, geographic and medical variables using Chi-square tests, and covariates statistically significant at the $p = 0.1$ level or identified in the literature to be associated with mortality were retained for multivariate logistic regression analysis. Relevant interactions were explored, and final model selection was conducted by Akaike information criterion optimization methods [15]. This process was repeated with models stratified by transmission route, including specific foodborne and non-foodborne exposures as potential covariates. Due to limited sample size, some categories or variables with similar outcomes were combined to maximize statistical power.

To update previously described shifts in *V. vulnificus* geography [16], latitude and longitude were assigned to non-foodborne cases from 1988 to 2022 using patient home county or location of domestic travel within a week of symptom onset. For 1,556 cases located within 200 km of the U.S. East Coast, maximum, mean and median case latitudes were calculated in five-year intervals. The 99th and 95th percentiles of latitudes were calculated to exclude possible outliers or incorrect values. Three-dimensional maps of case latitudes over time were created using the R rayshader package using county boundaries and log-transformed population data from the 2020 U.S. Census.

Patterns of missingness were explored using the R naniar package. Analyses were repeated using multiple imputation by chained equations as a sensitivity analysis. Ten imputed datasets were generated using the R mice package with 25 iterations. Logistic regression models were fit for each imputed data set overall and stratified by transmission route,

and final regression coefficients were generated using the MIANALYZE procedure in SAS 9.4 (SAS Institute Inc., Cary, NC) to combine regression coefficients across datasets. All variables were examined independently due to higher power conferred by increased sample size.

Results

Trends and demographic characteristics

From 2000 to 2022, 2,989 *V. vulnificus* cases were reported to COVIS, including 656 (21.9%) foodborne cases, 1,619 (54.2%) non-foodborne, and 714 (23.9%) with unknown transmission route (Table 1). Case patterns were highly seasonal, peaking in summer months (Figure 1). The median cases per year was 128 (IQR = 103–157) and ranged from 65 in 2000 to 192 in 2017 and 2022. The overall 5-year case total increased 70% from 487 during 2000–2004 to 827 during 2018–2022, with non-foodborne cases increasing 138% and foodborne cases decreasing 23%.

V. vulnificus patients were generally older (median age = 62, IQR = 51–73), male (83.1%), non-Hispanic White (72.5%), and had not traveled outside their home state the week before illness onset (76.2%) (Table 1, Table S1). On average, foodborne transmission patients were slightly younger than non-foodborne patients, were more likely to be female, and were twice as likely to be Black, Hispanic/Latino or Asian (24.6% vs. 11.4%). Most patients resided in the Gulf Coast for both transmission routes (51.5% foodborne, 61.7% non-foodborne), and a higher proportion of foodborne patients (15.5%) resided in Noncoastal states compared to non-foodborne patients (3.8%) (Table 1; Figures 2 and 3).

Cases per year increased across all sub-regions except the Pacific, with steepest increases seen in the Gulf Coast (slope = 2.3 cases/year) and Mid-Atlantic (slope = 1.5) (Figure 2). Due to small samples size, trends in Northeast and Pacific sub-regions were difficult to interpret. Among Atlantic Coast non-foodborne cases, the northernmost extent of cases has remained relatively static in recent years (Table S2, Figure S1).

Clinical characteristics and mortality

Most patients (76.2%) reported an underlying health condition, including 33.4% who reported liver disease and 30.2% who reported alcoholism. The most common specimen source for *Vibrio* culture was blood (65.0%); 84.5% of patients received antibiotics (Table S1). The most frequently reported medical signs and symptoms were cellulitis (60.0%), fever (51.8%), muscle pain (28.7%), septic shock (27.2%), and bullae (25.9%). Overall, 2,493 (83.4%) patients were hospitalized, 601 (20.1%) suffered serious medical sequelae (such as amputation or debridement), and 692 (23.2%) died.

Foodborne patients were more likely than non-foodborne patients to report any underlying condition (86.9% vs. 59.4%), including liver disease (50.6% vs. 14.0%) and alcoholism (36.7% vs. 14.8%), were more likely to have a blood or gastrointestinal specimen source, and were more likely to report vomiting, diarrhea, blood in stools, and abdominal cramps (Table S1). Non-foodborne patients were more likely to have a skin/soft tissue specimen source, report antibiotic use, and report cellulitis or bullae. Hospitalization rates were

comparable between transmission routes. Foodborne patients were more likely to experience septic shock (33.2% vs. 22.3%) and less likely to suffer serious medical sequelae (13.7% vs. 24.5%). In total, 260 (39.6%) foodborne patients and 200 (12.4%) non-foodborne patients died.

The case-fatality rate peaked at 50–59 years old for male, female and non-foodborne patients, declined in older ages, and then increased again for patients over 90 years (Figure 4). For patients reporting foodborne transmission or liver disease, the case-fatality rate peaked at 30–39 years old and remained high at subsequent ages. Over time, the overall 5-year case-fatality rate declined from 32.9% ($n = 160$) during 2000–2004 to 15.6% ($n = 129$) during 2018–2022, including declines in foodborne (50.0% to 28.4%) and non-foodborne (17.6% to 10.2%) mortality. This decline coincided with a decrease in reported liver disease prevalence among patients (37.2% to 16.7%) between the two periods.

Foodborne and non-foodborne exposures by transmission route

Among 656 foodborne patients with available data, 98.3% reported seafood consumption in the week before symptom onset, including 86.6% who ate molluscan bivalves and 78.9% who ate raw bivalves (Table S3). The most common seafood types consumed were any oysters (83.9%), raw oysters (78.1%), any shrimp (38.2%), and any fish (30.1%). Compared with non-fatal infections, patients with fatal foodborne infections were significantly more likely to report consuming any oysters (90.5% vs. 79.9%), raw oysters (86.2% vs. 73.4%) and raw clams (9.3% vs. 4.0%).

Among 1,619 non-foodborne patients with available data, 98.2% reported water/marine exposures, including exposures to any body of water (94.0%), salt water (54.9%), brackish water (31.1%), seafood drippings (50.1%) and marine life (36.6%). Most non-foodborne patients reported having a wound during these exposures (86.4%), including 54.2% who sustained the wound at the time of exposure, 24.8% with a pre-existing wound, and 7.2% who were uncertain. Compared with non-fatal infections, patients with fatal non-foodborne infection reported significantly lower rates of water exposure (88.5% vs. 94.6%) or having sustained a wound (37.8% vs. 56.5%) and significantly higher rates of having a wound of uncertain origin (12.8% vs. 6.5%).

Risk factors for mortality – overall

Bivariate Chi-square comparisons are shown in Table S4. In final multivariate regression models (Table 2), reported history of liver disease or alcoholism was the strongest risk factor and conferred nearly seven times higher odds of mortality (odds ratio (OR) = 6.5, 95% confidence interval (CI) = 4.6–9.3). Foodborne transmission was associated with 60% higher odds of mortality than non-foodborne transmission (OR = 1.6, 95% CI = 1.1–2.1). Antibiotic use was strongly protective, with 67% lower odds of mortality (OR = 0.33, 95% CI = 0.17–0.6). Compared with patients aged <30 years, all other age groups had higher mortality, with the strongest association in the 45–59 age group (OR = 11.3, 95% CI = 2.6–49.0). Residence in Gulf Coast (OR = 1.7) or Noncoastal (OR = 3.2) regions was associated with increased mortality compared with residence in Atlantic or Pacific regions. Non-Hispanic Black (OR = 1.8) or Asian (OR = 2.5) race was associated with significantly

increased mortality compared with non-Hispanic White race. Additional risk factors for mortality included history of gastric surgery (OR = 1.9) or cancer (OR = 1.5). History of heart disease was not statistically significant but contributed to model fit and was retained in the model.

In preliminary multivariate models, history of diabetes appeared to be protective, and possible interactions were investigated. A significant protective interaction was identified between history of liver disease/alcoholism and diabetes (OR = 0.5, 95% CI = 0.26–0.96).

Risk factors for mortality – stratified models

Final stratified multivariate models incorporated relevant transmission exposures (Table S5). Among foodborne cases, the strongest risk factor was history of raw bivalve consumption, which was associated with 3.4 times higher odds of mortality (95% CI = 1.8–6.5), followed by history of liver disease/alcoholism (OR = 2.6, 95% CI = 1.6–4.6), and history of ulcer (OR = 2.7, 95% CI = 1.2–6.1). There was a protective interaction between liver disease/alcoholism and diabetes (OR = 0.35, 95% CI = 0.13–0.98). No significant association with age, race/ethnicity or antibiotic use was identified.

Among non-foodborne cases, the strongest risk factors were history of liver disease/alcoholism (OR = 7.1, 95% CI = 4.3–11.8) and kidney disease (OR = 3.0, 95% CI = 1.7–5.5). Taking antibiotics was strongly protective (OR = 0.11, 95% CI = 0.04–0.33). Compared with patients aged <45 years, age groups of 45–59 (OR = 2.3) and 75+ (OR = 2.6) were associated with increased mortality, as was residence in the Gulf Coast compared with all other regions (OR = 1.7). Reported exposure to any body of water (OR = 0.37) and sustaining a wound during exposure (OR = 0.45) were protective of mortality. No significant association was identified with race/ethnicity and there were no significant interactions.

Missingness and sensitivity analyses

Patterns of missingness for key variables are shown in Figure S2. Missingness ranged from 0% (year, region) to >30% (certain pre-existing conditions and exposures). Patterns of missingness were not consistent across variables. Data completeness generally increased over time until the years during and immediately following the COVID-19 pandemic, when missingness increased for key medical and exposure variables.

In logistic regression models fit using multiply imputed datasets, results for the overall and non-foodborne models were nearly identical to corresponding non-imputed models (Tables S6 and S7), though race was associated with increased mortality in imputed non-foodborne models. However, in the imputed foodborne model, several variables (age, antibiotic use, race) were significantly associated with mortality that were not in the non-imputed model. The interaction term between diabetes and liver disease was indicative of a protective effect but was not statistically significant.

Discussion

This study provided critical insights into *V. vulnificus* epidemiology and involved the largest analysis of correlates of mortality to date. Over 23 years, nearly 3,000 cases and 700

deaths were reported to CDC, demonstrating a substantial public health and medical burden. More than 80% of patients were hospitalized, and one in five experienced serious medical sequelae. Most patients were male, resided in the Gulf Coast, and were infected through non-foodborne transmission; however, both the number of deaths and percent mortality were higher among foodborne cases, with mortality averaging 43% among those with a known outcome. The per-case cost of *V. vulnificus* averaging over \$4 million also makes this the most expensive foodborne infection, with direct costs per case approximately double those of *Listeria* or botulism and two to three orders of magnitude higher than *Salmonella*, *Campylobacter* or toxigenic *E. coli* [9,10].

Over the observed period, case counts increased substantially, with most of this increase driven by non-foodborne transmission. This corroborates previous research demonstrating the growing importance of environmental routes of *V. vulnificus* transmission [5,6]. Notably, the mortality rate for both foodborne and non-foodborne cases declined over time, which may be explained by an observed simultaneous decline in relevant comorbid conditions or may indicate improved medical awareness or management.

Concurring with previous literature, older age, history of liver disease, and other immunocompromising conditions were key correlates of mortality [4–7]. Middle age was most strongly associated with mortality even when controlling for pre-existing conditions, perhaps indicating that people with relevant comorbidities might have been less likely to survive into older adulthood. Furthermore, despite most patients being male, sex was not associated with mortality. This surprising result could indicate differential susceptibility to infection but not severe illness. Previous studies demonstrated a possible role of estrogen in preventing endotoxic shock from *V. vulnificus* [17], but this effect would presumably protect against both clinical illness and death.

Several novel findings emerged from this study that may support prevention and response efforts. This is the first known analysis showing differences in *V. vulnificus* mortality by race. Identifying as non-Hispanic Black or Asian was associated with significantly increased odds of mortality in overall and imputed models. This effect was not significant in stratified models, potentially due to smaller sample size and therefore reduced statistical power. Possible causes for this differing mortality rate are numerous and have been described for a wide range of acute and chronic health issues, including potential differences in healthcare access, treatment and quality [18,19]. Moving forward, educating healthcare providers and community members on the seriousness of *V. vulnificus* infection and the higher mortality rate of *V. vulnificus* among specific groups could encourage more rapid healthcare-seeking, diagnosis and appropriate management of infections in these populations.

Furthermore, the novel interaction between diabetes and liver disease/alcoholism indicates that having both conditions was associated with lower odds of mortality than having either condition alone, despite each being associated with increased mortality in bivariate analyses. Since liver damage is one of the known consequences of long-term diabetes, a possible explanation could be that early liver disease caused by diabetes is less strongly associated with *V. vulnificus* mortality than other types of liver disease, such as alcoholic cirrhosis or hepatitis. This explanation is consistent with previous literature showing that alcoholic

cirrhosis was the liver disease most strongly associated with *V. vulnificus* mortality, and that diabetes was not consistently associated with mortality [7,8,20,21]. Human and animal studies have also indicated that high blood levels of iron are correlated with increased proliferation of *V. vulnificus*, and that advanced cirrhosis caused by various etiologies is associated with excessive blood iron levels, reduced phagocytic activity, and reduced antibody response compared with other types of liver disease, offering a potential biological explanation for this observation [22,23].

In models stratified by transmission type, consuming raw bivalves was strongly associated with mortality among foodborne cases, concurring with previous literature [4,5,24,25]. However, surprising results emerged for non-foodborne transmission. Across all analyses, reported exposure to bodies of water and having sustained a wound were protective against mortality. This finding could be explained by the low proportion of patients reporting no water exposures, potentially resulting in unstable estimates. This could also be an artifact of reporting bias, differential care-seeking or differential medical treatment among patients who were aware of and remembered their exposures and/or sustaining a wound compared with those who did not.

The previously described expansion of *V. vulnificus* range related to shifts in ocean temperatures and the impact of extreme weather events is notable [16,26–28]. Since these bacteria thrive in warmer temperatures, even short-term temperature increases can provide conditions for proliferation. For instance, in 2023–2024, warmer-than-average sea temperatures on the U.S. Eastern Seaboard were associated with increased *V. vulnificus* case counts, including in several northeastern states (CT, RI, NY) with typically few reported cases [3,29,30]. International studies have also shown correlation between warming sea surface temperatures and the emergence of vibrios including *V. vulnificus* [31,32]. Increased cases were also reported after coastal flooding caused by hurricanes Katrina, Ian and Helene, and recent studies suggest higher sea surface temperatures may be associated with increased hurricane intensity [28,33–36]. If sea surface temperatures continue to rise, *V. vulnificus* cases may be expected to continue increasing, particularly at higher latitudes with large population centers and in regions susceptible to tropical storms [16,28].

These results suggest pathways for public health and medical management of *V. vulnificus*. Earlier diagnosis and medical intervention has been shown to improve patient outcomes [7,37,38]. To support faster initiation of care and appropriate clinical management including prompt antibiotic use, public health entities can partner with healthcare providers to improve *V. vulnificus* knowledge and increase awareness of risk factors for mortality. Education is likely needed among providers in areas of emergence (i.e. the Northeast, Noncoastal areas) and those who treat racial minority communities, who constitute a lower proportion of patients with *V. vulnificus* but are more likely to die from infection. To this end, providers nationwide should have a high suspicion of *V. vulnificus* infection among patients with liver disease or immunocompromising conditions who present with sepsis or characteristic dermatologic signs (cellulitis, bullae, necrosis). In turn, to support behavior change or earlier care-seeking by ill persons, healthcare providers should consider educating patients with liver disease and other immunocompromising conditions on potential risks of raw shellfish consumption or participating in coastal water activities and on appropriate rapid

action if symptoms develop. Similarly, local public health agencies can conduct community education for populations at increased risk, especially in emerging areas. Further research is also warranted to assess current levels of *V. vulnificus* awareness among healthcare providers and populations at increased risk.

Limitations

This analysis has several limitations. Due to the nature of *V. vulnificus* surveillance, it was possible to identify correlates of mortality but not of illness, since a suitable population comparison group was not available. Underreporting to COVIS is likely, particularly among subclinical cases, which could bias results towards more severe cases. Only culture-confirmed cases were included in this analysis; this excludes diagnoses by culture-independent diagnostic testing, potentially biasing results, but these effects are anticipated to be minimal. Finally, high levels of data missingness precluded a detailed analysis of antibiotic efficacy and could affect the ability to accurately identify correlates of mortality because patients who die are more likely to have missing data. This highlights the importance of complete data reporting for each case to the extent feasible. Still, imputed models were generally similar to models using non-imputed data, increasing confidence that associations identified are accurate. Differences in imputed models may be largely explained by the larger sample size and improved power.

Conclusions

Over 23 years, *V. vulnificus* was responsible for a significant and increasing public health burden in the United States. Non-foodborne transmission caused the highest number of cases, but foodborne transmission was associated with more deaths and had over three-times higher fatality rate during the observed period, underscoring the importance of this infection as both a foodborne and non-foodborne disease. To decrease morbidity and mortality from *V. vulnificus*, additional awareness and action is needed by healthcare workers and the public to reduce exposures, increase clinical suspicion, improve speed of diagnosis, and improve clinical management. This is particularly critical for people with predisposing conditions, in certain racial groups, and in regions with emerging endemicity. Moving forward, local public health and medical personnel can work together to reduce cases and improve outcomes.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Data availability statement

Data are publicly available upon request from the COVIS surveillance system at CDC.

References

- [1]. Baker-Austin C, Lake I, Archer E, et al. Stemming the rising tide of *Vibrio* disease. *Lancet Planet Health*. 2024; 8(7):e515–e520. doi:10.1016/S2542-5196(24)00124-4. [PubMed: 38969478]
- [2]. Centers for Disease Control and Prevention. Clinical overview of vibriosis; 2024. Available from: <https://www.cdc.gov/vibrio/hcp/clinical-overview/index.html> [accessed 2024 Dec 6].
- [3]. Hughes MJ, Flaherty E, Lee N, et al. Notes from the field: severe *Vibrio vulnificus* infections during heat waves – three Eastern U.S. States, July–August 2023. *MMWR Morb Mortal Wkly Rep*. 2024;73(4):84–85. doi:10.15585/mmwr.mm7304a3. [PubMed: 38300849]
- [4]. Jones MK, Oliver JD. *Vibrio vulnificus*: disease and pathogenesis. *Infect Immun*. 2009;77(5):1723–1733. doi:10.1128/IAI.01046-08. [PubMed: 19255188]
- [5]. Baker-Austin C, Oliver JD. *Vibrio vulnificus*: new insights into a deadly opportunistic pathogen. *Environ Microbiol*. 2018;20(2):423–430. doi:10.1111/1462-2920.13955. [PubMed: 29027375]
- [6]. Dechet AM, Yu PA, Koram N, et al. Nonfoodborne *Vibrio* infections: an important cause of morbidity and mortality in the United States, 1997–2006. *Clin Infect Dis*. 2008;46(7):970–976. doi:10.1086/529148. [PubMed: 18444811]
- [7]. Elnahla A, Attia AS, Toraih E, et al. Prognostic factors of mortality in *Vibrio vulnificus* sepsis and soft tissue infections: meta-analysis. *Surg Infect*. 2021;22(9):928–939. doi:10.1089/sur.2020.243.
- [8]. Liu JW, Lee IK, Tang HJ, et al. Prognostic factors and antibiotics in *Vibrio vulnificus* septicemia. *Arch Intern Med*. 2006;166(19):2117–2123. doi:10.1001/archinte.166.19.2117. [PubMed: 17060542]
- [9]. Minor T, Lasher A, Klontz K, et al. The per case and total annual costs of foodborne illness in the United States. *Risk Anal*. 2015;35(6):1125–1139. doi:10.1111/risa.12316. [PubMed: 25557397]
- [10]. Hoffmann S, White AE, McQueen RB, et al. Economic burden of foodborne illnesses acquired in the United States. *Foodborne Pathog Dis*. 2025;22(1):4–14. doi:10.1089/fpd.2023.0157. [PubMed: 39354849]
- [11]. Bross MH, Soch K, Morales R, et al. *Vibrio vulnificus* infection: diagnosis and treatment. *Am Fam Physician*. 2007;76(4):539–544. [PubMed: 17853628]
- [12]. Mead PS, Slutsker L, Dietz V, et al. Food-related illness and death in the United States. *Emerg Infect Dis*. 1999; 5(5):607–625. doi:10.3201/eid0505.990502. [PubMed: 10511517]
- [13]. Centers for Disease Control and Prevention. Cholera and Other *Vibrio* Illness Surveillance; 2024 [accessed 2024 Nov 26]. Available from: <https://www.cdc.gov/vibrio/php/surveillance/index.html>
- [14]. Centers for Disease Control and Prevention. Cholera and Other *Vibrio* Illness Surveillance: annual summary, 2019; 2024 [accessed 2024 Nov 26]. Available from: <https://www.cdc.gov/vibrio/php/surveillance/annual-summary-2019.html>
- [15]. Yamashita T, Yamashita K, Kamimura R. A stepwise AIC method for variable selection in linear regression. *Commun Stat Theor Methods*. 2007;36(13):2395–2403. doi:10.1080/03610920701215639.
- [16]. Archer EJ, Baker-Austin C, Osborn TJ, et al. Climate warming and increasing *Vibrio vulnificus* infections in North America. *Sci Rep*. 2023;13(1):3893. doi:10.1038/s41598-023-28247-2. [PubMed: 36959189]
- [17]. Merkel SM, Alexander S, Zufall E, et al. Essential role for estrogen in protection against *Vibrio vulnificus*-induced endotoxic shock. *Infect Immun*. 2001;69(10):6119–6122. doi:10.1128/IAI.69.10.6119-6122.2001. [PubMed: 11553550]
- [18]. Fiscella K, Sanders MR. Racial and ethnic disparities in the quality of health care. *Annu Rev Public Health*. 2016;37(1):375–394. doi:10.1146/annurev-publhealth-032315-021439. [PubMed: 26789384]

- [19]. Lee C, Ayers SL, Kronenfeld JJ. The association between perceived provider discrimination, healthcare utilization and health status in racial and ethnic minorities. *Ethn Dis.* 2009;19(3):330–337. [PubMed: 19769017]
- [20]. Chuang PY, Yang TY, Huang TW, et al. Hepatic disease and the risk of mortality of *Vibrio vulnificus* necrotizing skin and soft tissue infections: a systematic review and meta-analysis. *PLOS One.* 2019;14(10):e0223513. doi: 10.1371/journal.pone.0223513. [PubMed: 31652263]
- [21]. Zhao H, Xu LC, Dong HH, et al. Correlations between clinical features and mortality in patients with *Vibrio vulnificus* infection. *PLOS One.* 2015;10(8):e0136019. doi:10.1371/journal.pone.0136019. [PubMed: 26274504]
- [22]. Hor LI, Chang TT, Wang ST. Survival of *Vibrio vulnificus* in whole blood from patients with chronic liver diseases: association with phagocytosis by neutrophils and serum ferritin levels. *J Infect Dis.* 1999;179(1):275–278. doi:10.1086/314554. [PubMed: 9841854]
- [23]. Hor LI, Chang YK, Chang CC, et al. Mechanism of high susceptibility of iron-overloaded mouse to *Vibrio vulnificus* infection. *Microbiol Immunol.* 2000;44(11):871–878. doi:10.1111/j.1348-0421.2000.tb02577.x. [PubMed: 11145266]
- [24]. Hlady WG, Klontz KC. The epidemiology of *Vibrio* infections in Florida, 1981–1993. *J Infect Dis.* 1996;173(5): 1176–1183. doi:10.1093/infdis/173.5.1176. [PubMed: 8627070]
- [25]. Shapiro RL, Altekruse S, Hutwagner L, et al. The role of Gulf Coast oysters harvested in warmer months in *Vibrio vulnificus* infections in the United States, 1988–1996. *J Infect Dis.* 1998;178(3):752–759. doi:10.1086/515367. [PubMed: 9728544]
- [26]. Froelich BA, Daines DA. In hot water: effects of climate change on *Vibrio*-human interactions. *Environ Microbiol.* 2020;22(10):4101–4111. doi:10.1111/1462-2920.14967. [PubMed: 32114705]
- [27]. Deeb R, Tufford D, Scott GI, et al. Impact of climate change on *Vibrio vulnificus* abundance and exposure risk. *Estuaries Coast.* 2018;41(8):2289–2303. doi:10.1007/s12237-018-0424-5. [PubMed: 31263385]
- [28]. Jayakumar JM, Martinez-Urtaza J, Brumfield KD, et al. Climate change and *Vibrio vulnificus* dynamics: a blueprint for infectious diseases. *PLoS Pathog.* 2024;20(12):e1012767. doi:10.1371/journal.ppat.1012767. [PubMed: 39680617]
- [29]. National Oceanic and Atmospheric Administration. U.S. saw its 9th-warmest August on record; 2023 [accessed 2024 Nov 26]. Available from: <https://www.noaa.gov/news/us-saw-its-9th-warmest-august-on-record>
- [30]. Rhode Island Department of Health. Rhode islanders reminded about health risks of open wounds and coastal waters [press release]; 2024. <https://www.ri.gov/press/view/47914>
- [31]. Baker-Austin C, Trinanès JA, Taylor NGH, et al. Emerging *Vibrio* risk at high latitudes in response to ocean warming. *Nat Clim Change.* 2013;3(1):73–77. doi:10.1038/nclimate1628.
- [32]. LeRoux F, Wegner KM, Baker-Austin C, et al. The emergence of *Vibrio* pathogens in Europe: ecology, evolution, and pathogenesis (Paris, 11–12th March 2015). *Front Microbiol.* 2015;6:830. [PubMed: 26322036]
- [33]. Gilford DM, Giguere J, Pershing AJ. Human-caused ocean warming has intensified recent hurricanes. *Environ Res Clim.* 2024;3(4):045019.
- [34]. Centers for Disease Control and Prevention (CDC). *Vibrio* illnesses after Hurricane Katrina—multiple states, August–September 2005. *MMWR Morb Mortal Wkly Rep.* 2005;54(37):928–931. [PubMed: 16177685]
- [35]. Sodders N, Stockdale K, Baker K, et al. Notes from the field: vibriosis cases associated with flood waters during and after Hurricane Ian – Florida, September–October 2022. *MMWR Morb Mortal Wkly Rep.* 2023;72(18): 497–498. doi:10.15585/mmwr.mm7218a5. [PubMed: 37141149]
- [36]. Florida Department of Health. *Vibrio vulnificus* [accessed 2025 Jan 6]; 2025. Available from: <https://www.floridahealth.gov/diseases-and-conditions/vibrio-infections/vibrio-vulnificus/index.html>
- [37]. Lee YC, Hor LI, Chiu HY, et al. Prognostic factor of mortality and its clinical implications in patients with necrotizing fasciitis caused by *Vibrio vulnificus*. *Eur J Clin Microbiol Infect Dis.* 2014;33(6):1011–1018. doi:10.1007/s10096-013-2039-x. [PubMed: 24419406]

- [38]. Hong G, Wu B, Lu C, et al. Emergency treatment of 16 patients with necrotizing fasciitis caused by *Vibrio vulnificus* infection complicated with septic shock. Chin Med J. 2014;127(10):1984–1986. doi:10.3760/cma.j.issn.0366-6999.20140145. [PubMed: 24824268]

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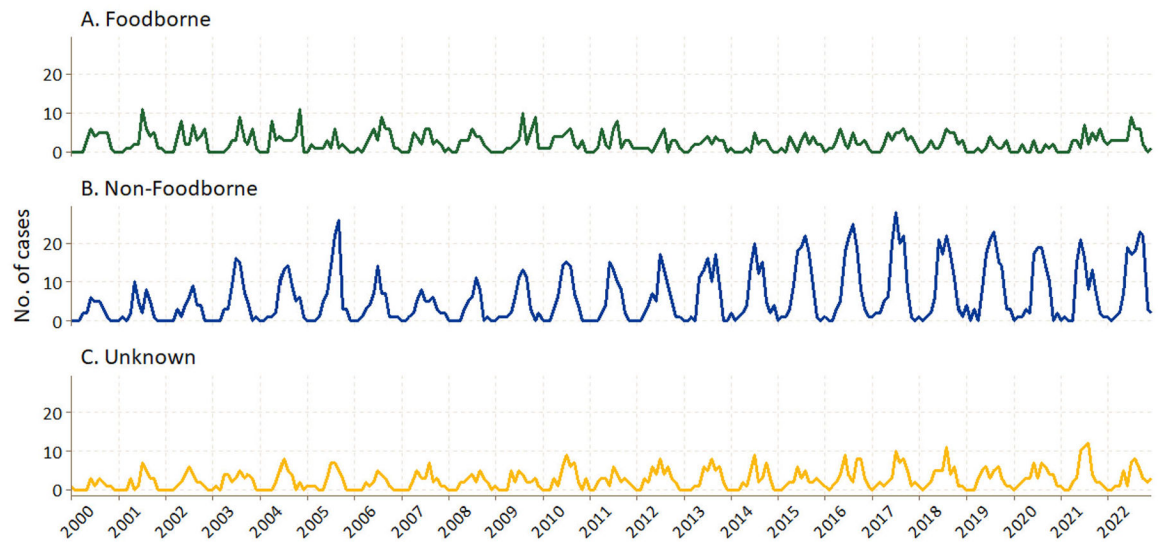
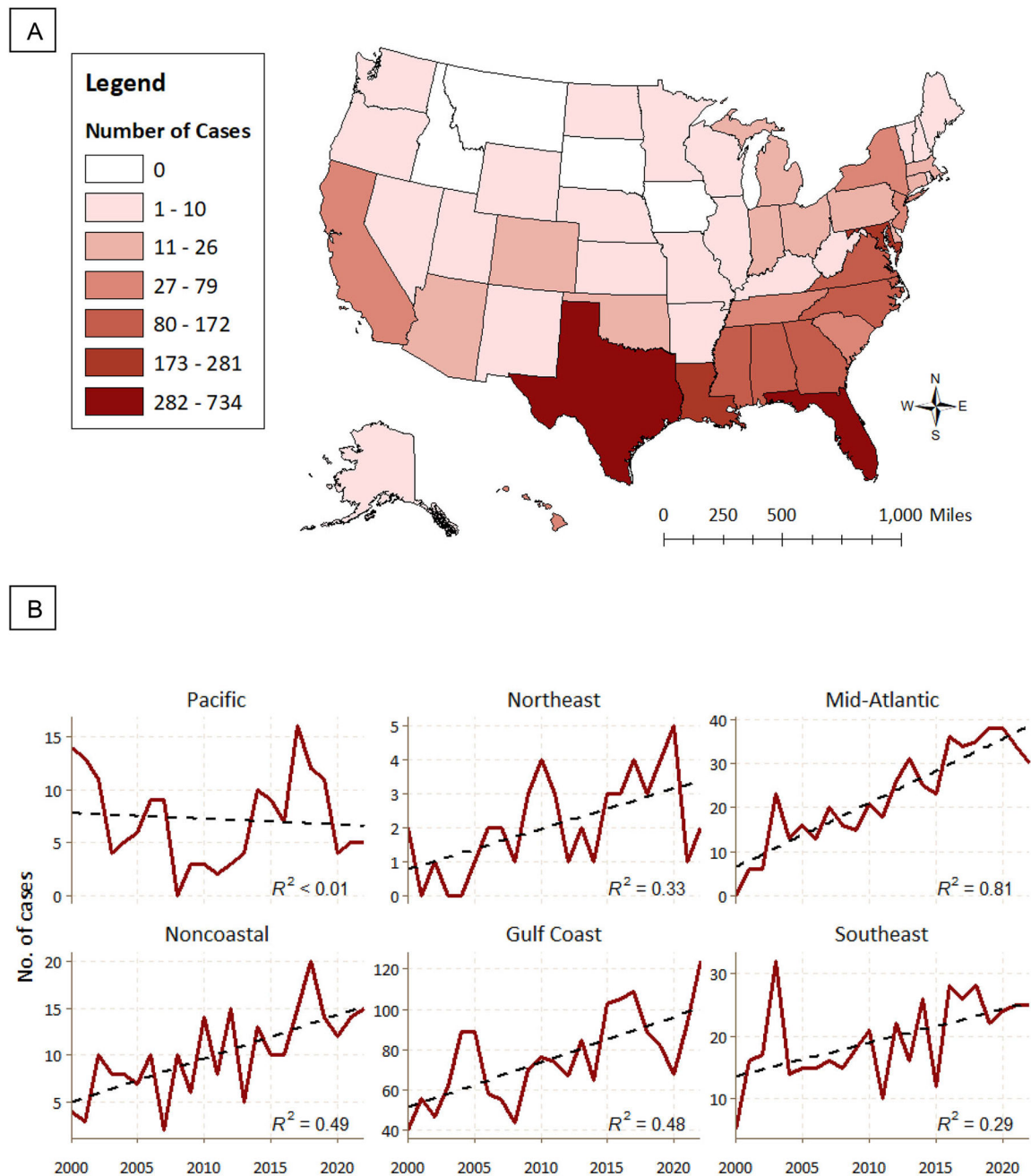


Figure 1.

Timeline of *Vibrio vulnificus* reported by month to COVIS surveillance system from 2000 to 2022 by transmission type: (A) confirmed or probable foodborne transmission, (B) confirmed or probable non-foodborne transmission, or (C) unknown transmission type.

**Figure 2.**

(A) National distribution of *Vibrio vulnificus* cases reported to COVIS from 2000 to 2022.

(B) Change in *V. vulnificus* cases over time for the following regions: Pacific (AK, HI, WA or CA); Gulf Coast (TX, LA, MS, AL, FL); Southeast (NC, SC, GA); Mid-Atlantic (NY, NJ, DE, MD, DC, VA), Northeast (ME, VT, NH, MA, CT, RI) and Non-Coastal (all others).

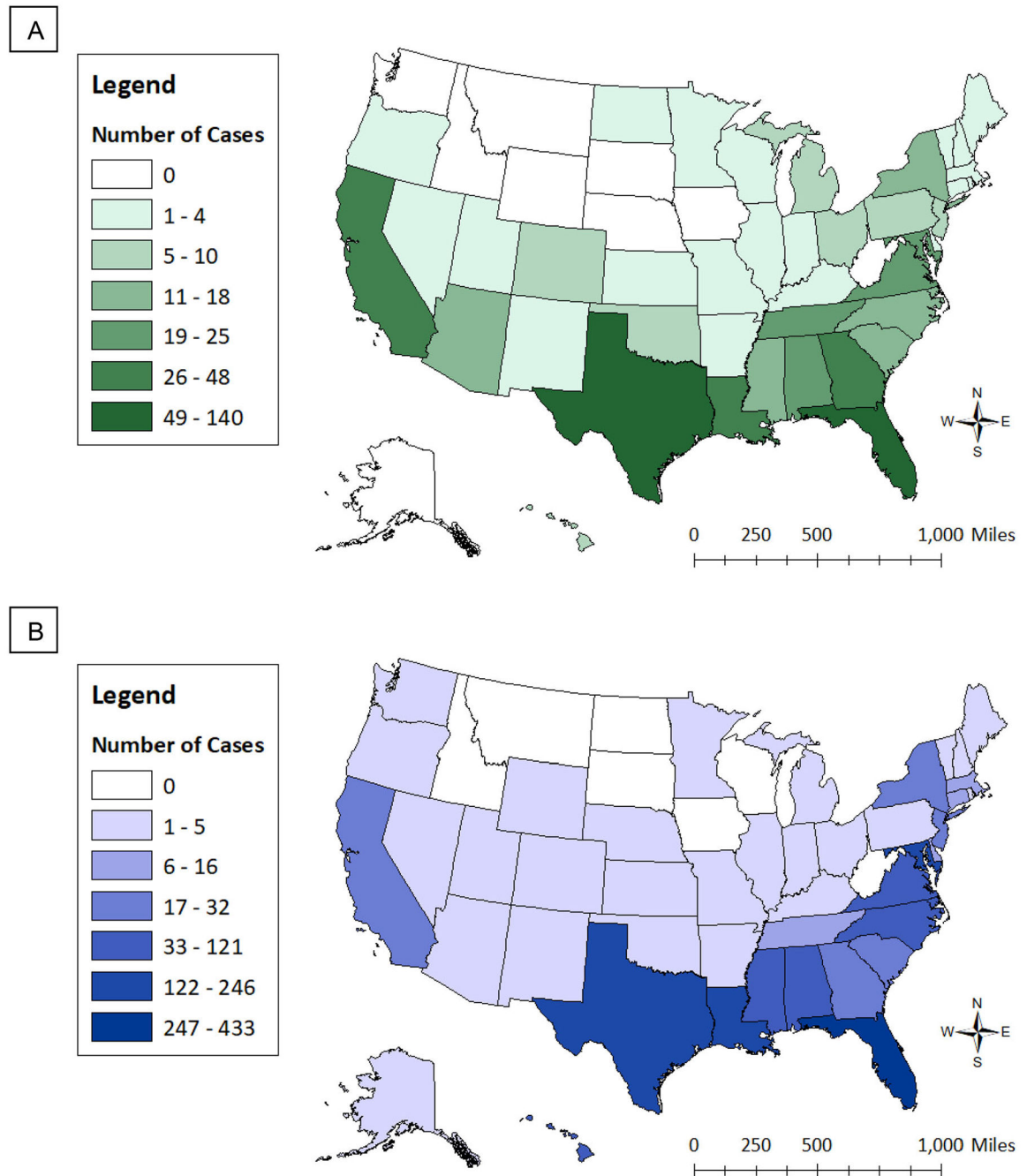
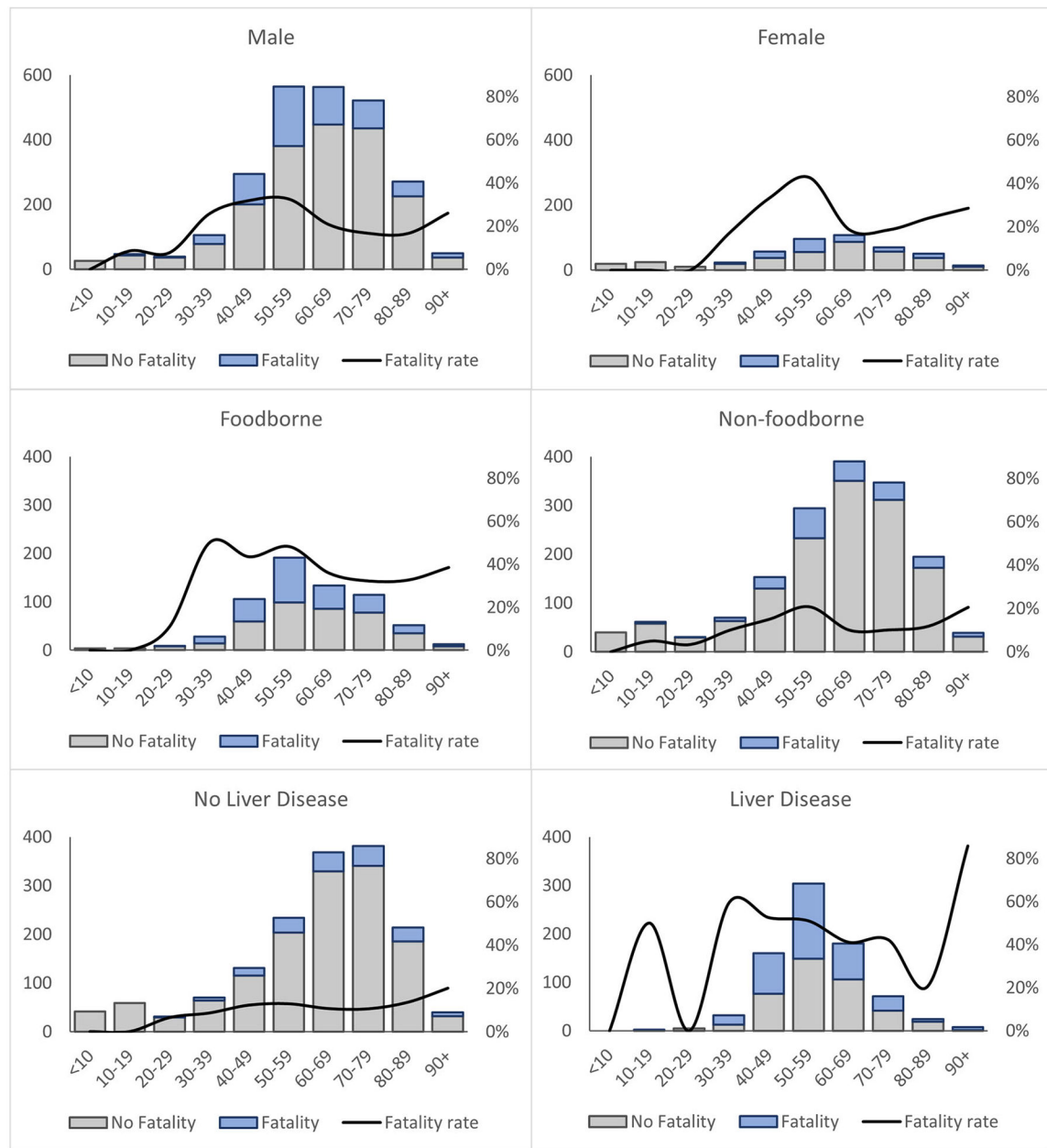


Figure 3.
Distribution of (A) foodborne and (B) non-foodborne *Vibrio vulnificus* cases reported to COVIS from 2000 to 2022.

**Figure 4.**

Age distribution of fatal and non-fatal *Vibrio vulnificus* cases reported to COVIS from 2000 to 2022 by sex, transmission type, and liver disease status. Fatality rates range from 0 to 86% by category.

Table 1.

Demographic characteristics and clinical outcomes for *Vibrio vulnificus* cases reported to COVIS between 2000 and 2022 by transmission route (defined as confirmed or probable foodborne transmission, confirmed or probable non-foodborne transmission, or unknown).

	All cases (%) <i>N</i> = 2,989	Foodborne (%) <i>n</i> = 656 (21.9%)	Non-foodborne (%) <i>n</i> = 1,619 (54.2%)	Unknown (%) <i>n</i> = 714 (23.9%)
<i>Demographic characteristics</i>				
Median age (years) [IQR, range]	62 [51–73, 0–100]	59 [50–71, 0–100]	64 [51–74, 1–96]	62 [52–73, 0–96]
Age group (years)				
<30	168 (5.6%)	17 (2.6%)	131 (8.1%)	20 (2.8%)
30–44	292 (9.8%)	70 (10.7%)	145 (9.0%)	77 (10.8%)
45–59	857 (28.7%)	255 (38.9%)	372 (23.0%)	230 (32.2%)
60–74	981 (32.8%)	186 (28.4%)	567 (35.0%)	28 (31.9%)
75+	660 (22.1%)	123 (18.7%)	382 (23.6%)	155 (21.7%)
Unknown	31 (1.0%)	5 (0.8%)	22 (1.4%)	4 (0.6%)
Sex				
Male	2,484 (83.1%)	517 (78.8%)	1,375 (84.9%)	592 (82.9%)
Female	470 (15.7%)	131 (20.0%)	223 (13.8%)	116 (16.2%)
Unknown	35 (1.2%)	8 (1.2%)	21 (1.3%)	6 (0.8%)
Race/ethnicity				
White/Caucasian	2,166 (72.5%)	409 (62.4%)	1,291 (79.7%)	466 (65.3%)
Black/African American	191 (6.4%)	57 (8.7%)	69 (4.3%)	65 (9.1%)
Hispanic/Latino	213 (7.1%)	70 (10.7%)	82 (5.1%)	61 (8.5%)
Asian	98 (3.3%)	34 (5.2%)	32 (2.0%)	32 (4.5%)
Other ^a	52 (1.7%)	10 (1.5%)	29 (1.8%)	13 (1.8%)
Unknown	269 (9.0%)	76 (11.6%)	116 (7.2%)	77 (10.8%)
Geographic region of residence				
Gulf Coast	1,750 (58.6%)	338 (51.5%)	999 (61.7%)	413 (57.8%)
Atlantic	839 (28.1%)	169 (25.8%)	475 (29.3%)	195 (27.3%)
Pacific	165 (5.5%)	47 (7.2%)	83 (5.1%)	35 (4.9%)
Noncoastal	235 (7.9%)	102 (15.5%)	62 (3.8%)	71 (9.9%)
<i>Clinical outcomes</i>				
Patient died				
Yes	693 (23.2%)	260 (39.6%)	200 (12.4%)	233 (32.6%)
No	2,017 (67.5%)	350 (53.4%)	1,268 (78.3%)	399 (55.9%)
Unknown	279 (9.3%)	46 (7.0%)	151 (9.3%)	82 (11.5%)
Patient hospitalized				
Yes	2,493 (83.4%)	560 (85.4%)	1,311 (81.0%)	622 (87.1%)
No	342 (11.4%)	76 (11.6%)	229 (14.1%)	37 (5.2%)
Unknown	154 (5.2%)	20 (3.0%)	79 (4.9%)	55 (7.7%)
Serious sequelae ^b				
Yes	601 (20.1%)	90 (13.7%)	396 (24.5%)	115 (16.1%)
No	1,575 (52.7%)	372 (56.7%)	837 (51.7%)	366 (51.3%)

	All cases (%) <i>N</i> = 2,989	Foodborne (%) <i>n</i> = 656 (21.9%)	Non-foodborne (%) <i>n</i> = 1,619 (54.2%)	Unknown (%) <i>n</i> = 714 (23.9%)
Unknown	813 (27.2%)	194 (29.6%)	386 (23.8%)	233 (32.6%)

^a Includes approximately 0.7% native Hawaiian/Pacific Islander and 0.4% American Indian/Alaska Native.

^b Includes outcomes such as amputation, debridement and skin grafts.

Table 2.

Factors associated with mortality among *Vibrio vulnificus* cases reported to COVIS between 2000 and 2022 using multivariate logistic regression ($N = 1,669$).

Participant characteristic	OR	95% CI	<i>p</i>
History of liver disease or alcoholism ^a	6.5	4.6, 9.3	<0.001
History of diabetes	1.0	0.63, 1.7	0.9
Interaction: (liver disease or alcoholism) × diabetes	0.50	0.26, 0.96	0.04
History of gastric surgery	1.9	1.2, 3.2	0.01
History of cancer	1.5	1.0, 2.3	0.04
History of heart disease	1.3	0.96, 1.9	0.09
Taken antibiotics	0.33	0.17, 0.63	0.001
Foodborne transmission route	1.6	1.1, 2.1	0.006
Age <30	Ref.		
Age 30–44	7.5	1.6, 34.2	0.01
Age 45–59	11.3	2.6, 49.0	0.001
Age 60–74	6.9	1.6, 30.4	0.01
Age 75+	10.2	2.3, 45.5	0.002
Residence in Atlantic region	Ref.		
Gulf Coast region	1.7	1.2, 2.4	0.005
Noncoastal region	3.2	1.8, 5.8	<0.001
Pacific region	1.1	0.50, 2.3	0.9
White/Caucasian	Ref.		
Black/African American	1.8	1.1, 3.1	0.03
Hispanic/Latino	1.5	0.91, 2.5	0.1
Asian	2.5	1.3, 4.9	0.009
Other race/ethnicity ^b	0.48	0.13, 1.7	0.3

^a Combined history of liver disease and alcoholism in multivariate analyses to preserve sample size and analytic power.

^b Includes native Hawaiian/Pacific Islander, American Indian/Alaska Native and reported 'other' category. Italic values denote *p* values <0.05.