The Influence of Climate Change on Vibriosis in the United States: Projected Health and Economic Impacts for the 21st Century

Session: **GH45A. Modeling Exposure of Infectious and Vector-Borne Disease I eLightning**

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Mike Kolian, USEPA

Washington, DC

Research Overview

Background: This work represents the first national-level (United States) estimate of the economic impacts of vibriosis cases as exacerbated by climate change. Vibriosis is an illness contracted through foodborne and waterborne exposures to various *Vibrio* species (e.g., non-*V. cholerae* O1 and O139 serotypes) found in estuarine and marine environments, including within aquatic life such as shellfish and finfish.

Objective: The objective of this study was to project climate-induced changes in vibriosis related to sea surface temperatures (SSTs) and the associated economic impacts in the U.S.

Methods: Our analysis constructed three logistic regression models by *Vibrio* species, using vibriosis data sourced from the Cholera and Other Vibrio Illness Surveillance (COVIS) system and using historical SSTs. We relied on previous estimates of the cost-per-case of vibriosis to estimate future total annual medical costs, lost income from productivity loss, and mortality-related indirect costs throughout the U.S. We separately report results for *V. parahaemolyticus*, *V. vulnificus*, *V. alginolyticus*, and “V. spp" given the different associated health burdens of each. SSTs) and associated economic impacts in the U.S.

Results and Discussion

Results: By 2090, increases in SST are estimated to result in a 51 percent increase in cases annually relative to the baseline era (1995) under Representative Concentration Pathway (RCP) 4.5 and a 108 percent increase under RCP8.5. The cost of these illnesses is projected to reach over $5.2 billion annually under RCP4.5 and $7.3 billion annually under RCP8.5, relative to $2.2 billion in the baseline (2018 dollars), equivalent to 140 percent and 234 percent increases, respectively.

Discussion: Vibriosis incidence is likely to increase in the U.S. under moderate and unmitigated climate change scenarios through increases in SST, resulting in a substantial burden of morbidity and mortality, and costing millions of dollars. These costs are mostly attributable to deaths, primarily from exposure to *V. vulnificus*. Evidence suggests that other factors, including sea surface salinity, may contribute to further increases in vibriosis cases in some regions of the U.S. and should be investigated.

Status: Our paper just resubmitted and is currently in review with the journal Environmental Health Perspectives (EHP).

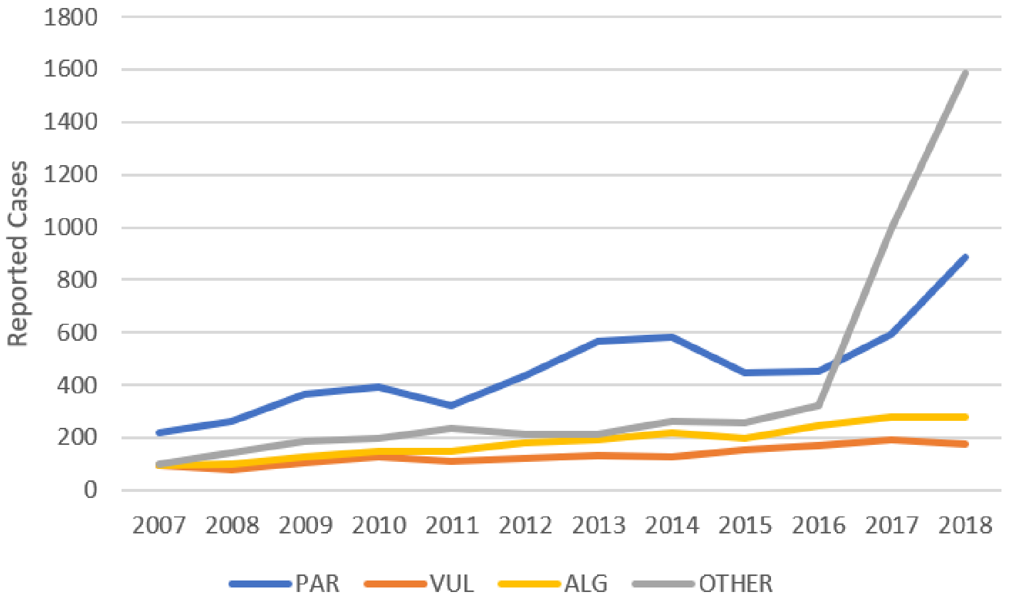
Research Team:
Megan Sheahan[2], Caitlin Gould[1], James Neumann[2], Patrick L Kinney[3], Sandra Hoffmann[4], Charles Fant[2] and Selina Wang[5], (1)Environmental Protection Agency Washington DC, Washington, DC, United States, (2)Industrial Economics, Inc., Cambridge, MA, United States, (3)Boston University, School of Public Health, New York, NY, United States, (4)US Department of Agriculture Economic Research Service, Washington, DC, United States, (5)Tufts University, Medford, United States

Steps

1. Develop the conceptual linkage between SST and non-*V. cholerae* O1 and O139 serotype-associated vibriosis;
2. Associate vibriosis cases with the coastal counties where the exposure occurred between 2007 and 2018;
3. Process SST to identify historical monthly average values in coastal counties;
4. Estimate a health impact function to model the historical relationship between SST and vibriosis;
5. Estimate future SST using projected future increases in air temperatures in coastal counties;
6. Predict future probability of vibriosis infections throughout the 21st-century using the health impact function (step 4) and future projections of SST (step 5) then scale to number of cases using multipliers derived from historical case data; and
7. Value the direct and indirect costs of future vibriosis illnesses from available literature.

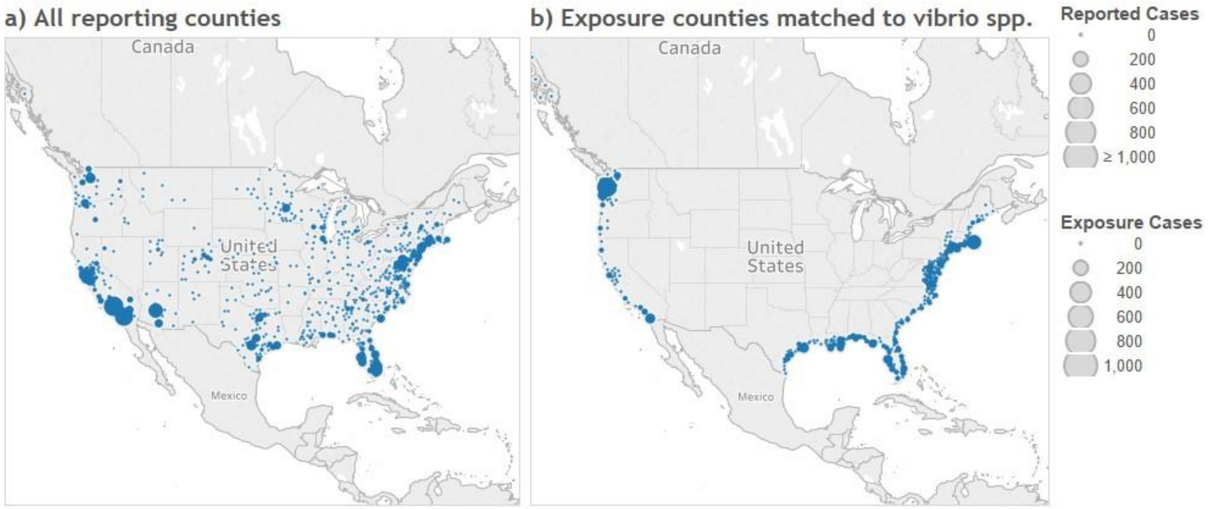
Historical Data: Key Figures

Figure 1: Trends in cases of reported vibriosis in the U.S. by species



Trend identified in vibriosis cases in the United States reported to COVIS (2007-2018) by species. "PAR" refers to *V. parahaemolyticus*. "VUL" refers to *V. vulnificus*. "ALG" refers to *V. algionolyticus*. "OTHER" refers to other non-*V. cholerae Vibrio* species. These include: *V. cholerae* non-O1 and non-O139, *V. cincinnatiensis*, *V. damsela*, *V. fluvialis*, *V. furnissii*, *V. hollisae*, *V. metschnikovii*, *V. mimicus*, V. species not identified, multiple V. species, and other. This figure does not present the number of total cases, which would account for under-reporting and mis-diagnosis.

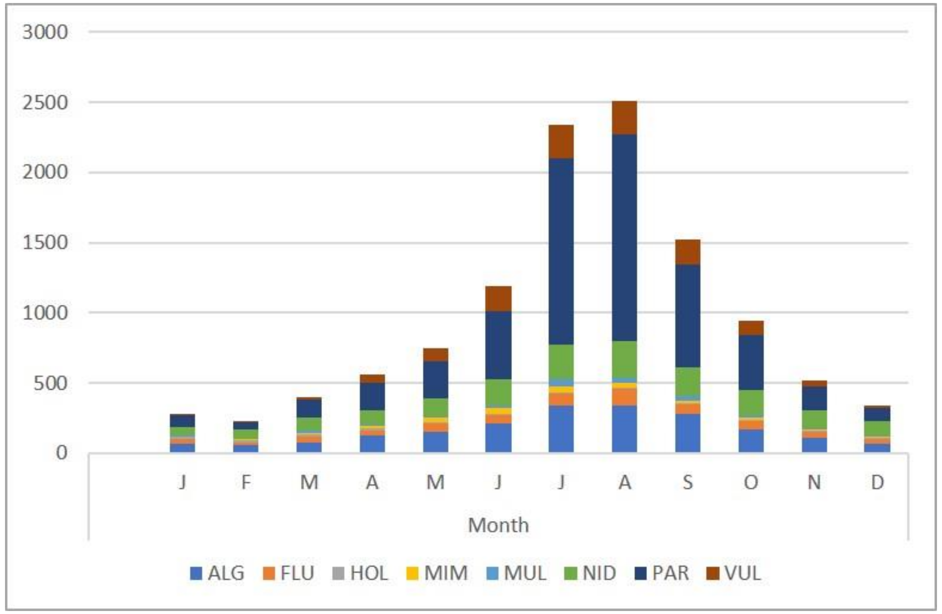
Figure 2: Geographic distribution of reported cases and exposure locations of vibriosis in the U.S.



Geographic distribution of vibriosis cases in the United States reported to COVIS (2007-2018) by reporting county (a) and cases by county of exposure identified during the screening analysis (b). COVIS case data shown here include all non-*V. cholerae Vibrio* species. Individual county totals are symbolized at the county centroid. The data from COVIS include all confirmed, confirmed and probable, and probable cases recorded from the contiguous 48 states, Hawaii, and Alaska. Given the inconsistency with which geographic information is recorded and the variation in level of detail provided in COVIS, the number of identified exposure locations matched with the 323 coastal exposure counties (29 percent) was 4,023 of 14,017 total recorded vibriosis infections.

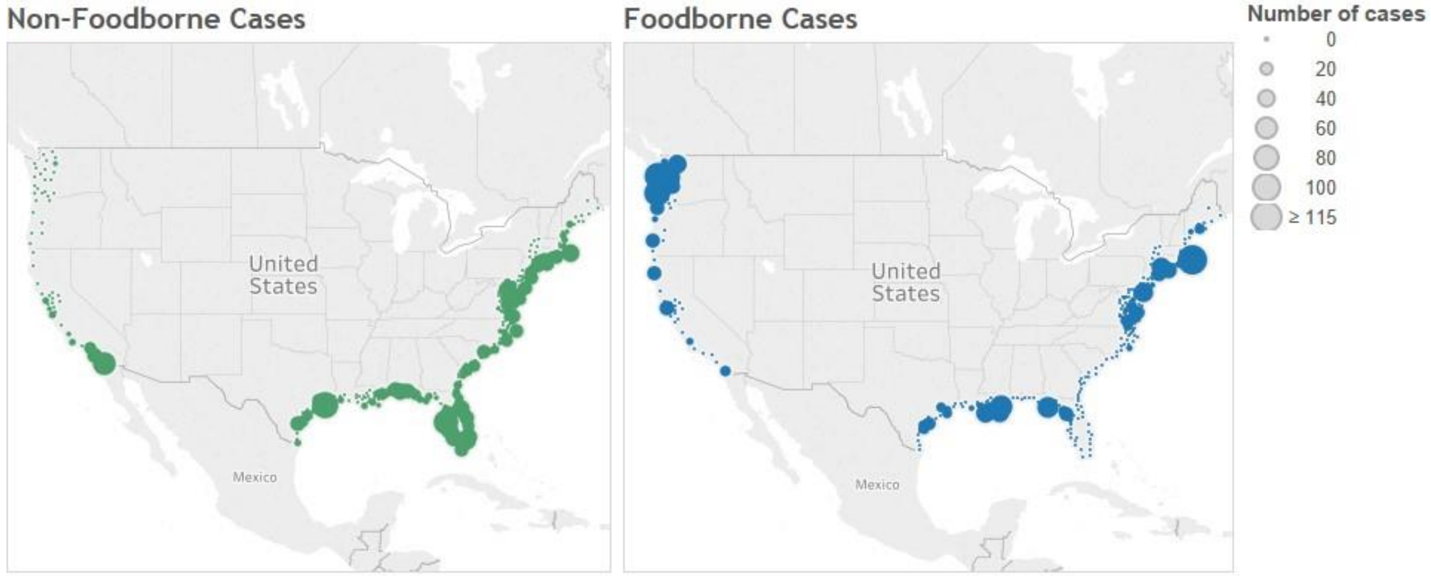
Historical Data: Supplemental Material

Figure S1: Reported vibriosis cases by month and species in the U.S.



Reported number of vibriosis cases in the United States by month and species based on all confirmed, confirmed-and-probable, and probable cases reported to COVIS (2007-2018). Case totals are provided for each species and month from January (J) through December (D). The total number of reported cases for the species designations shown is 11,580 and include the contiguous 48 states, Alaska, and Hawaii. Abbreviations and species designations: ALG- *V. alginolyticus;* FLU- *V. fluvialis;* HOL- *Grimontia hollisae;* MIM- *V. mimicus;* MUL- multiple species *only listed in overall case classification; NID- species not identified; PAR-*V. parahaemolyticus;* VUL- *V. vulnificus.*

Figure S2: Trends in cases of reported vibriosis in the U.S. by species



Geographic distribution of vibriosis cases in the United States based on transmission mechanism as reported to COVIS (2007-2018). The geographic distribution of reported non-foodborne (left panel) and foodborne cases (right panel) of *Vibriosis species* by exposure county identified through the screening analysis. The total number of cases matched to exposure counties is 1,837 for foodborne and 2,209 for non-foodborne. Alaska and Hawaii not shown.

Results

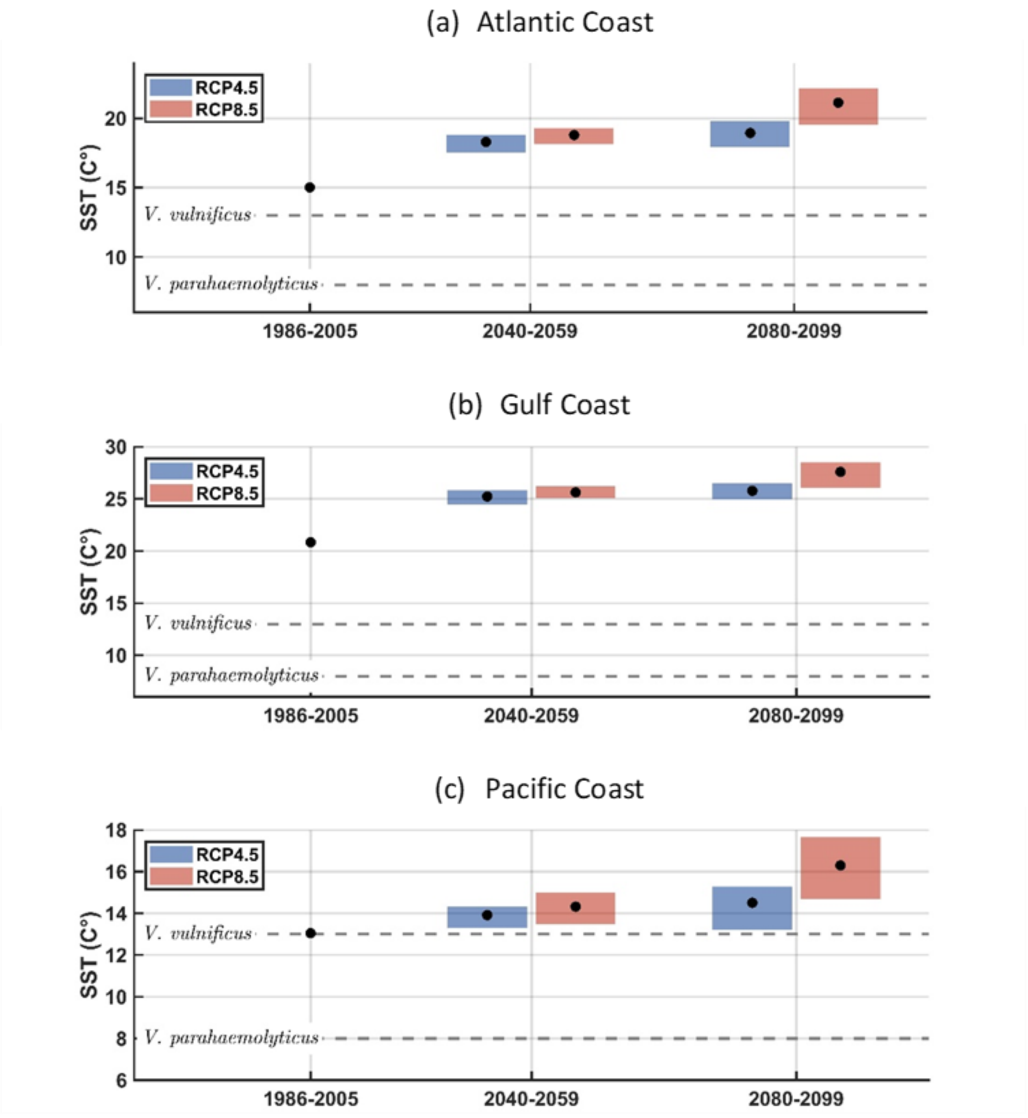
- Summarizes results specific to the SST variables for each of the three species models. For the *V. parahaemolyticus* model, we identify a statistically significant positive relationship between SST and the likelihood of vibriosis illness for the temperature ranges of each species.
- We find that the relationship between SSS and vibriosis is highly location- and species-specific and that, overall, increases in SSS translate into a higher probability of vibriosis cases.
- By species, about 39 percent of total predicted cases will be *V. parahaemolyticus* by 2090, less than 1 percent *V. vulnificus*, 12 percent *V. alginolyticus*, and 48 percent *V*. spp. under RCP4.5. Similarly, under RCP8.5, the distribution is expected to be 41 percent *V. parahaemolyticus*, less than 1 percent *V. vulnificus*, 13 percent *V. alginolyticus*, and 46 percent *V.* spp. Relative to the 1995 era, *V. parahaemolyticus* cases increase the most by 2090 (64 percent), followed by *V. vulnificus* (61 percent), *V. alginolyticus* (54 percent) then *V.* spp (41 percent) under RCP4.5. Likewise under RCP8.5, *V. parahaemolyticus* cases increase the most by 2090 (139 percent), followed by *V. vulnificus* (131 percent), *V. alginolyticus* (113 percent) then *V.* spp (85 percent). These results suggest that all species are sensitive to SST increases, although some more than others, which supports the importance of considering species type when evaluating future temperature change scenarios.
- We find that projected end-of-century increases in SST may result in total vibriosis cases 51 to 108 percent greater than modeled cases for the baseline era (1995), under lower- and higher-emissions scenarios respectively.

Results

Valuing the economic impact of infections requires modeling disease outcomes and estimation of the economic impact of those outcomes. We choose to draw on the USDA's Cost Estimates of Foodborne Illnesses data product (USDA 2021)

While the future costs we estimate are substantial, there are several reasons why they may be under-estimated relative to the total future cost of vibriosis.

Figure 3: Historical and projected SST by region and climate model



Author calculations using NOAA's OI SSTV2, PRISM, and GHCND. The figure shows the 20-year mean for the 1986-2005 baseline and two 20-year eras (2040-2059 and 2080-2099) for both RCPs. The blue and red boxes show the range across the six GCMs. Near the end of the century, increases in mean annual temperature for the GCM-mean compared to the baseline are about 4 and 6 °C for the Atlantic, 5 and 7 °C for the Gulf, and 1 and 3 °C for the Pacific, for RCP4.5 and RCP8.5, respectively. The growth temperature thresholds for V. parahaemolyticus and V. vulnificus are included for comparison purposes.

Discussion of Estimates

Under-estimate

- First, the projections presented here are specific to increases in SST attributable to climate change and do not account for additional factors that may influence vibriosis prevalence. The analysis provides suggestive evidence that SSS may also be an important environmental driver in vibriosis, particularly for the West Coast and to a lesser extent on the East Coast.
- Second, the increased prevalence of *Vibrio* spp. may have impacts beyond physical illness and associated costs considered in this paper. For example, fisheries and beaches may close when *Vibrio* is detected at or above certain levels, leading to economic losses for commercial fisheries and recreation industries directly. Finally, the cost of illness model applied in this analysis does not consider the likelihood or cost of amputation, and increasing evidence demonstrates that amputations occur in a non-negligible number of vibriosis cases and have significant lifetime costs.

Over-estimate

- There also are reasons our results may over-estimate baseline and future costs. Our analysis applies under-reporting and under-diagnosis multipliers from Scallan et al. (2011) estimated before the change in vibriosis testing regime. These changes may have reduced under-reporting and under-diagnosis, subsequently resulting in smaller multiplier values to predict the true number of vibriosis cases.
- Lastly, increased awareness at the local, state, and federal levels pertaining to the public health threats of *Vibrio* exposure and vibriosis may encourage the implementation of further mitigation and/or adaptation mechanisms. These adaptation measures could lead to fewer vibriosis cases, rendering the results presented in this paper to over-estimate future costs; at the same time, closing beaches and fisheries to prevent the spread of vibriosis has economic costs of its own not accounted for in this analysis.
- Additionally, state-level policy changes limiting the seasonal import of seafood from regions where *Vibrio* may be in coastal waters reduced vibriosis relative to states that did not implement such policies (Vugia et al. 2013). Future vibriosis cases and associated costs could be further reduced through continued communication and understanding of research outcomes, monitoring, and surveillance, including via operational forecasts for early warning of elevated concentrations of *Vibrio* in coastal waters and seafood, and improved traceback along the supply chain. More data on exposures related to foodborne and waterborne cases will aid in this effort.

E-lightening Poster

- https://agu2021fallmeeting-agu.ipostersessions.com/default.aspx?s=8C-B0-AA-25-EB-F7-58-0E-A0-F4-EA-4F-D0-55-E2-4B