Three species of *Vibrio* pathogen in the Chesapeake Bay under future climate change scenarios

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**Vibrio in Chesapeake Bay**

- Several species present naturally
- Vibriosis cases in warmer months
  - *V. parahaemolyticus* most common, *V. vulnificus* most severe
- Warmer waters associated with higher occurrence of bacteria in the water
- Species-specific salinity ranges
Vibrio in Chesapeake Bay
Habitat models

V. vulnificus
Probability of occurrence (/1)
Jacobs et al. 2014

V. cholerae
Probability of occurrence (/1)
Louis et al. 2003

V. parahaemolyticus
log cells/g
USFDA 2005
Vibrio and climate change in the Chesapeake Bay

- Jacobs et al. (2015) projected *V. vulnificus* in water and *V. parahaemolyticus* in oysters out to 2100.
- Estimated water temperature from near-surface air temperatures.
- But: modeled Chesapeake Bay as 1-dimensional.
  - Salinity also held constant at 12 psu.
Climate model resolution and estuarine environments

• General circulation models (GCMs) too coarse to resolve local-scale dynamics in estuaries
• If we want to represent fine-scale features like estuaries, GCMs must be **downscaled** to area of interest
• *Statistical downscaling*: relies on present-day relationships between regional and local-scale processes
  • Low computational cost, can compare multiple GCMs
  • Needs long observational record (~30 years+)

[Image of map with temperature change and magnifying glass]
Our modeling framework

- See Muhling et al. 2017 Estuaries and Coasts

**Potential Salinity and Temperature Futures for the Chesapeake Bay Using a Statistical Downscaling Spatial Disaggregation Framework**

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![Susquehanna River Watershed and Thomas Point](image1)

- Daily air temperature (Susquehanna Watershed and Thomas Point)
- Daily precipitation (Susquehanna Watershed)
- Non-linear Surface Water Temperature Model
- Water Balance Model
- Monthly Susquehanna River Streamflow
- Monthly Chesapeake Bay Spatial Temperature
- Monthly Chesapeake Bay Spatial Salinity

**General Circulation Model**

**Statistical downscaling**

**Downscale**

**Get variables of interest**

**Spatial disaggregation**

**Downscale**

**Model Tree**

**Model Tree**

**Monthly Chesapeake Bay Spatial Temperature**

**Monthly Chesapeake Bay Spatial Salinity**

**Susquehanna River Watershed**

**Thomas Point**
How will conditions change in the future?

- Two primary sources of uncertainty for long-range projections
  1. Representative Concentration Pathway (RCP): how much CO$_2$ will we emit?
     - We chose to consider the “business as usual” scenario, RCP8.5
  2. Variability in projections from different GCMs
     - We selected four GCMs with diverging but plausible temperature and precipitation futures
Future projections: estuarine conditions

- Mean surface water temperatures increased >5°C in the warm/wet model, but only 2-3°C in the cool/wet model.
- Salinity was strongly variable, reflecting high uncertainty with precipitation, but increased in the two dry models.
Future projections: estuarine conditions

- **Spatial variability** in warming was less than **inter-model variability**
  - Greatest warming in upper tributaries, less near continental shelf
- Salinity changes greatest in winter – spring, responding to **changing snow melt**
  - Salinity decrease in wetter models, increase in dry models within mesohaline regions

### Summer temperature change
1970 - 1999 vs. 2071 - 2100

### Winter salinity change
1970 - 1999 vs. 2071 - 2100
Effects on *Vibrio: V. vulnificus*

- Increase in probability of occurrence from April through to November
- Summer to fall increases strongest in warmer models, weakest in cool/wet model

![Graph showing probability of occurrence of V. vulnificus over months with different models]
Effects on *Vibrio*: *V. parahaemolyticus*

- Increase in predicted concentration in oysters throughout the year
- Models give similar results winter – spring, warmer models associated with higher risk summer - fall
Effects on *Vibrio: V. cholerae*

- Both wet models projected an increase in probability of occurrence in winter – spring
- Warm/dry model projected a decrease compared to the recent historical period
V. vulnificus

- Strongest increases in probability of occurrence in mesohaline regions
- Overall increase in high-risk area
**V. parahaemolyticus**

- Increases in predicted concentration in oysters throughout most of the Bay
- Except regions where salinity remains < 5 psu
**V. cholerae**

- High-risk areas remain restricted to low salinity areas
- Warming increases probability of occurrence within these areas
- Dry models project contraction of high-risk areas upstream
Conclusions

• Likely increase in occurrence of *V. vulnificus* in the Chesapeake Bay and increase the mean concentration of *V. parahaemolyticus* in oysters by the end of the 21st century

• In contrast, occurrence for *V. cholerae* may increase only in wetter future, high-risk areas are restricted to low salinity zones of the bay

• The length of the high-risk summer season for *V. vulnificus* and *V. parahaemolyticus* is projected to increase

• Implications for future recreational use and seafood extraction from the Chesapeake Bay, with the potential for considerable economic costs as a result

• Downscaled projections are available for other studies and uses

Future work

• High resolution seasonal forecasts of *Vibrio* risk (Gonzalez-Taboada et al.)
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Questions?

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