Remote Sensing of Environmental Vibrio in the Chesapeake Bay

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Study Area
(The Chesapeake Bay)

- **Salinity gradient**
  - Oligohalic (0-6 ppt)
  - Mesohalic (6-18 ppt)
  - Polyhalic (18-30+ ppt)
- **Sea surface temperature**
  - -0.5°C to 31°C
- **Major inputs**
  - Atlantic Ocean
  - Susquehanna River
- **2-Layer gravitational circulation scheme**
Vibrio in the Chesapeake Bay

- V. cholerae
- V. vulnificus
- V. parahaemolyticus

ENVIRONMENTAL PARAMETERS

PHYSICAL
- Precipitation
- Circulation
- Sea surface height

BIOLOGICAL
- SST
- Salinity
- Nutrients
- pH

-Copepods
-Bacteria

-Shellfish
-Rec. water

Untreated sewage

HUMANS

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Vibrio in the Chesapeake Bay

Reported Vibrio Cases, Maryland and Virgina

Maryland Dept. of Health and Mental Hygiene
Virgina Department of Health.

*Estimated 2010 VA Cases
Pre-existing Empirical Vibrio Models

\[ z(V.v) = -7.867 + (0.316 \times \text{Temp}) + (-0.342 \times |\text{Saln} - 11.5|) \]

(Jacobs et al., 2010)

\[ z(V.c) = -1.1939 + (0.1233 \times \text{Temp}) - (0.1997 \times \text{Saln}) - (0.0324 \times \text{Temp} \times \text{Saln}) \]

(Louis et al., 2003)

\[ f(z) = \frac{e^z}{1 + e^z} \]

- **In situ** and **modeled** temperature and salinity inputs
- Probability of occurrence Vibrio spp. models
- Historical cruise (V.c) and CBay Program (V.v) bacteria collection
Remote Sensing of Vibrio in the Chesapeake Bay

\[ z(V.c) = -1.1939 + (0.1233 \times \text{Temp}) - (0.1997 \times \text{Saln}) - (0.0324 \times (\text{Temp} \times \text{Saln})) \]

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Remote Sensing of Sea Surface Salinity

- NASA Aquarius Salinity Product
  - 150 km spatial resolution
  - Monthly composites

- Neural Network Salinity Product
  - Geiger et al. (2011): UDEL
  - Statistically Derived from MODIS-Aqua Ocean Color
    - Additional RS input products
    - Trained on Mid-Atlantic region
    - Historical cruise data
Satellite Based Salinity Algorithms

- MODIS-Aqua Ocean Color Standard Products
  • 10 Remote sensing reflectances (visible)
  • 2003-2010

- In situ – remote sensed measurement matchups
  • 68 CBay Program in situ stations
  • Single pass RS ocean color data
  • 1km radius RS averaging
  • 2003-2010

- Salinity Prediction Models
  • GLM
  • GAM
  • CART
  • BCART
  • BART
  • RF
  • ANN
  • MARS

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Satellite Based Salinity Algorithms

- Generalized Linear Model (GLM)
- Generalized Additive Model (GAM)
- Artificial Neural Network (ANN)
- Multivariate Adaptive Regression Spline (MARS)

Tree-Based Data Mining

- Categorical and Regression Tree (CART)
- Bagged Categorical and Regression Tree (BCART)
- Bayesian Additive Regression Tree (BART)
- Random Forest (RF)
## Satellite Based Salinity Algorithms

<table>
<thead>
<tr>
<th></th>
<th>GAM</th>
<th>ANN</th>
<th>GLM</th>
<th>CART</th>
<th>BCART</th>
<th>RF</th>
<th>MEAN</th>
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<tbody>
<tr>
<td>MAE</td>
<td>1.82</td>
<td>1.85</td>
<td>1.93</td>
<td>2.39</td>
<td>2.38</td>
<td>2.06</td>
<td>3.72</td>
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<tr>
<td>RMSE</td>
<td>2.38</td>
<td>2.50</td>
<td>2.53</td>
<td>3.03</td>
<td>3.01</td>
<td>2.67</td>
<td>4.69</td>
<td>2.60</td>
<td>2.52</td>
</tr>
</tbody>
</table>

- Top performing prediction models: **GAM** and **ANN**
- GAM and ANN are not statistically different
- All models outperform the mean salinity prediction
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\[ z(V_c) = -1.1939 + (0.1233 \times \text{Temp}) - (0.1997 \times \text{Saln}) - (0.0324 \times (\text{Temp} \times \text{Saln})) \]

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General Additive Model (GAM) for Predicting Salinity

GAM.MODEL<-gam(Salinity~s(Rrs_678)+s(Rrs_547)+s(Rrs_488))

y = 0.81\times + 2.8

MAE: 1.82
RMSE: 2.38
Daily Remote Sensing of SST and Saln

MODIS- Aqua SST 9/18/2006

MODIS- Derived SSS 9/18/2006

RMSE: 0.51

RMSE: 1.22

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9/18/2006 V.cholerae

9/18/2006 V.vulnificus

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In situ Vibrio Sampling

![Image of in situ Vibrio sampling](image1.png)

![Image of Vibrio culture](image2.png)

![Image of laboratory setup](image3.png)

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Future Research Directions

• Salinity algorithm applications

• Applications within the Chesapeake Bay

• Applications beyond the Bay
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