Environmental influences on cholera outbreaks in Bangladesh and Vietnam: Implications for prevention and prediction

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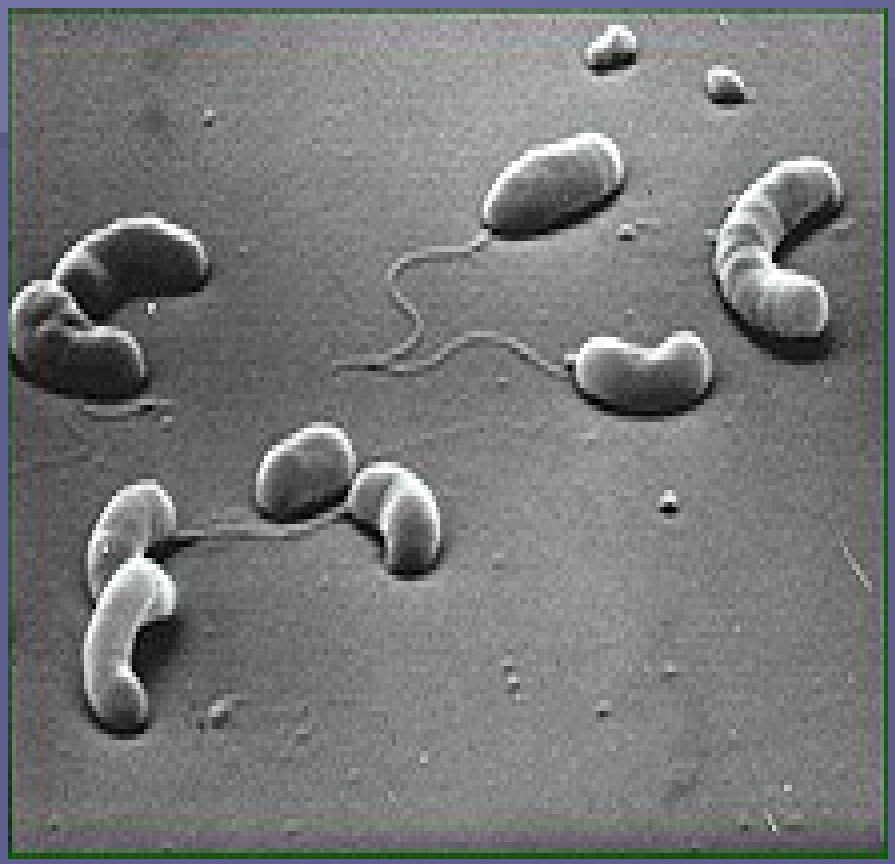
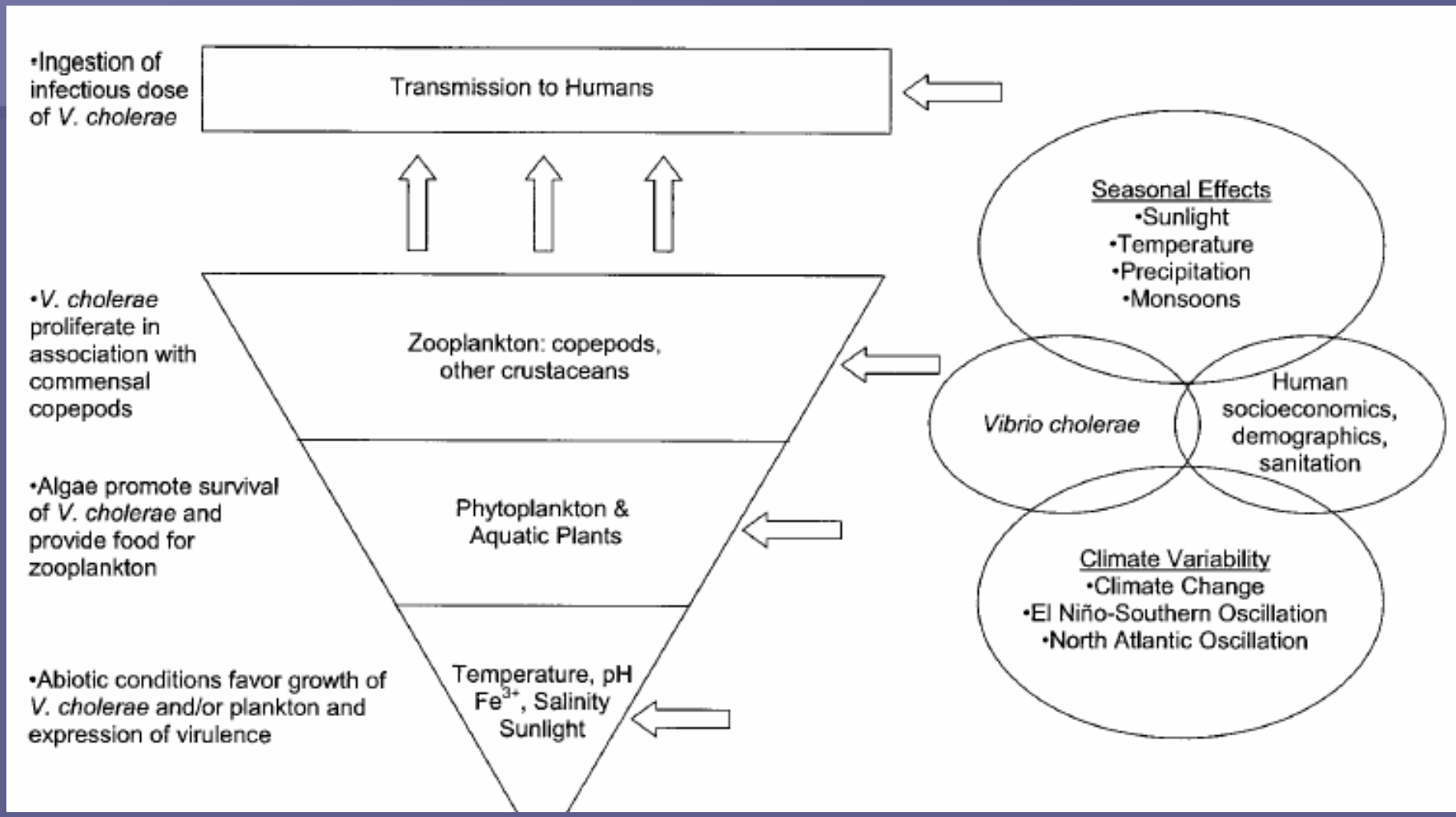
Cholera Background



- *Vibrio cholerae* are bacterium comprised of curved rods with a polar flagellum
- Produce cholera toxin
- Cause watery diarrhea leading to severe dehydration
- Treatment by IV fluid
- If untreated ~50% case fatality rate, if treated ~1%

Source: Stephens, T. U.C. Santa Cruz, Photo: F. Yildiz.

Cholera Ecology



Source: Lipp, Huq, and Colwell, 2002.

Specific Aims

1. Examine the role of local environmental drivers of cholera including sea surface temperature (SST), sea surface height (SSH), ocean chlorophyll concentration (OCC), rainfall, river height/discharge.

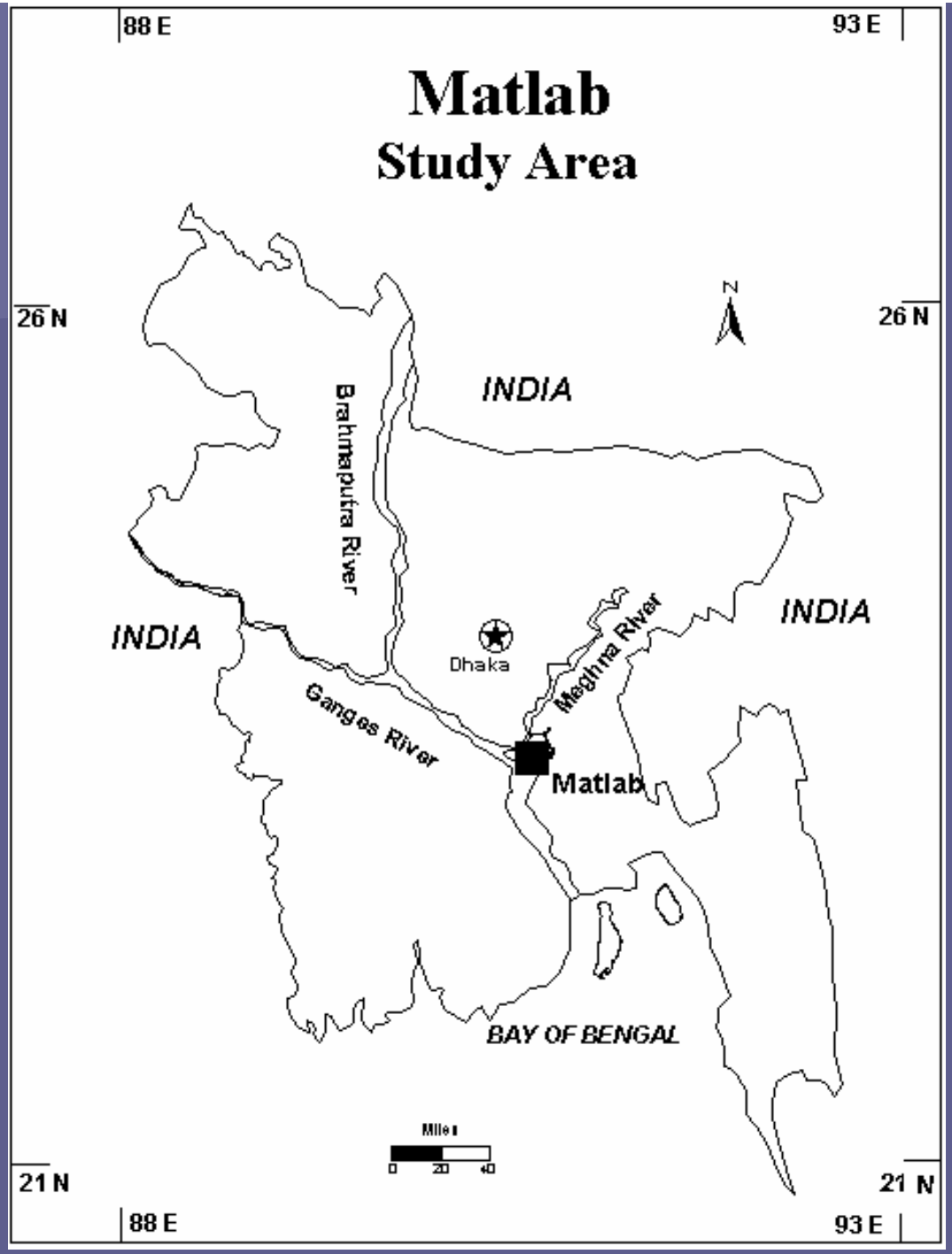
2. Compare associations between the local environment and cholera across 3 study sites in Bangladesh and Vietnam

3. Build a predictive model using satellite-derived and/or in situ variables to develop a cholera early warning system.

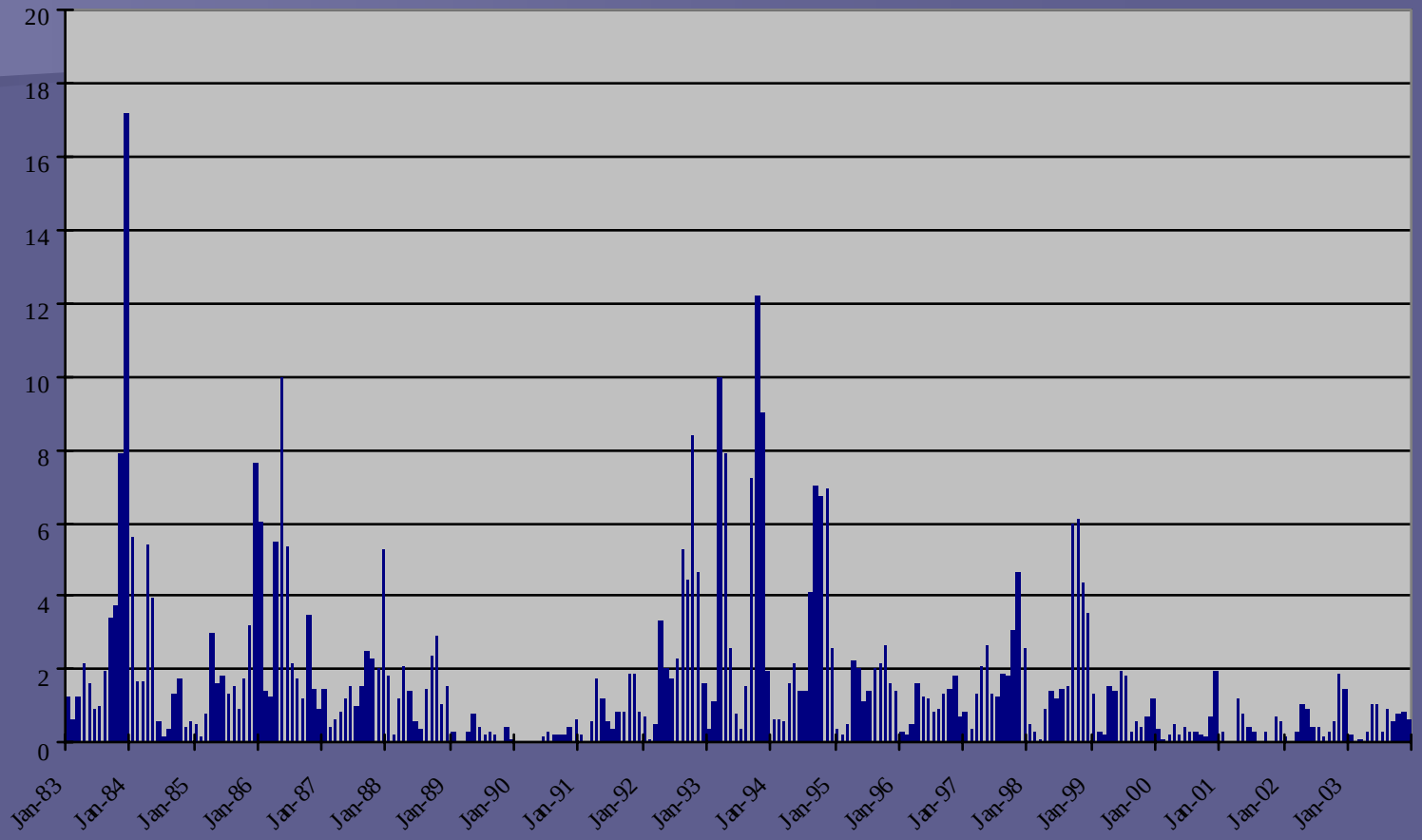
Factors of Interest for Cholera Prediction

Variable – Monthly Mean Values	Data Source
Environmental Independent Variables (satellite-derived)	
Ocean chlorophyll concentration	SeaWiFS, Aqua MODIS (future)
Sea surface temperature	AVHRR, Aqua MODIS (future)
Sea surface height	TOPEX/ Poseidon, Jason-1 (both)
Climatic Independent Variables (in situ)	
Temperature	Weather stations
Rainfall	Weather stations
River discharge/height	Gauges
Dependent Variable	
Average # monthly cholera cases	Hospitalized cases/ demographic surveillance system (Bangladesh) or census (Vietnam)

Bangladesh



Cholera Incidence



Cholera Cases Per 10,000 in Matlab, Bangladesh: 1983-2004

Dependent Variable: Bangladesh

- Model 1: Cholera severity at the 70th percentile
  - 3 categories: low (0-30), medium (30-70), high (70-100)
  - Models extreme cholera months
- Model 2: Cholera severity at the 85th percentile
  - 3 categories: low (0-15), medium (15-85), high (85-100)
  - Models more extreme cholera months

Matlab, Bangladesh
Explanatory Variables

- Sea surface temperature
- Sea surface height
- Ocean chlorophyll concentration
- Rainfall
- Temperature at 4 locations
- River discharge at 6 stations
  - All variables tested for 2-month lag effects
  - Variables are monthly mean values

The Relationship Between Cholera Severity and Environmental Variables: Bivariate Analysis

Variable	N	Severity at the 70th Percentile	Severity at the 85th Percentile
Ocean Chlorophyll Concentration	75	1.47***	.955**
		(.443)	(.367)
Ocean Chlorophyll Concentration 2-month lag	75	2.75***	.654*
		(.695)	(.275)
Mean cleaned tidal discharge at Bhairab	104	-.0000546 *	-.0000473*
		(.0000217)	(.0000213)
Mean cleaned tidal discharge at Demra	61	-.000677	-.000905*
		(.000379)	(.000390)
Sea surface temperature	228	.0138	-.004
		(.014)	(.012)
Rainfall	243	-.003	.002
		(.012)	(.013)
Sea surface height	135	-.005	-.011
		(.0105)	(.013)
Temperature	228	.011	.003
		(.026)	(.027)

Results from ordered probit model. Robust standard errors in parenthesis. *p< .05, **p< .01, ***p< .001

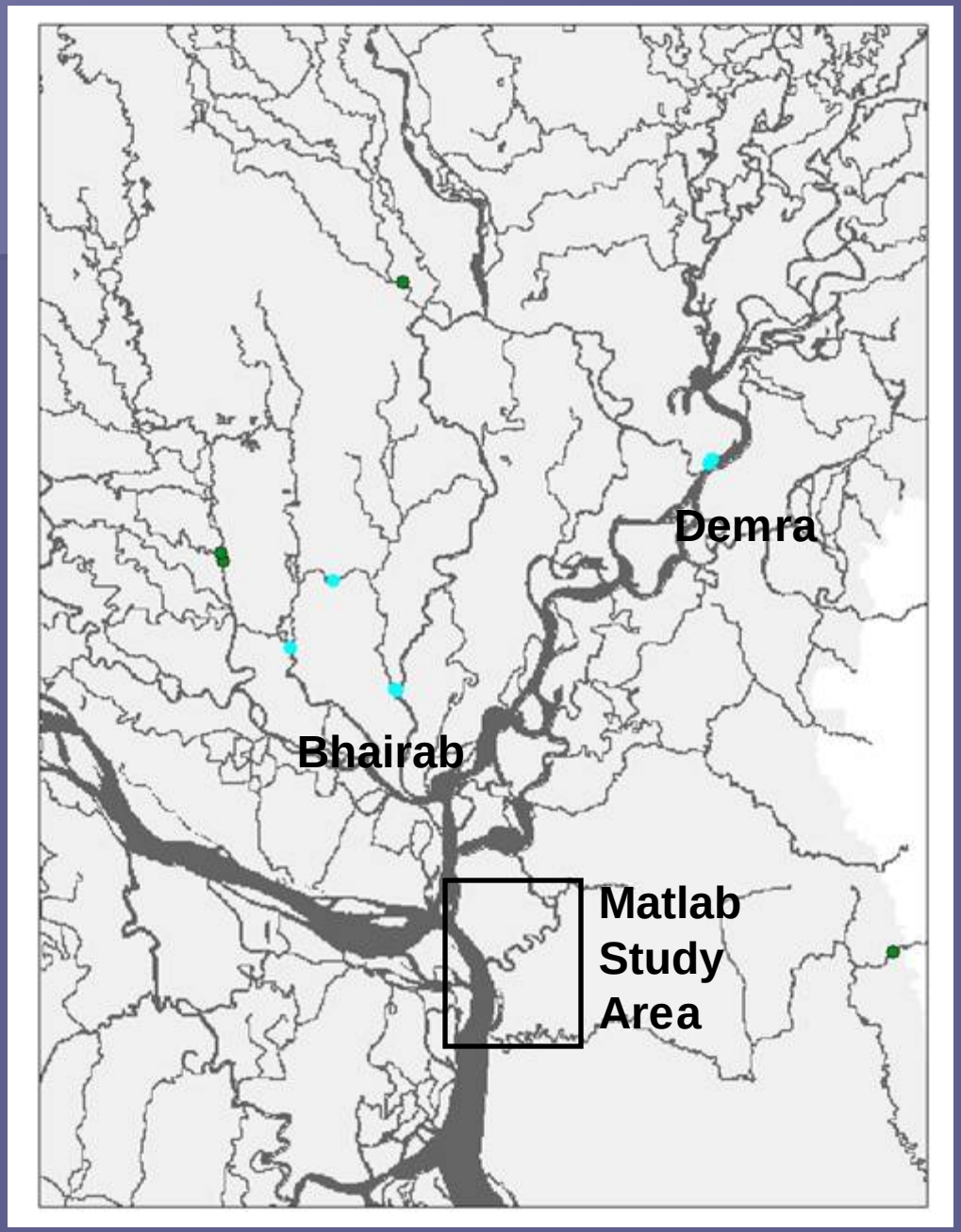
The Marginal Effect of an Increase in 1 Standard Deviation on Cholera Severity: Bivariate Analysis

Marginal effects*	70th percentile Severity Ranking			85th percentile Severity Ranking		
Variable	Low	Middle	High	Low	Middle	High
Ocean Chlorophyll Concentration	-.195	.063	.132	-.083	.047	.036
Ocean Chlorophyll Concentration 2-month lag	-.312	.067	.245	-.062	.036	.026
Mean cleaned tidal discharge at Bhairab	.073	.019	-.093	.055	.00039	-.055
Mean cleaned tidal discharge at Demra	.075	.00143	-.076	.0784	-.0189	-.059

*average expected percentage point change

The marginal effects are calculated independently for severity at the 70th and 85th percentile. Computation of the *change in average of the probabilities* is utilized to measure the effects of an increase in one standard deviation (Norton, 2005).

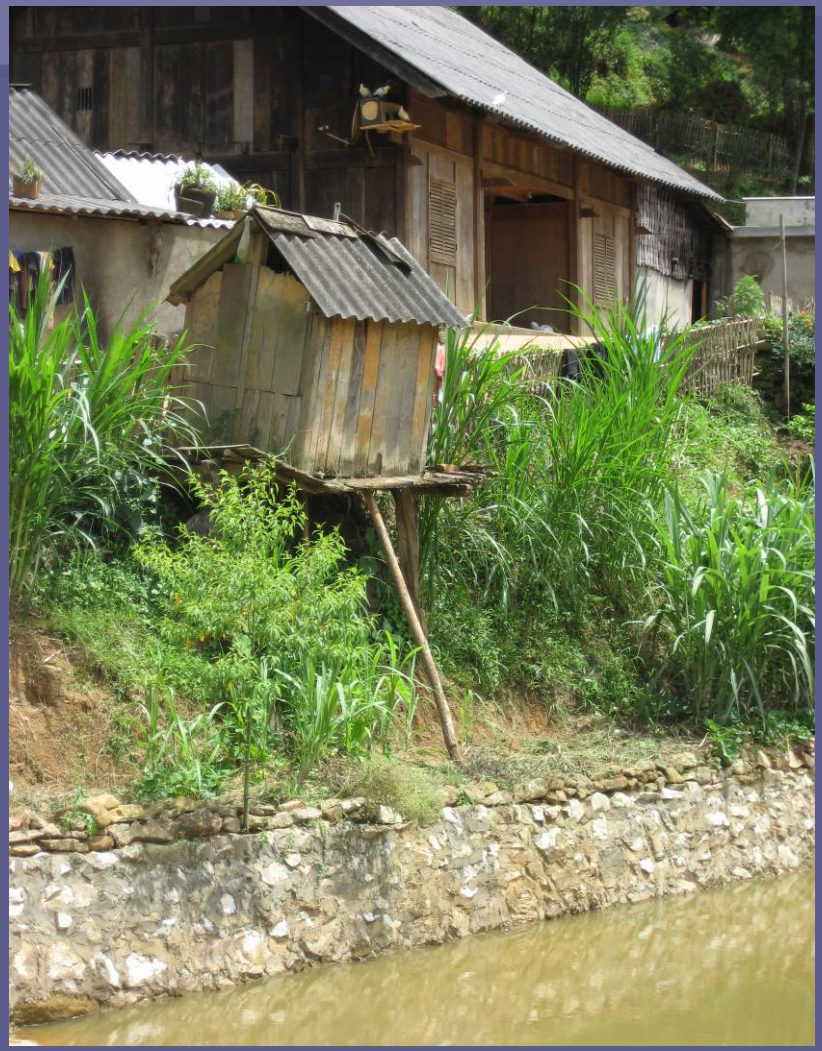
River Discharge Stations

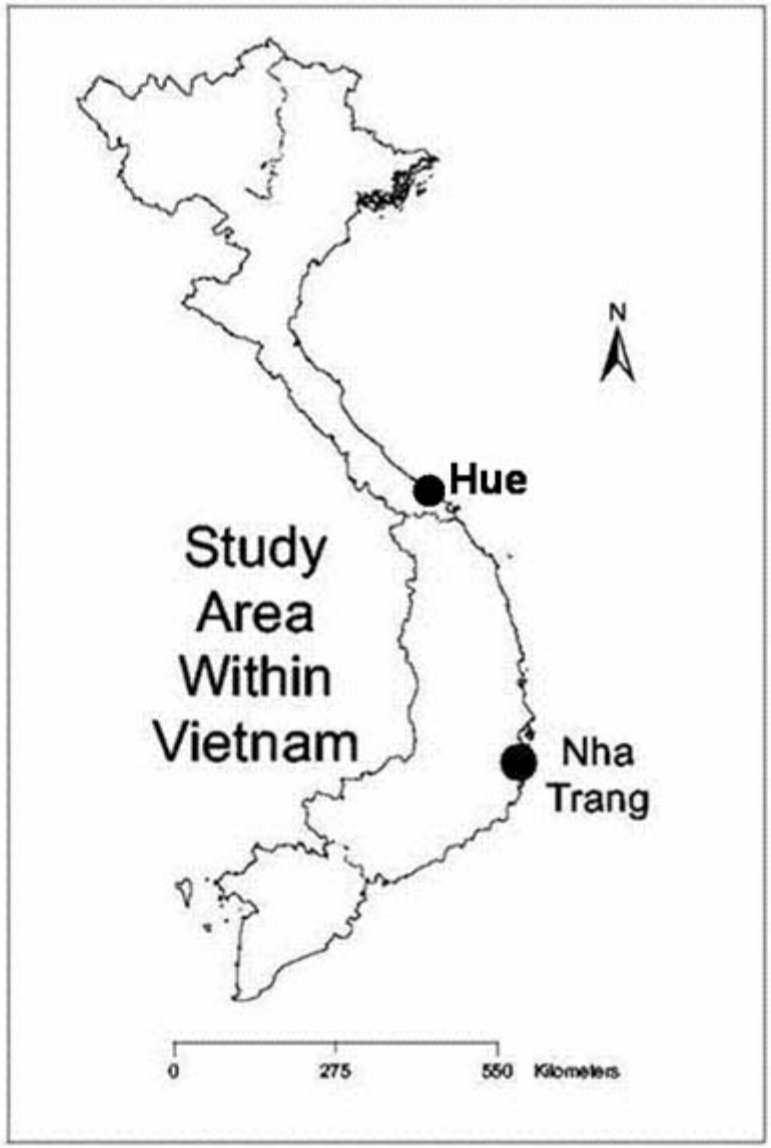


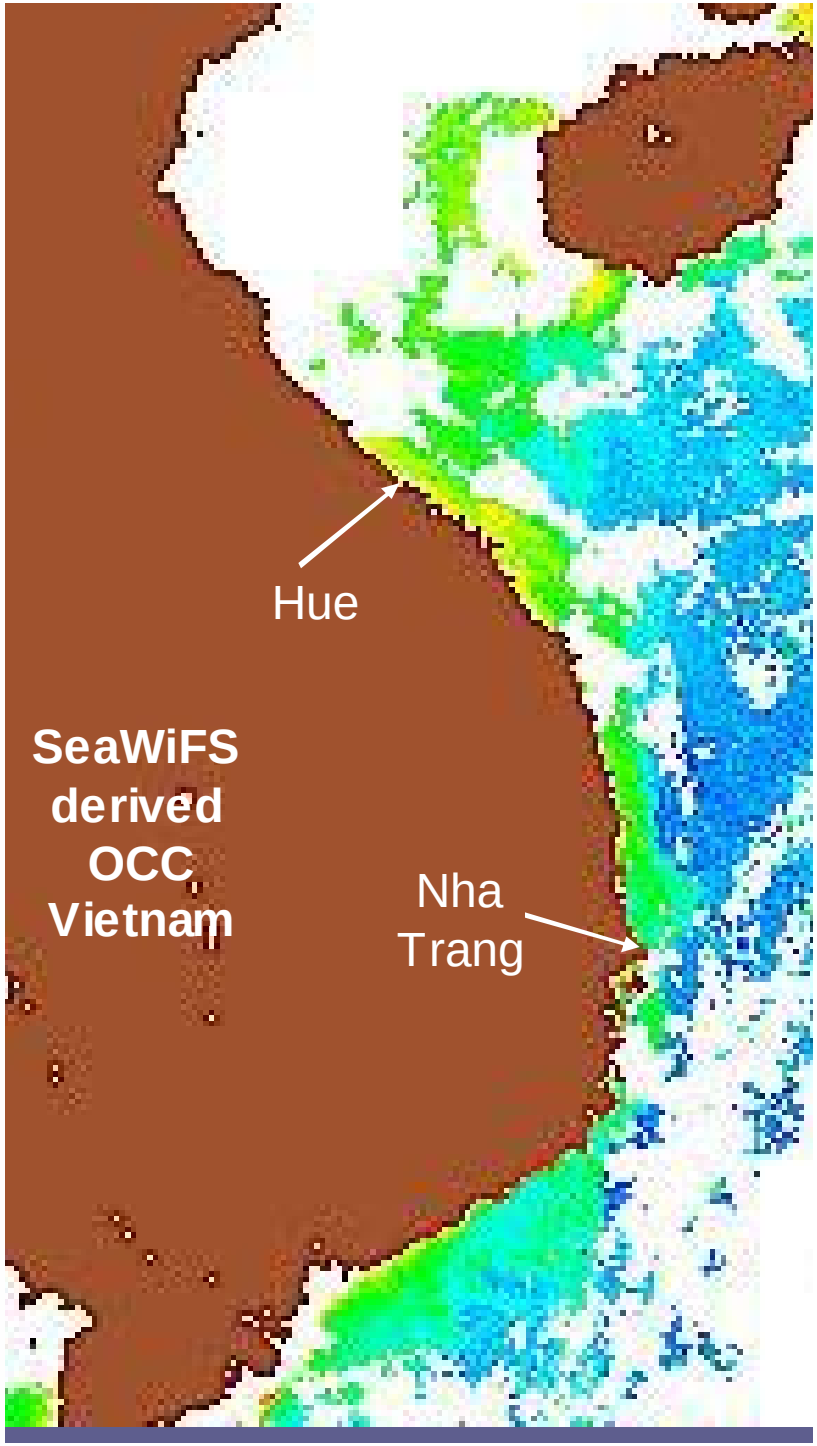
Summary findings: Bangladesh

- Increases in ocean chlorophyll concentration appear associated with increased cholera severity.
- Increases in ocean chlorophyll also have a lag effect on cholera. This finding may prove beneficial for early warning systems.
- Increases in river discharge appear associated with decreased cholera severity, suggesting a dilution effect.

Vietnam



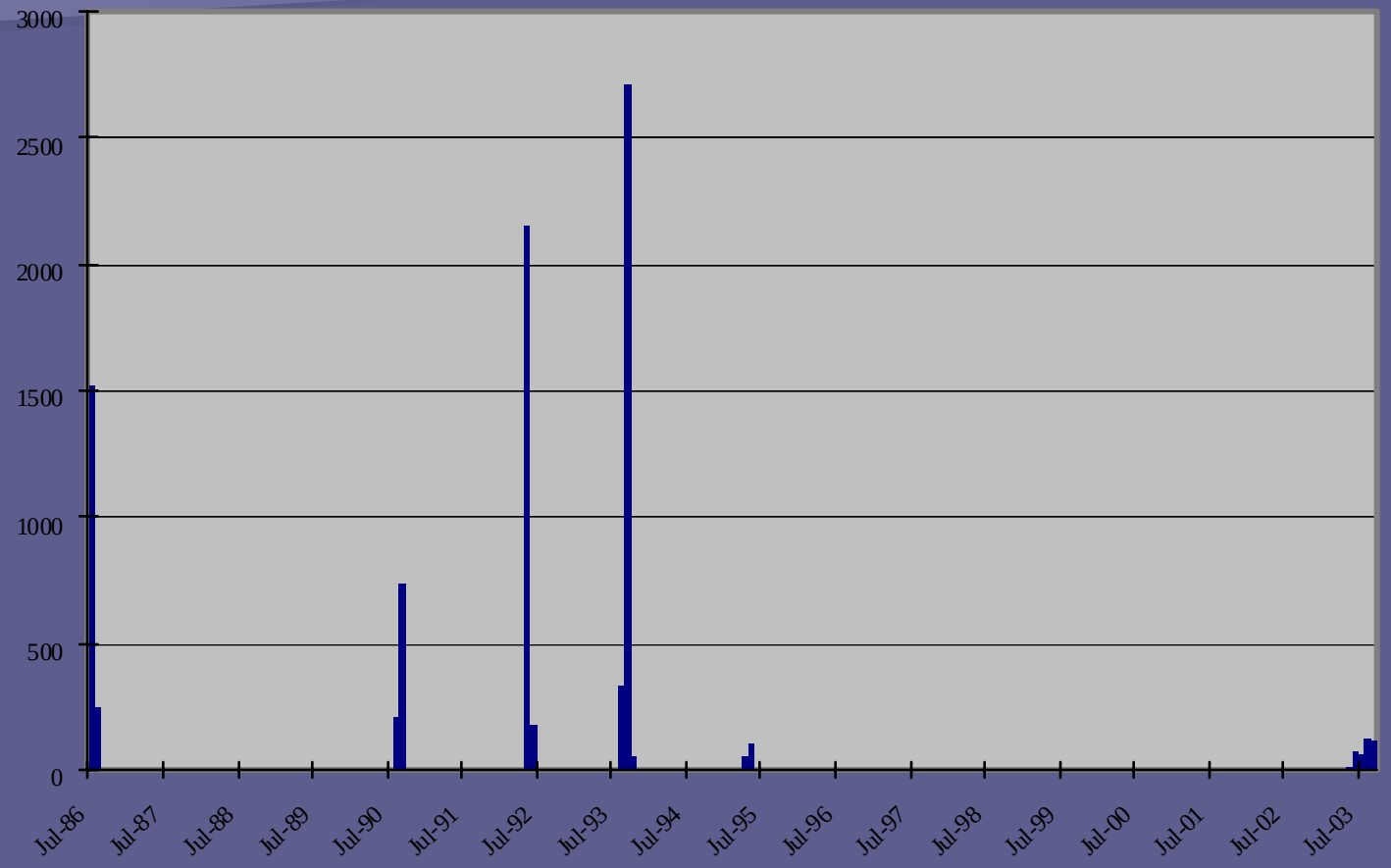




Vietnam
Explanatory Variables

- Sea surface temperature
- Sea surface height
- Ocean chlorophyll concentration
- Rainfall
- Temperature
- River height
  - All variables tested for 2-month lag effects
  - Variables are monthly mean values
- Dependent: Dichotomous cholera cases

Cholera Incidence: Hue



Cholera Cases Per Million in Hue, Vietnam: 1986-2004

Local environmental influences on cholera: Hue

Variable	N	Bivariate	Multivariate
River height 2-month lag	228	-.044***	
		(.012)	
Sea surface temperature	148	.233***	.194*
		(.063)	(.0934)
Sea surface height	148	-.029*	-.010
		(.012)	(.015)
Sea surface height 2-month lag	228	-.041**	
		(.014)	
Rainfall 2-month lag	228	-.004***	
		(.001)	
Temperature	100	.183	
		(.044)	
Ocean chlorophyll concentration	240	-1.18	
		(1.16)	
Log Likelihood			-30.19
Wald			13.94***

Results from probit model. Robust standard errors in parenthesis. *p< .05, **p< .01, ***p< .001

The Marginal Effect of an Increase in 1 Standard Deviation on Cholera Outbreaks: Hue

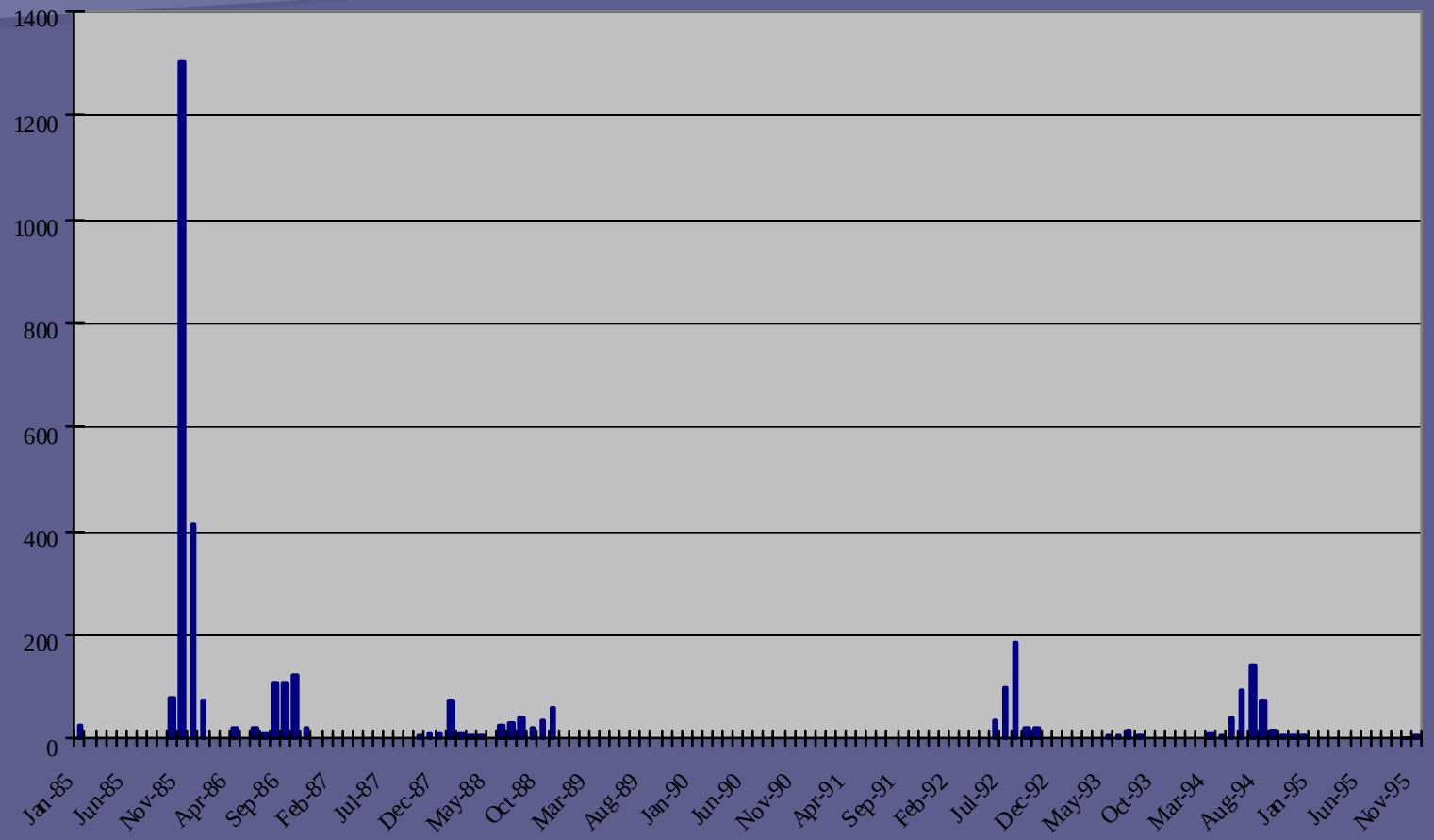
Variable	Bivariate	Multivariate
River height above sea level	-.029	
River height above sea level 2-month lag	-.063	
Sea surface temperature	.150	.122
Sea surface height	-.037	(in model)
Sea surface height 2-month lag	-.045	
Rainfall 2-month lag	-.067	

*average expected percentage point change

Summary findings: Hue

- Similar to Bangladesh, the height of the river and its lag effect appears to have a diluting effect on cholera in Hue, decreasing its outbreak.
- Increases in sea surface height and rainfall may also have a diluting effect on cholera, decreasing the risk of outbreak.
- The effects of the sea temperature appear to have an enhancing effect – increases in sea surface temperature increase the probability of a cholera outbreak.

Cholera Incidence



Cholera Cases Per Million in Nha Trang, Vietnam: 1984-2004

Local environmental influences on cholera outbreaks: results from Nha Trang

Variable	N	Bivariate analysis	Multivariate
Monthly rainfall	131	.002*	
		(.001)	
Dong Trang river height	228	.004**	.0000186
		(.002)	(.002)
Ninh Hoa river height	215	.0123***	.0123***
		(.003)	(.003)
Ninh Hoa river height 2-month lag	215	.008**	
		(.002)	
Discharge at Dong Trang	228	.004*	
		(.002)	
Sea Surface Temperature	228	-.007	
		(.032)	
Sea Surface Height	148	-.012	
		(.017)	
Temperature	131	.093	
		(.065)	
N			215
Log Likelihood			-126.412
Wald			20.45

Robust standard errors in parenthesis. Wald Chi Square significance at *p< .05, **p< .01, ***p< .001

The Marginal Effect of an Increase in 1 Standard Deviation on Cholera: Nha Trang

Variable	Bivariate*	Multivariate*
Monthly rainfall	.098	
Dong Trang river height	.088	(in model)
Ninh Hoa river height	.143	.143
Ninh Hoa river height 2-month lag	.102	
Mean discharge at Dong Trang	.116	

*average expected percentage point change

Summary findings: Nha Trang

- Unlike Bangladesh or Hue, the effects of rain, river height, and discharge appear to have a **positive** effect on cholera outbreaks.
- In other words, as rain, river height or discharge increase, the probability of an outbreak also increases. This holds for the lag effect of river height as well.
- These results are unexpected and suggest an inundation effect, perhaps associated with Nha Trang's coastal location.

Limitations

- Current data set is small, limiting power
- There might be significant interactions and mediators not explored in this analysis
- Aggregation by month reduces variation
- Spatial and temporal autocorrelation not addressed in this analysis

Areas for further investigation

- Do to high correlations in the variables, possible interactive effects warrant attention
- Examination of variations within the study sites, i.e., are differences in local- or neighborhood-level factors (like SES) also influential in predicting cholera?
- Multi-level modeling of neighborhood and climate effects to examine the relative influences of community and climate influences
- Use of GIS to model the relationship between SES and cholera at the neighborhood level

Conclusions

- Local environmental factors have differential effects on cholera severity and outbreaks
- Variations exist both between and among country-level environmental influences on cholera
- Prediction models may need to be developed for each unique environment
- Climate change may affect these relationships, reducing the potential for prediction

Questions?