

Can modeling *E. coli* concentrations improve risk-based assessments at swimming beach(es)?

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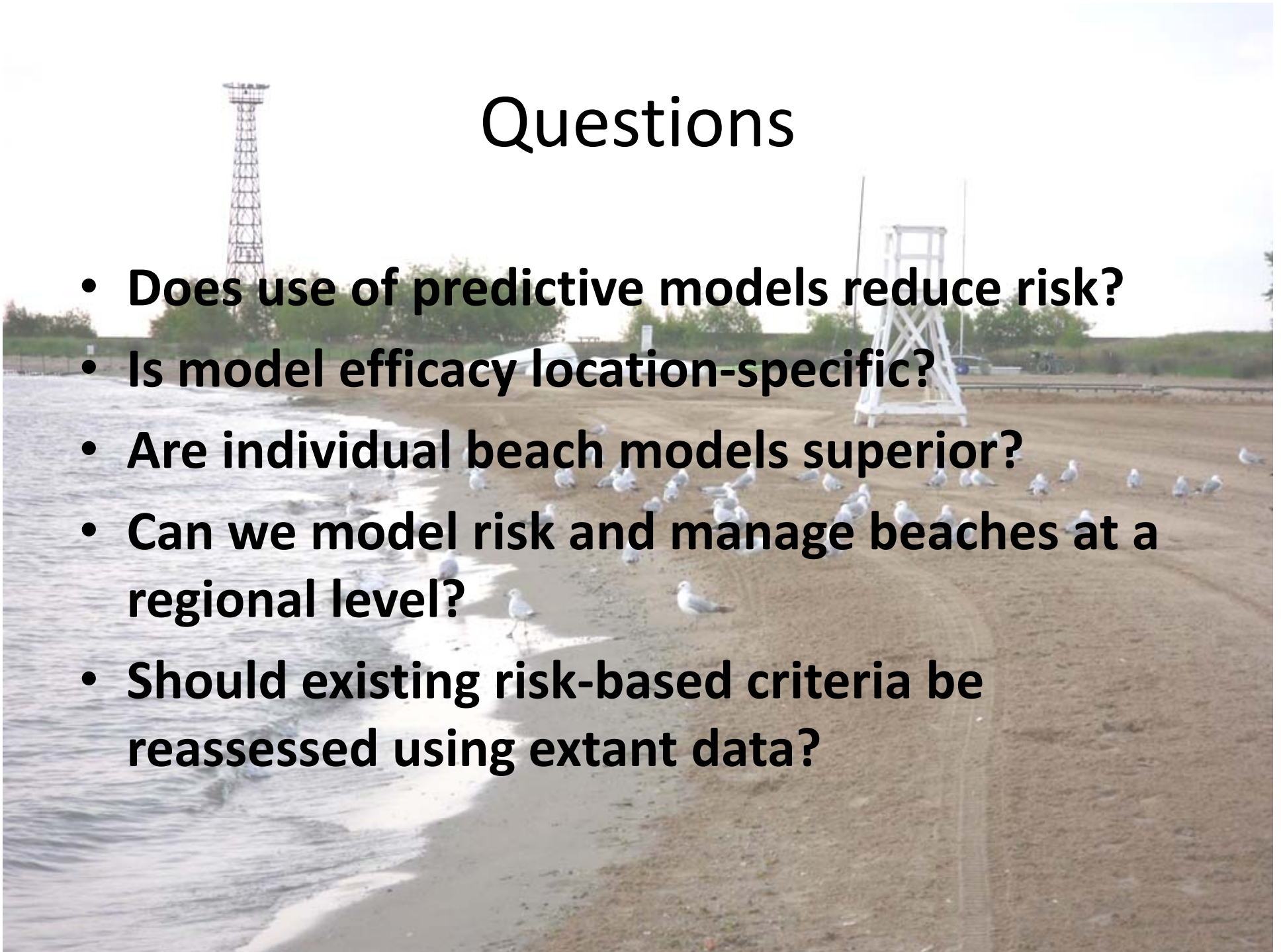
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Questions

- **Does use of predictive models reduce risk?**
- **Is model efficacy location-specific?**
- **Are individual beach models superior?**
- **Can we model risk and manage beaches at a regional level?**
- **Should existing risk-based criteria be reassessed using extant data?**



North Beach Park Beach Ottawa County Michigan E. coli Data 2002-2009

VB2 MLR $\text{Log}_{10}(\text{E. coli}) = \text{Const} + \text{Coef1} * \text{Var1} + \dots + \text{Coef6} * \text{Var6}$

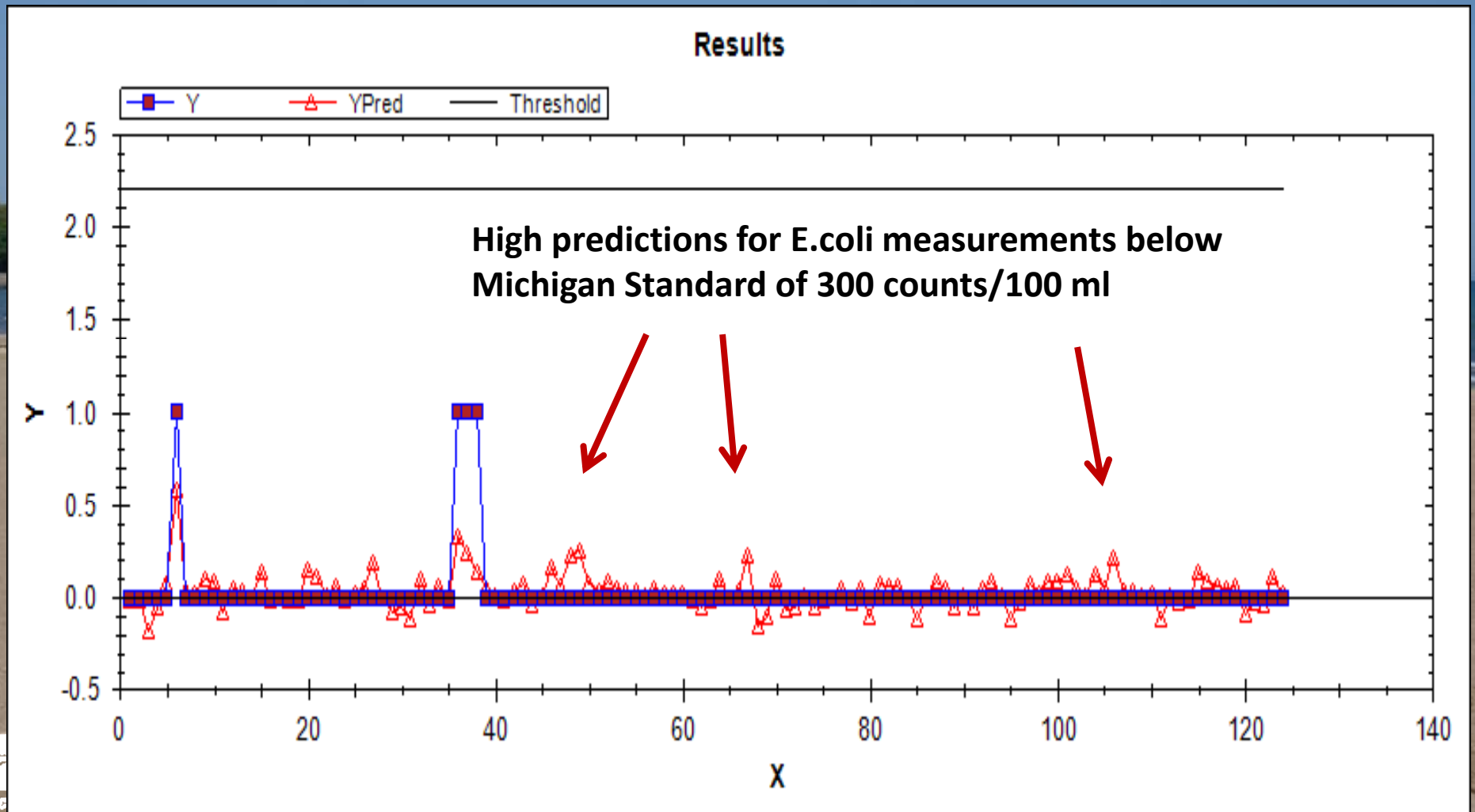
Variable Coefficient Std Error t Statistic p Value

Variable	Coefficient	Std Error	t Statistic	p Value
(Intercept)	149.4352	41.2617	3.6216	0.0004
[GRD1d] ^{1/2}	0.0058	0.0025	2.3502	0.02
WVH0	0.5436	0.1888	2.8798	0.005
Year	-0.0745	0.0206	-3.6266	0.0004
TP24Hr M	0.4109	0.2018	2.0362	0.04
DP24Hr M	0.0525	0.0119	4.4062	0.0000

R-square =39.6% Adj. R-square =37.0% N=124 Model Std Error=0.49

- [GRD1d]^{1/2} Sq Rt (Grand R. Flow at Grand Rapids 1 Day prior Sampling)**
- WVH0 Wave Height at time of Sampling**
- Year Calendar Year (not Julian Date)**
- TP24 M Total Precipitation Measured at Muskegon for 24 hours**
- DP24 M Dew Point Measured at Muskegon averaged over 24 hours**

Predicted versus Measurements for Binary *E. coli* Model



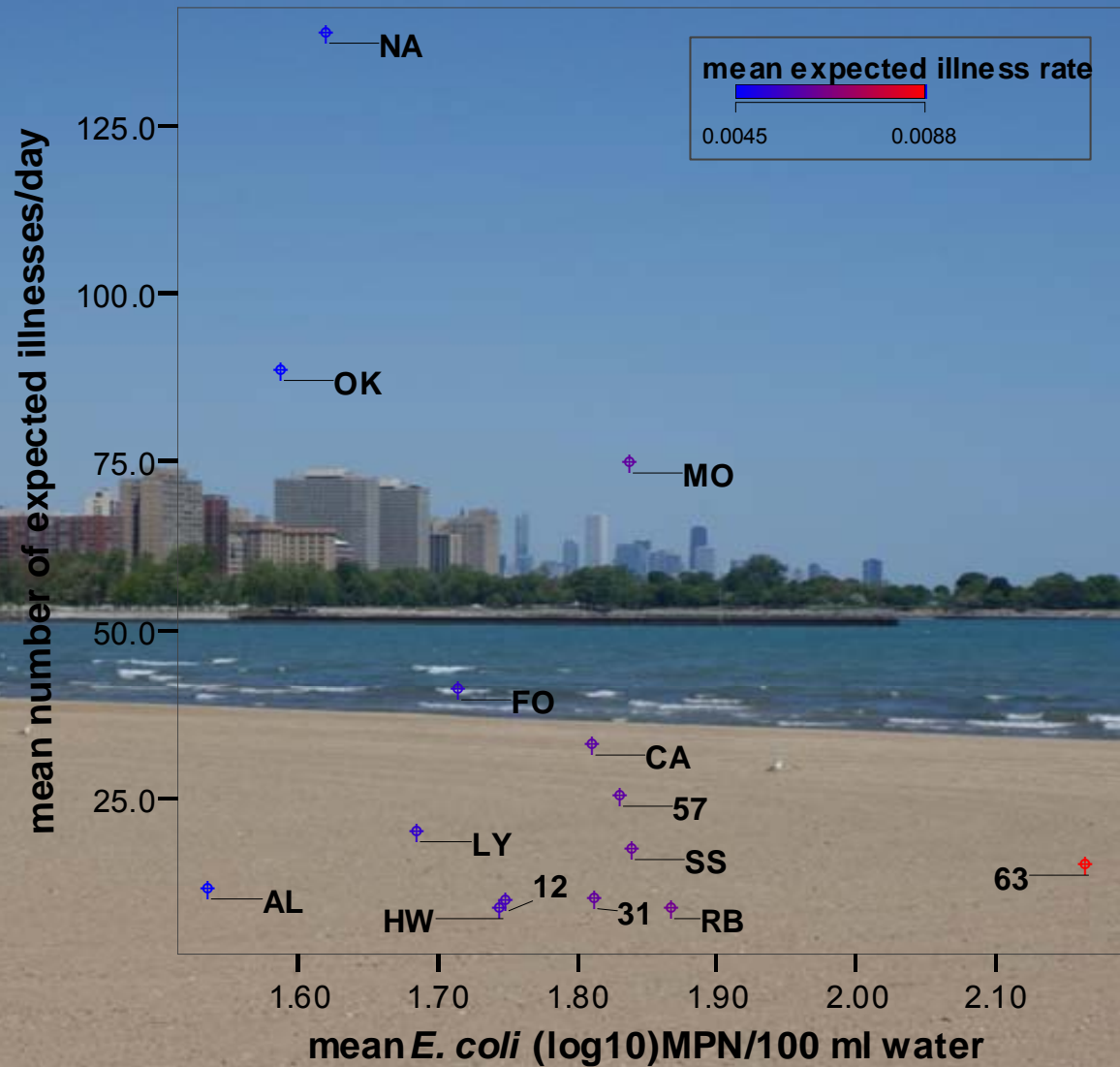
Methods

- Chicago beaches monitored 5 days a week for *E. coli*
- Data for developing predictive models from numerous locations
- Previous research found higher concentrations associated with south side beaches, overall



14 Chicago beaches included in analysis

Expected risk by beach relative to *E. coli* concentration



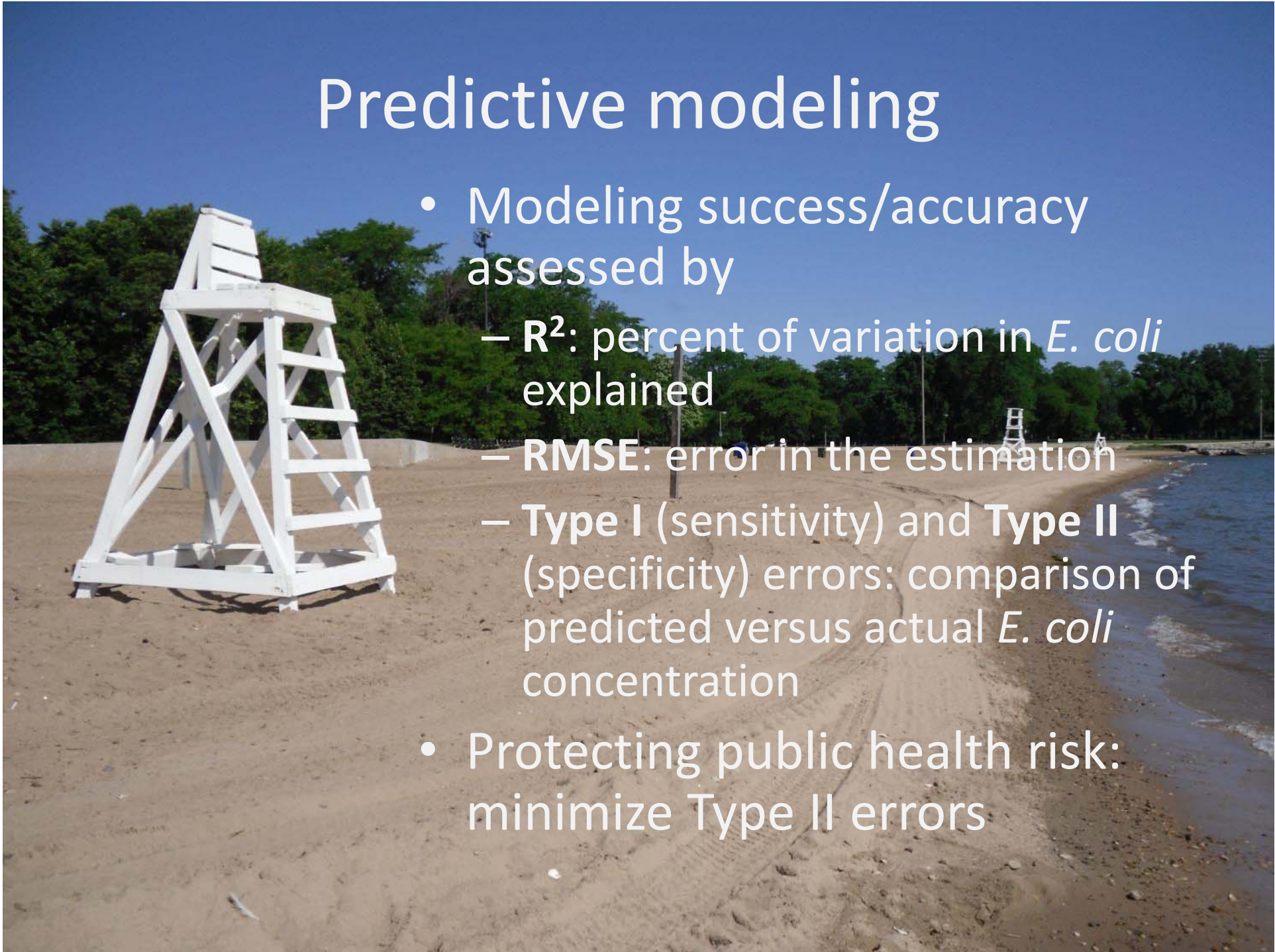
- High visited beaches: higher expected risk but low mean *E. coli*
- 63rd St Beach often stands alone

Four Possible Monitoring Outcomes Under a Binary Monitoring System

Management Outcome	Error	Health Risk	Loss of Use	Health Protection	Range of Reported Outcome Frequency for Chicago beaches	Range of Mean Illness Rate for Chicago Beaches (swimmers/1000)
Correct Open	none	low	low	accurate	49-78%	2.7-5.0
Correct Closed	none	high	high	accurate	3-14%	13.6-15.3
Incorrect Open	type 2	high	low	overly liberal	12-21%	14.4-16.1
Incorrect Closed	type 1	low	high	overly conservative	9-17%	4.2-6.4

Predictive modeling

- Modeling success/accuracy assessed by
 - R^2 : percent of variation in *E. coli* explained
 - RMSE: error in the estimation
 - Type I (sensitivity) and Type II (specificity) errors: comparison of predicted versus actual *E. coli* concentration
- Protecting public health risk: minimize Type II errors



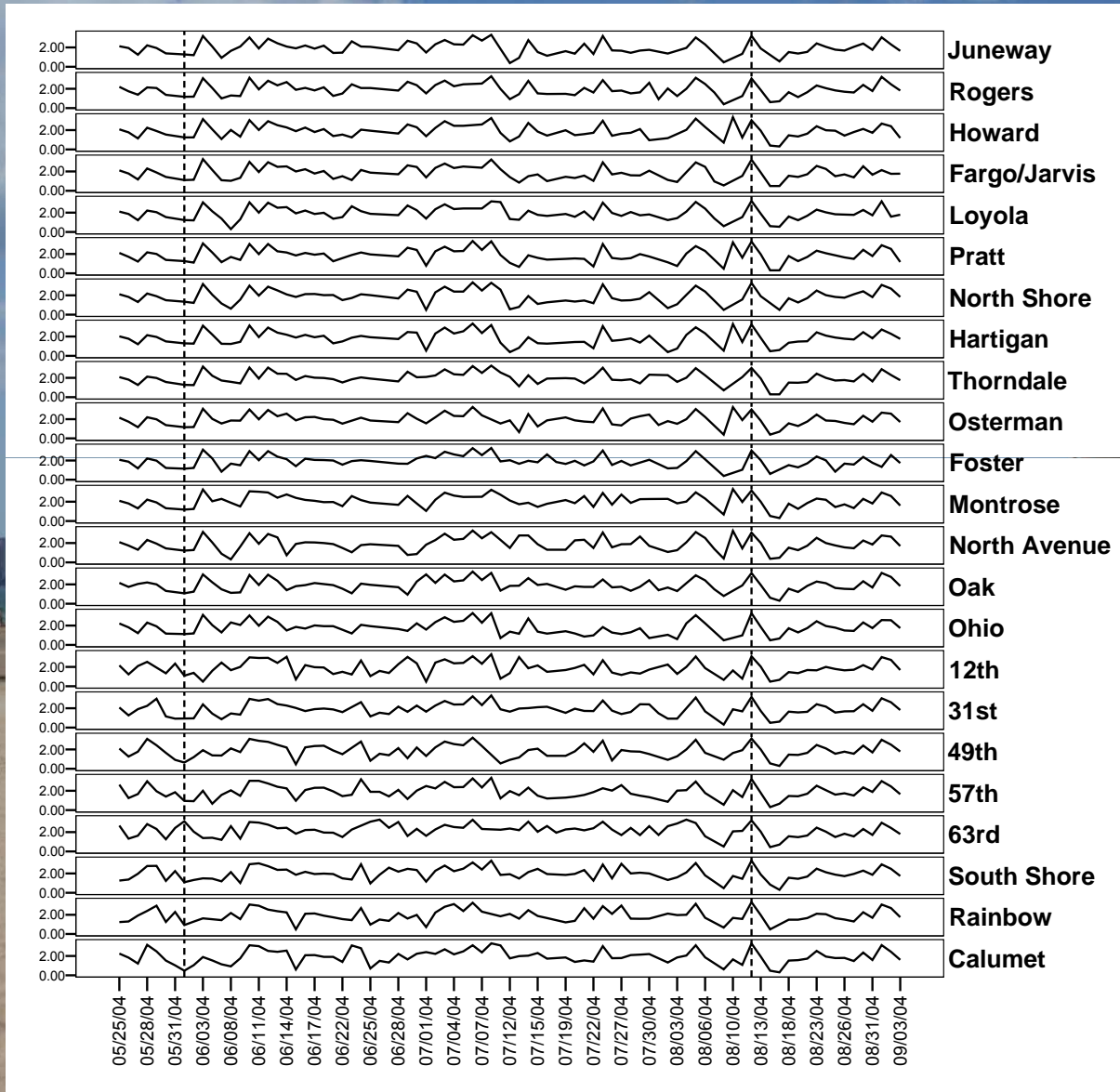
Model Development

- Individual Models Predictors: insolation and precipitation (24 h); air temperature, barometric pressure, and wave height (mean for 4-10 AM); and day of year
- Regional Model Predictors: barometric pressure, wave height, and day of year

Individual Beach Models

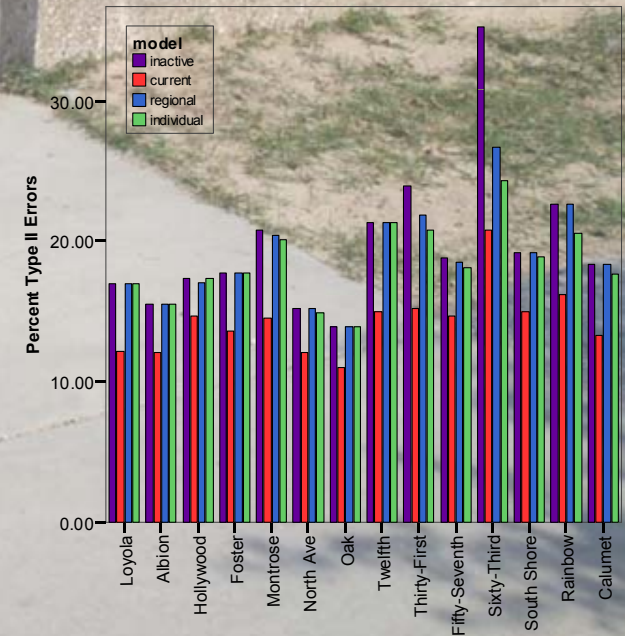
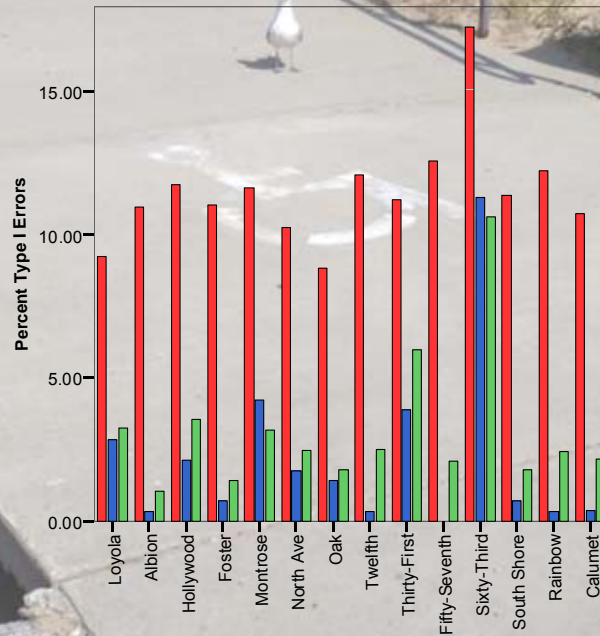
Beach	Predictors						Model Outcomes		
	solar insolation	pressure	air temp	precipitation	wave height	day of year	no. of predictors	RMSE	adj R ²
Loyola	X	X			X	X	4	0.654	0.261
Albion	X	X		X	X	X	5	0.676	0.269
Hollywood		X	X	X	X	X	5	0.604	0.267
Foster	X	X	X		X	X	5	0.620	0.209
Montrose		X		X	X	X	4	0.590	0.220
North Ave	X	X	X	X	X	X	5	0.591	0.313
Oak	X	X			X	X	4	0.605	0.271
Twelfth		X	X	X	X	X	5	0.656	0.198
Thirty_First	X	X			X	X	4	0.631	0.259
Fifty_Seventh	X	X	X	X	X	X	6	0.626	0.141
Sixty_Third	X		X	X	X	X	5	0.600	0.141
SouthShore	X	X	X		X	X	5	0.613	0.179
Rainbow	X		X		X	X	4	0.600	0.192
Calumet	X	X	X		X	X	5	0.601	0.211

Regional Beaches Model



Whitman, R.L. and M.B. Nevers. 2008. Summer *E. coli* Patterns and Responses along 23 Chicago Beaches. *Environmental Science & Technology* 42 (24), 9217-9224

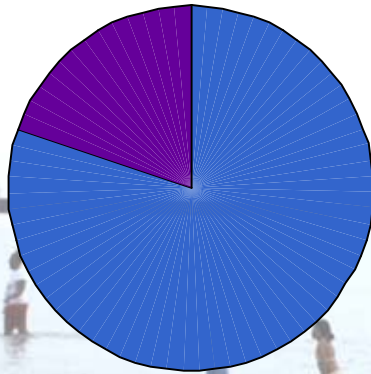
Model outcomes using three types of assessment



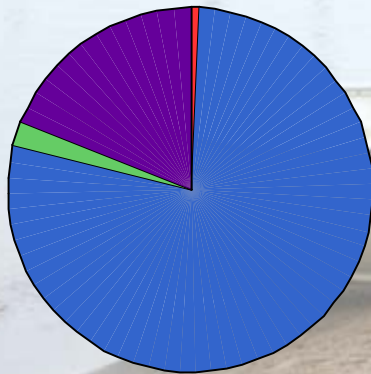
- Increasing accuracy at most beaches with model refinement
- Significant decrease in type I errors
- Decrease in type II errors associated with closing beach more often

Model Accuracy

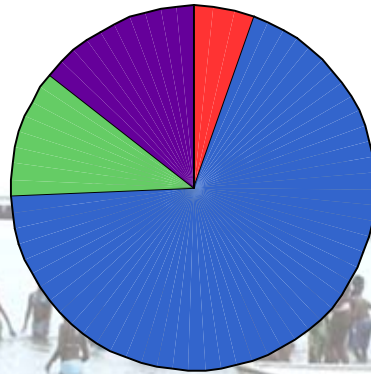
inactive



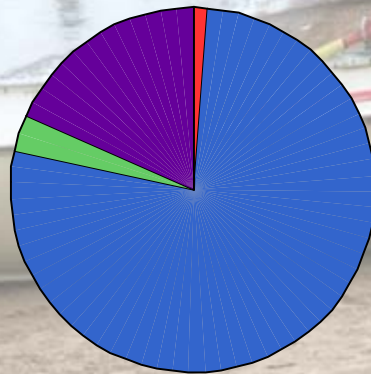
region



current



individual



outcome

- correct closed
- correct open
- type I error
- type II error

Current model had lowest percent of type II errors but also more type I errors

Calculating the single-sample monitoring standard

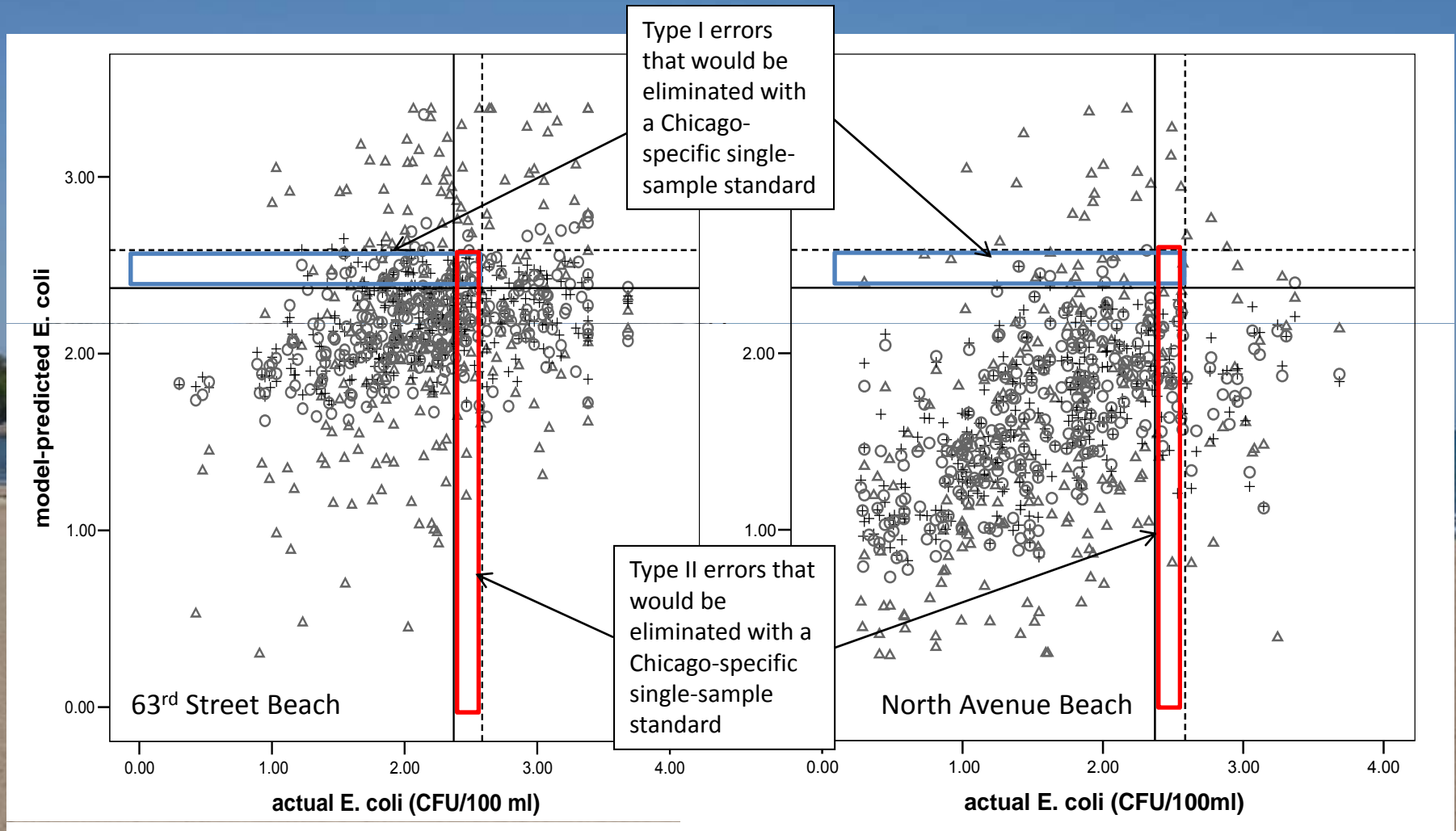
$$ss = 10^{\left\lceil \log_{10} GM + \{cl \times \log_{10} sd\} \right\rceil}$$

where ss= the single sample limit; GM=126, geometric mean *E. coli* concentration for acceptable illness rate of 8 per 1000; cl=0.675, the 75% calculated one-sided confidence level for a designated heavily used beach area, and sd= is the calculated standard deviation for a given jurisdiction

Ambient criteria use standard deviation = 0.4, resulting in single-sample limit of **235**

Standard deviation for Chicago beaches for 2000-2004 = 0.718, resulting in a single-sample limit of **385**

Use of Chicago-specific single sample standard and a predictive model increased beach access without influencing risk estimates



Δ current model
+ regional model
○ individual model

— 235 single sample limit
- - - 385 single sample limit

Conclusions

- Refinement of monitoring models generally increases predictability of *E. coli* but does not always result in fewer errors/excess illnesses
- Regional and individual models provide similar levels of accuracy in many locations
- For Chicago beaches, use of a location-specific single sample standard, combined with empirical predictive models, provided the greatest beach access without sacrificing public health protection
- Certain beaches lend themselves to modeling, even low closure beaches

Future Directions

- High *E. coli* events at beaches with large numbers of visitors should be targeted
- Forecasting *E. coli* will depend on understanding the interaction of these key predictive parameters
- The ideal monitoring method may differ among beaches; availability of a variety of approaches that increase health protection may be desirable