

Introduction

Long-term datasets are available from beach water quality monitoring programs. Many times when these monitoring programs identify poor water quality, the causes are unknown, making it difficult to remove contamination sources. One approach to greater understanding of the causes would be to analyze these datasets and develop beach management policies that would help minimize the occurrence of contamination spikes.

Monitoring Programs

Monitoring programs led by city, county, and state agencies provide analyses and determine beach closings. One of the larger programs in Florida is the Florida Healthy Beaches program led by the Florida Department of Health (DOH). With the assistance of Florida's 34 coastal counties, 316 beaches in the state are monitored and data is recorded.

Measuring Water Quality

Water quality is assessed through the measurement of fecal indicator bacteria, (FIB), such as enterococci. Enterococci serves as the indicator microbe for disease-causing pathogens in salt water. Water is sampled and analyzed through the process of membrane filtration. This process involves the filtration of 100mL of sampled water through membrane. The membrane is then analyzed for the number of colony-forming units (CFU) present per the sampled 100 mL. The blue-green areas shown in Figure 2 are the colony forming units. According to the most recent DOH standards, an exceedance of bacteria is determined to have occurred at **71 CFU/100 mL**. In our study, we defined an exceedance at **104 CFU/100 mL (enterococci)** per the standards in place during our period of study.

Category	Enterococci, CFU/100 ml		Fecal Coliform, CFU/100ml		Fecal coliform dropped
	July 2000 – December 2015	January 2016 – present	August 2000 – June 2002	July 2002 – June 2011	
Good	0-34	0-35	0 – 799	0 – 199	Fecal coliform dropped
Moderate	35-103	35-70		200 – 399	Not applicable
Poor	104 or greater	71 or greater	800	400	Not applicable

Table 1. Water quality standards for recreational beaches

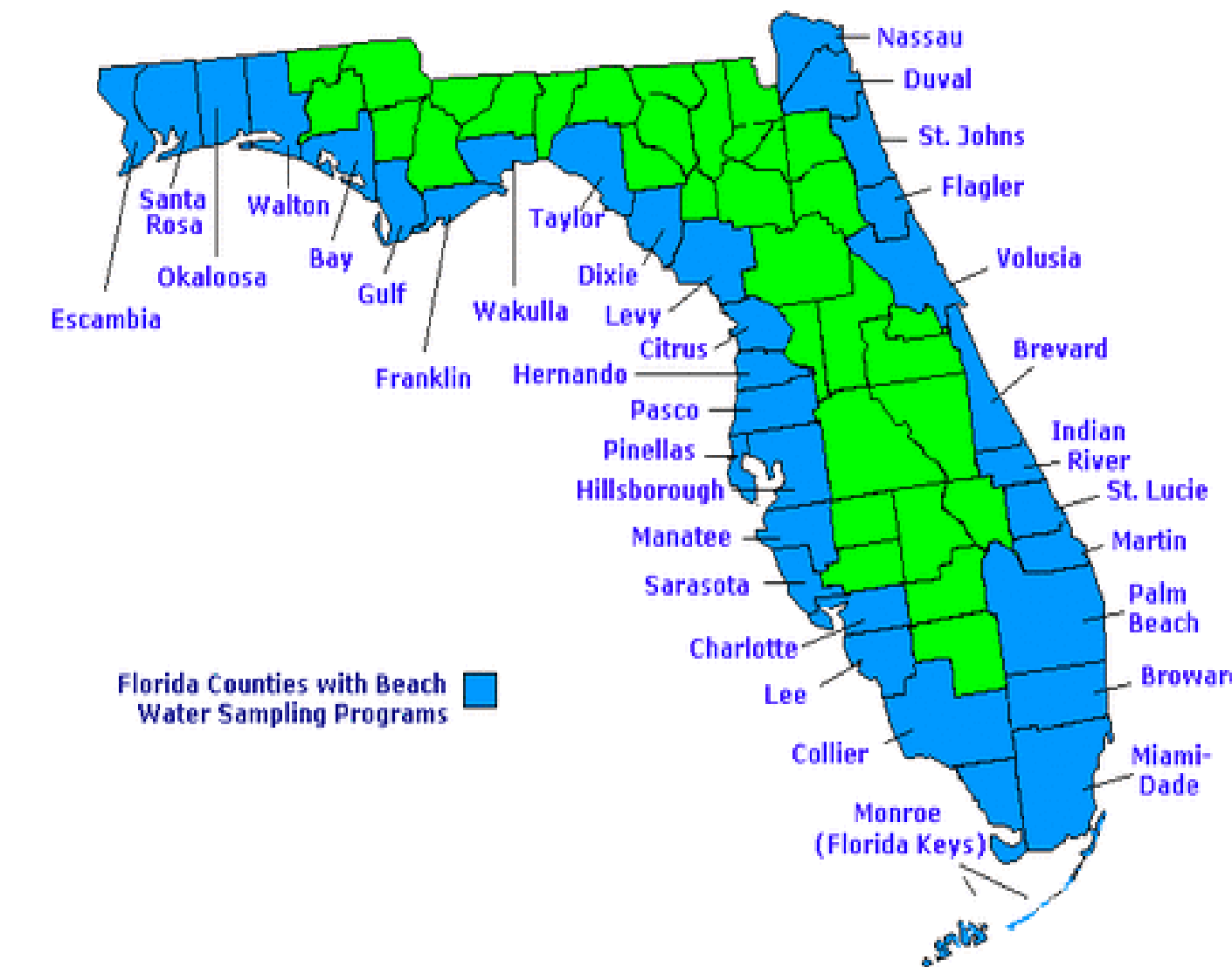


Figure 1. Counties (34) participating in the Florida Healthy Beaches program.

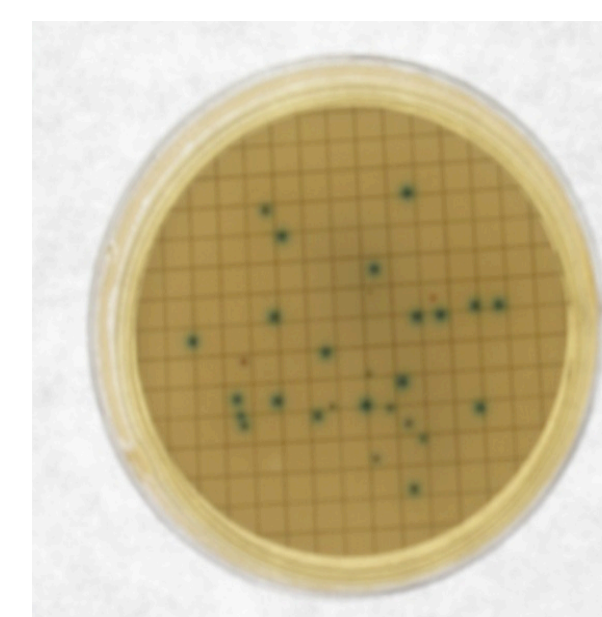


Figure 2. Filtration membrane for bacterial analysis. Blue-green areas are bacterial CFUs.

Methods

The objective of this study was to evaluate associations between beach water quality and beach management policies in an effort to assess management approaches that minimize exceedances of fecal indicator bacteria (FIB) through the data collected by the Florida Healthy Beaches program.

To address this objective, a survey was conducted to document beach management approaches for a large number of beaches (316 beaches throughout the state of Florida) and then analyzed to identify associations with FIB data (enterococci and fecal coliform). Part I evaluated county sampling and analysis policies and Part II examined beach management policies at the individual beaches. We also evaluated and classified the beaches by geomorphologic type.

Beach Type	Enterococci				Fecal Coliform			
	Mean % Exceed.	Standard Dev	Range	Statistical Significance*	Mean % Exceed	Standard Dev	Range	Statistical Significance*
Type 1, Open-coast (n=211)	1.7	1.7	0.0 – 16.4	A	0.6	1.0	0.0-5.3	A
Type 2, Bay (n=72)	6.9	5.3	0.0 – 25.2	B	3.8	4.0	0.0-18.2	B, C, E
Type 3, Inlet-channel-situated (n=3)	3.5	1.6	1.7 - 4.6	A, B	1.4	1.4	0.6-3.1	A, B, D
Type 4, Structure-protected (n=5)	6.5	5.5	1.2 - 12.9	B	6.1	3.6	3.0-10.8	C, E
Type 5, Marsh-surrounded (n=17)	14.5	10.5	0.7 - 30.5	C	2.9	1.6	1.0-7.1	D, E
Type 6, Back-reef (n=8)	3.5	2.0	0.7 – 7.5	A,B	1.1	0.9	0.0-2.8	A, D

*Beach types sharing the same letter are statistically not different.

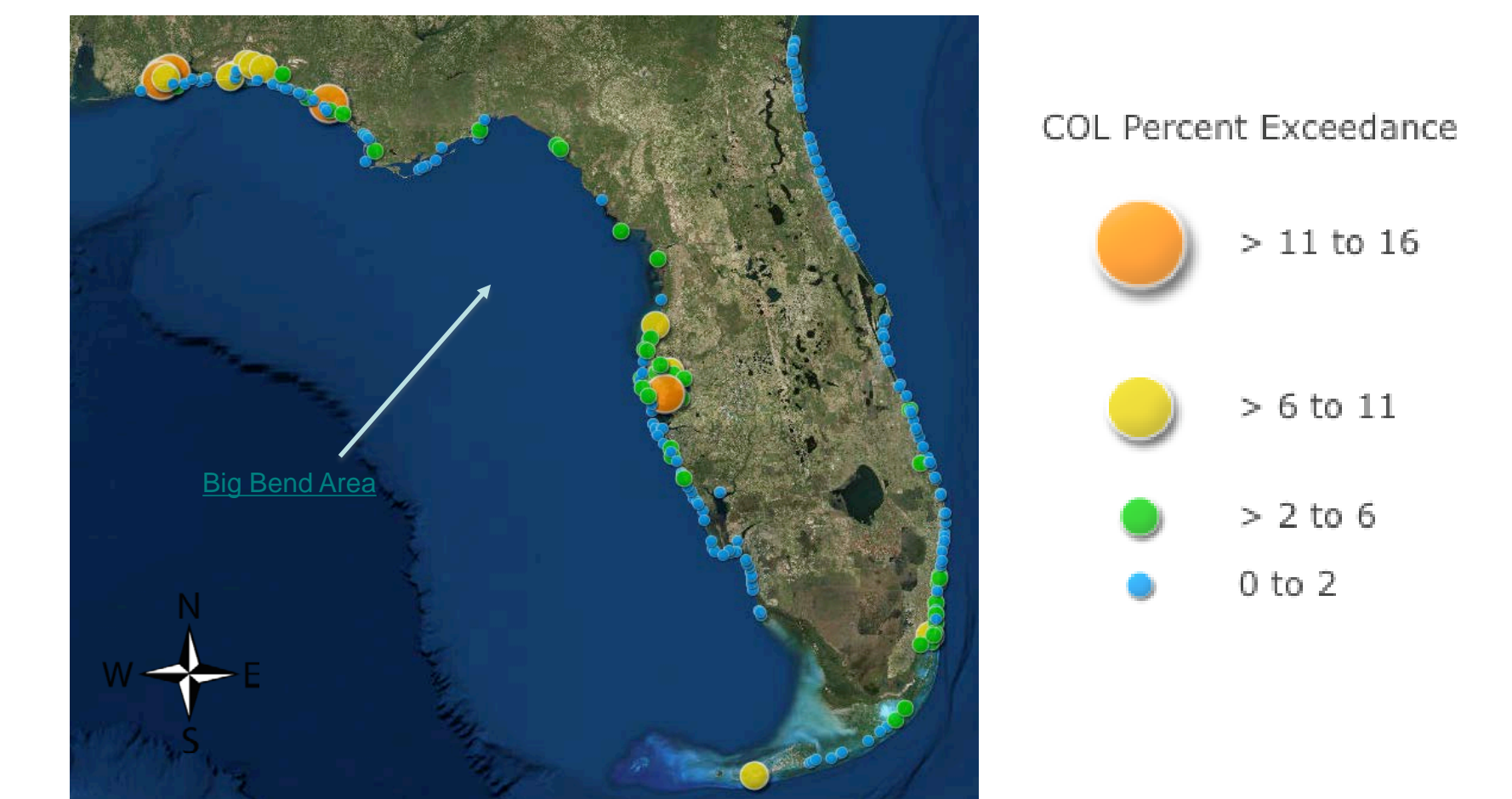
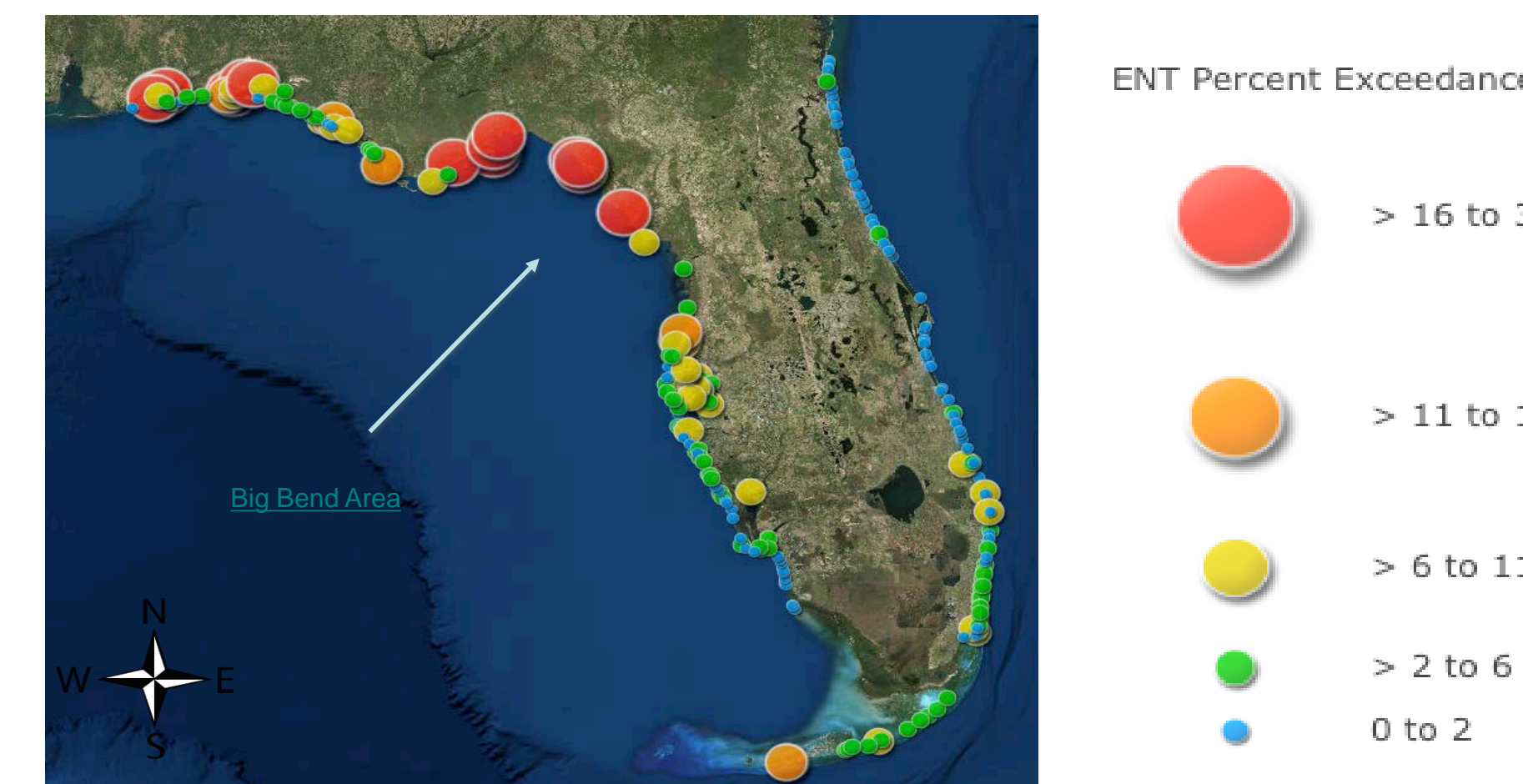
Table 2. Beaches by geomorphologic type.

Results

Results show that beach geomorphology is highly associated with exceedance of regulatory standards. For open-coast beaches (n=211), low enterococci levels were associated with:

- sparse human densities
- low densities of dogs and birds
- beaches with bird management policies
- beaches with lifeguards
- beaches with access fees
- beaches where maintenance vehicles are not permitted
- low amounts of seaweed
- beaches without nearby marinas
- beaches with public restrooms

Fecal coliform resulted in fewer regulatory exceedances and, therefore, statistical differences among beaches with different management policies were fewer.



Address Dogs	Enterococci % Exceedance	Fecal Coliform % Exceedance
ALL RESPONSES		
yes (n=155)	2.6	1.2
no (n=25)	4.1	2.3
p-value	0.1	0.1
TYPE 1 OPEN COAST		
yes (n=119)	1.7	0.7
no (n=13)	2.1	1.3
p-value	0.3	0.1

Table 3. Beaches that address dogs at beaches where they are not allowed versus those that do not address them, all responses and Type 1 Open Coast

Bird Policies	Enterococci % Exceedance	Fecal Coliform % Exceedance
ALL RESPONSES		
yes (n=59)	2.1	0.7
no (n=211)	4.1	1.7
p-value	<0.1	<0.1
TYPE 1 OPEN COAST		
yes (n=41)	0.9	0.3
no (n=138)	1.7	1.6
p-value	<0.1	<0.1

Table 4. Beaches that have bird policies versus those that do not, all responses and responses for Type 1 Open Coast beaches.

Marinas	Enterococci % Exceedance	Fecal Coliform % Exceedance
ALL RESPONSES		
yes (n=108)	4.1	2.3
no (n=112)	2.3	0.8
p-value	<0.1	<0.1
TYPE 1 OPEN COAST		
yes (n=64)	1.8	0.8
no (n=91)	1.5	0.4
p-value	0.4	0.02

Table 5. Beaches with marinas nearby versus those where there are not, all responses and Type 1 Open Coast beaches.

Manage Storm Water	Enterococci % Exceedance	Fecal Coliform % Exceedance
ALL RESPONSES		
yes (n=141)	3.0	2.5
no (n=62)	5.2	3.1
p-value	0.04	0.3
TYPE 1 OPEN COAST		
yes (n=101)	1.4	0.5
no (n=39)	1.4	0.5
p-value	0.8	0.9

Table 6. Storm water management at the beaches, all responses and Type 1 Open Coast beaches.

Conclusions

As we conducted our survey and analysis, we found that 1) not all beach policies were associated with improvements in water quality, 2) beach management varies greatly throughout the state, and 3) is accomplished through various unrelated agencies and independent actions by different groups. Beach management is not standardized, and beach management policies are carried out and enforced through multiple, sometimes overlapping agencies at the private, municipal, county, state, and national level. The amount of beach management that can be accomplished varies according to the amount of funding set aside for monitoring and management, along with the policies written for the specific agency responsible for individual management and monitoring tasks. Monitoring and management must compete with other programs that also require funding, and water quality funding is frequently a low priority.

Our results indicate that future work on human use including dogs, birds, beach use and amenities, beach access, and local beach environment will be necessary to understand individual beach environments and to develop recommendations for sustainable beach environments within environments and communities, especially as threats of sea level rise and flooding increase along Florida's coast.

Overall, beach management policies influence FIB levels and beach geomorphology should be considered when making beach policy decisions. Standardization of beach management policy could improve beach water quality. Future work could focus on expanding upon our findings or evaluating other similar long-term datasets using similar approaches.