To: John Foster, Elbow Cay, the Bahamas; Friends of the Environment, Marsh Harbor, the Bahamas

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Group: Tufts University Water: Systems, Science, and Society (WSSS) Program

Subject: A Study of Fecal Coliform in the Coastal Waters of Elbow Cay, March 13 to March 18, 2009

Summary

This memo describes the results of water testing on Elbow Cay between March 13 and 18, 2009 for sewage indicator bacteria. Hope Town Harbour and White Sound as well as several background sites around Elbow Cay were analyzed for fecal coliform bacteria, a general indicator of sewage. Our results indicate that fecal coliform bacteria levels in the two harbors were higher than the Florida Department of Environmental Protection (Florida DEP) standard for shellfish harvesting and propagation, and were approaching the levels at which water would be classified as unfit for recreational contact and maintenance of a healthy ecosystem. In general, Hope Town Harbour exhibited higher fecal coliform counts than White Sound. The background sites had much lower fecal coliform counts than either Hope Town Harbour or White Sound. Significant spatial variation in coliform counts within the two harbors was not evident.

Objective

The objective of this study was to characterize the severity of sewage pollution in Hope Town Harbour and White Sound, Elbow Cay. Fecal coliform, a group of several different bacteria species that grow in the intestinal tract of warm-blooded animals, are used to indicate the presence of more harmful pathogenic bacteria found in sewage. If sewage bacteria are present in high concentrations in recreational waters and are ingested while swimming (or enter the skin through a cut or sore), they may cause disease, infections or rashes. By testing water for fecal coliform, the presence of sewage within

coastal waters can be inferred and the safety of water for recreational uses and fishing can be assessed by comparing fecal coliform levels to published standards.

Methods

Fifty-five water samples were collected in the coastal waters around Elbow Cay from March 13 to March 18, 2009. Samples were taken from Hope Town Harbour, White Sound and several background sites for comparison. In each harbor, samples were taken both near the shore and in the middle of the harbor. Sites for background levels were chosen based on distance from potential human influences such as boat moorings and land-based sewage disposal systems. Hope Town Harbour had a larger number of boats moored in the harbor, and more homes and businesses on the shore than White Sound. The buoy at the entrance to White Sound, and several locations near Eagle Rock and Fry's Mangrove were used as background sites. Figures 1-3 show the sampling results.

Fecal coliform testing followed United States Environmental Protection Agency (US EPA) *Standard Method 1604: Total Coliforms and Eschericia coli in Water by Membrane Filtration Using a Simultaneous Detection Technique (MI Medium)*. Fecal coliform concentrations are reported as coliform forming units per 100 mL sample (cfu/100mL) and were compared to Class II and Class III waters as defined by the Florida DEP Surface Water Quality Classifications (Florida DEP, 2008). Class II waters are considered suitable for shellfish propagation and harvesting. Class III waters are suitable for recreation and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The Class II water regulations require that (i) the median value of fecal coliform counts not exceed 14 cfu/100 mL; (ii) no more than 10% of fecal coliform counts exceed 43 cfu/100 mL; and (iii) no coliform counts exceed 800 cfu/100 mL on any one day. The Class III water regulations require that fecal coliform counts from marine waters not exceed (i) a monthly average of 200 cfu/100 mL; (ii) 400 cfu/100 mL in 10% of the samples; or (iii) 800 cfu/100 mL on any one day. Monthly averages are to be expressed as geometric means based on a minimum of 10 samples taken over a 30-

day period. Geometric means reported in this memo are based on samples collected over the study period (March 13 – March 18, 2009).

Results

Hope Town Harbour exhibited a larger median fecal coliform count (146 cfu/100 mL) than White Sound (31 cfu/100 mL) (Figure 4). The areas tested to determine background levels had a much lower median fecal coliform count (3 cfu/100 mL) than either Hope Town Harbour or White Sound. There was no discernable spatial pattern in fecal coliform levels in either Hope Town Harbour or White Sound; within each harbor, fecal coliform levels did not exhibit a high degree of correlation with the distance of the sample location from shore.

Sampling results indicate that the waters tested met the Florida DEP Class III standards for recreational uses and maintaining healthy ecosystems, but some test areas did not meet Florida DEP Class II standards for shellfish propagation and harvesting. Results are compared with Florida DEP standards in Table 1. Both the median fecal coliform count and the percentage of samples over 43 cfu/100 mL in Hope Town Harbour exceeded the Class II median coliform number concentration for shellfish propagation and harvesting. The Class II thresholds for median coliform count and for percentage over 43 cfu/100 mL were also exceeded in White Sound. Fecal coliform counts in the background sites did not exceed the Class II thresholds.

Sample locations are shown in Appendix B. A complete listing of all fecal coliform data is provided in Appendix C.

Recommendations for Further Testing

The fecal coliform bacteria levels in Hope Town Harbour and White Sound should be monitored regularly to gauge ecosystem health and to detect trends in fecal pollution. At a minimum, sampling should occur weekly during times of peak tourism. Ideally, sampling would occur throughout the year to capture the trends in fecal coliform during seasonal changes. The temperature and pH of the water bodies should be monitored due to the potential for influence of fecal coliform growth (Shibata, et. al,

2004 and Roeder, et. al, 2008*). Entrococci* bacteria are most suited for the detection of human sewage in coastal waters (US EPA, 2002). The results of the tests should be analyzed for seasonal and annual trends.

Based on the high fecal coliform concentrations found during our week-long fecal coliform testing, Hope Town Harbour and White Sound should continue to be monitored. Two sampling sites (one near shore, one near the center) within each harbor should be chosen and used consistently. In addition, popular recreational beaches – such as Tahiti Beach – should be monitored. Background levels should be measured as a reference and to detect any natural, long-term trends.

Figures and Tables

Figure 1 - Sampling results within Hope Town Harbour. Fecal coliform counts (cfu/100 mL) shown.

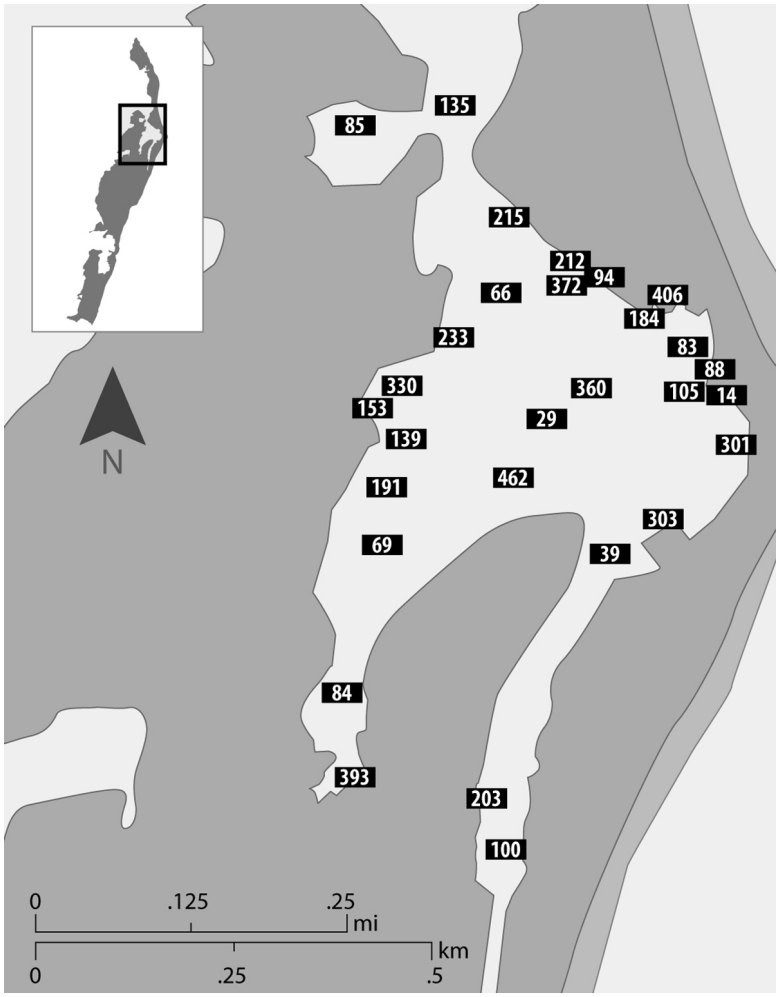


Figure 2 - Sampling results within White Sound. Fecal coliform counts (cfu/100 mL) shown.

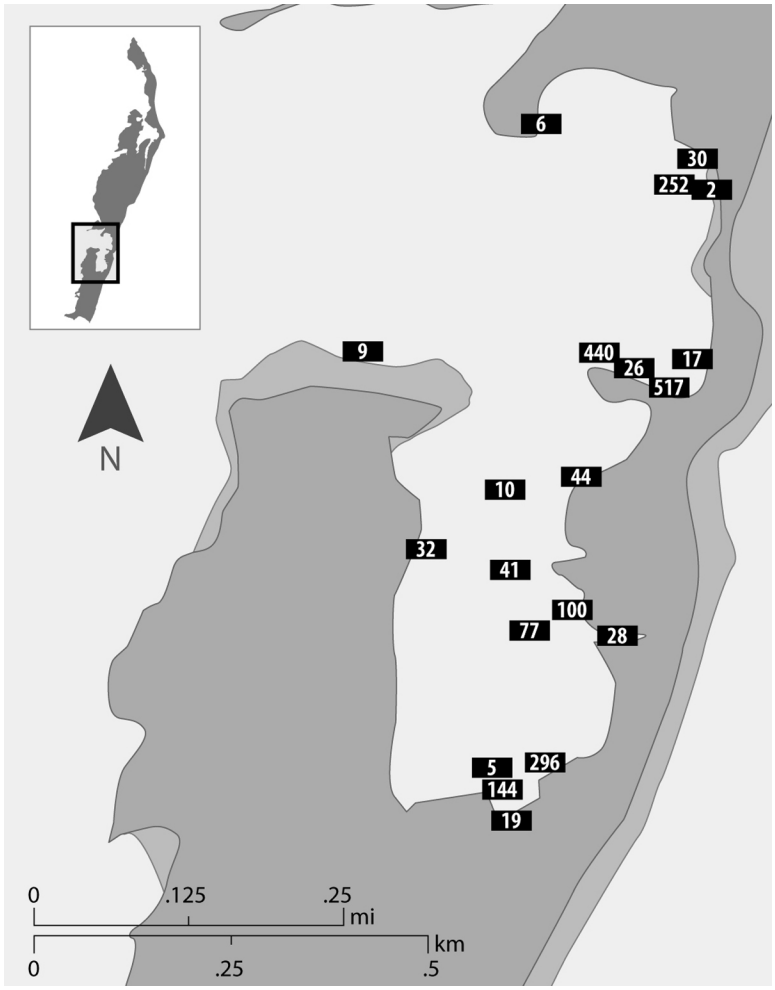


Figure 3 - Background sampling results. Fecal coliform counts (cfu/100 mL) shown.

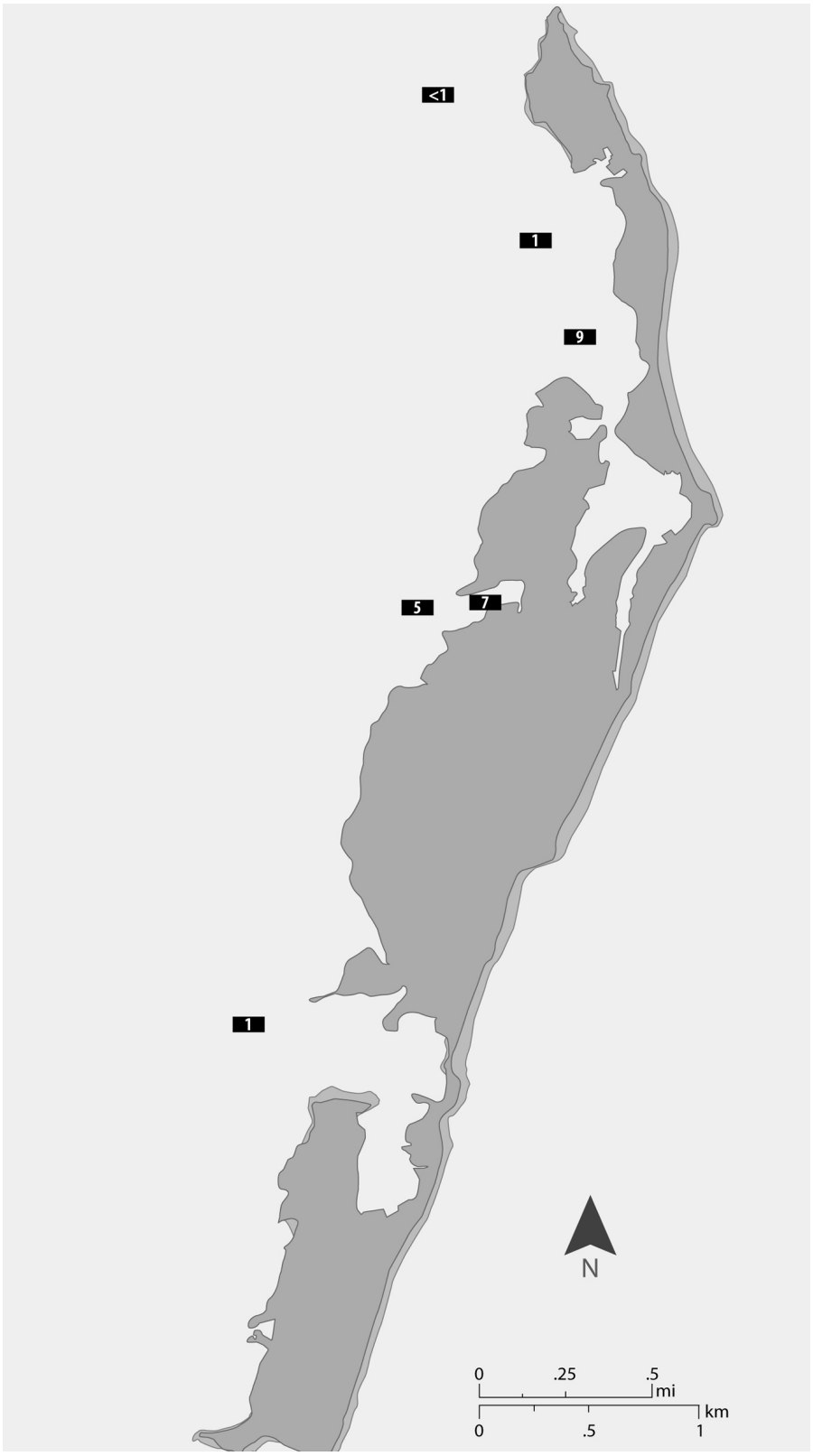
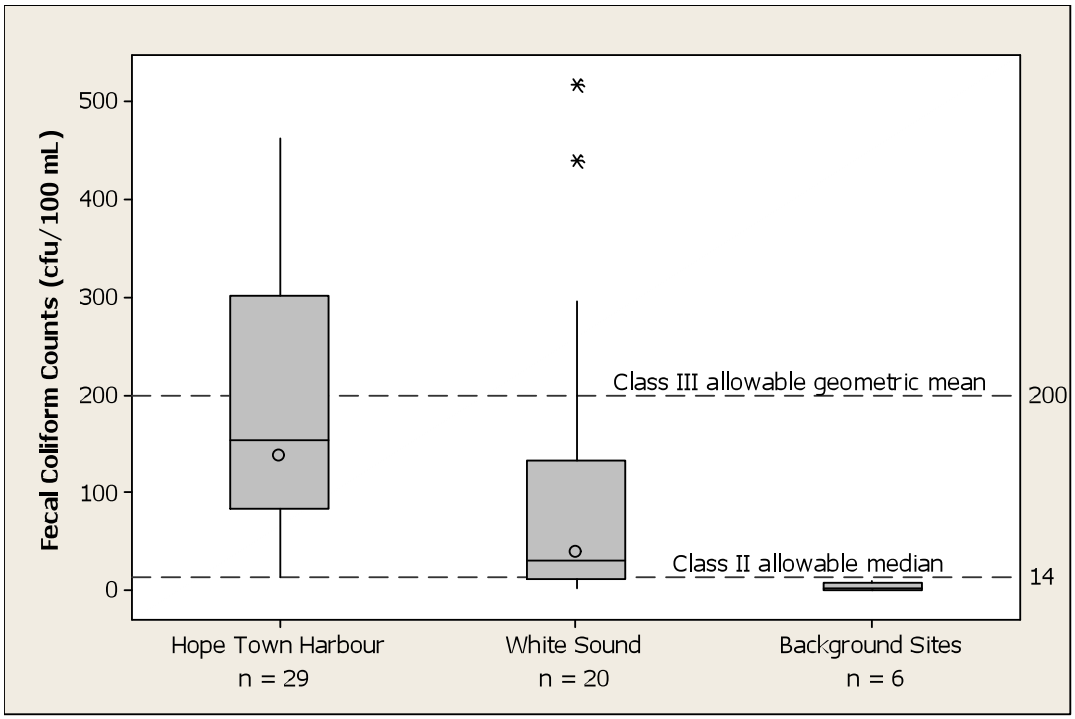


Figure 4 - Summary of fecal coliform data on Elbow Cay, March 13-18, 2009.



Shaded boxes represent the 25th through 75th percentiles. Vertical lines extend to the largest and smallest values within 1.5 times the interquartile range of the shaded box, where the interquartile range is equal to the value of the 75th percentile minus the value of the 25th percentile. Open circles represent the geometric means. Solid lines through the shaded boxes represent the medians. A figure labeling boxplot components is provided in Appendix A.

Table 1 - Comparison of results with Florida DEP standards.

Test Areas	No. of Samples	Class II waters			Class III marine waters		
		Median	Percent of samples with cfu > 43	No. of samples with cfu > 800	Geometric mean (cfu)	Percent of samples with cfu > 400	No. of samples with cfu > 800
EPA Threshold		14	10%	0	200	10%	0
Hope Town Harbour	29	153	93%	0	142	7%	0
White Sound	20	31	40%	0	38	10%	0
Background Sites	6	3	0%	0	3	0%	0

References

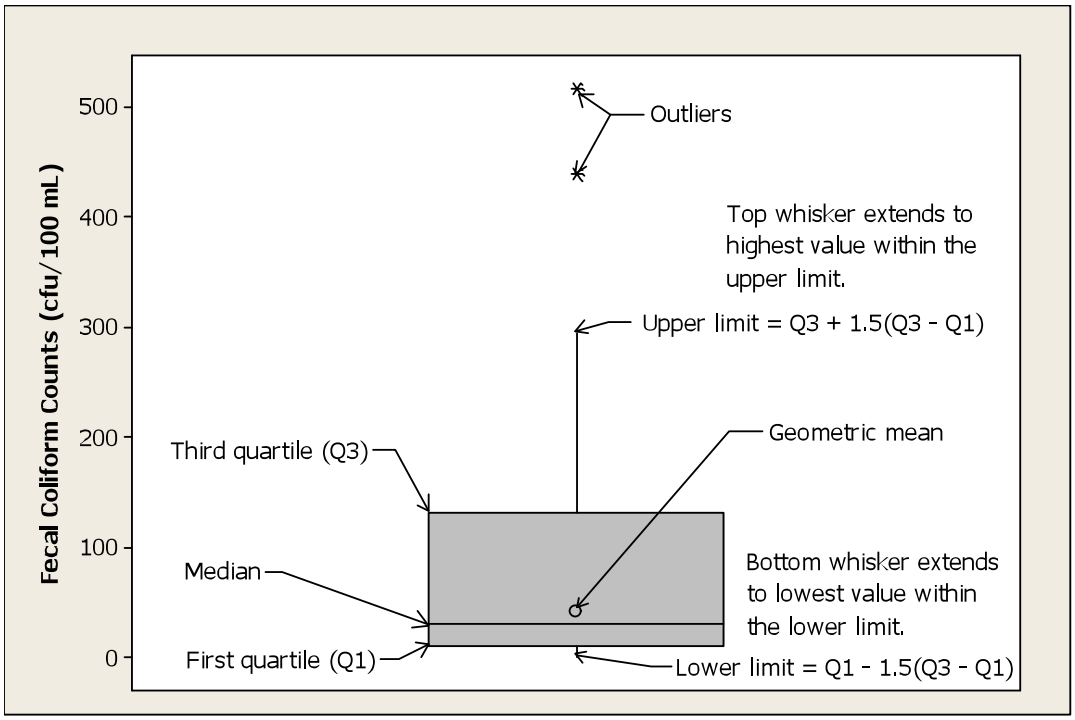
Florida DEP, 2008. Florida Administrative Code Section 62-302.530 – Table: Criteria for Surface Water Quality Classifications. http://www.dep.state.fl.us/water/wqssp/classes.htm (Accessed on October 20, 2009).

Roeder, E., Rachal, J., 2008. *Draft Report Phase 1. Taylor County Coastal Community Water Quality Monitoring*. Taylor County Health Department. DOH-Bureau of Onsite Sewage Programs. http://www.doh.state.fl.us/Environment/ostds/research/05-29-08Materials/20_TaylorPhase1.pdf.

Shibata, T, Solo-Gabriele, H.M., Fleming, L.E., and Elmir, S., 2004. *Monitoring Marine Recreational Water Quality Using Multiple Microbial Indicators in an Urban Tropical Environment.* Water Research 38.

US EPA, 2002. *Method 1600: Enterococci in Water by Membrane Filtration Using Membrane-Enterococcus Indoxyl-β-D-Glucoside Agar (mEI).* http://www.epa.gov/nerlcwww/1600sp02.pdf.

Appendix A – Sample Boxplot



Appendix B

Figure B.1 - Sampling locations within Hope Town Harbour. Sample numbers shown.

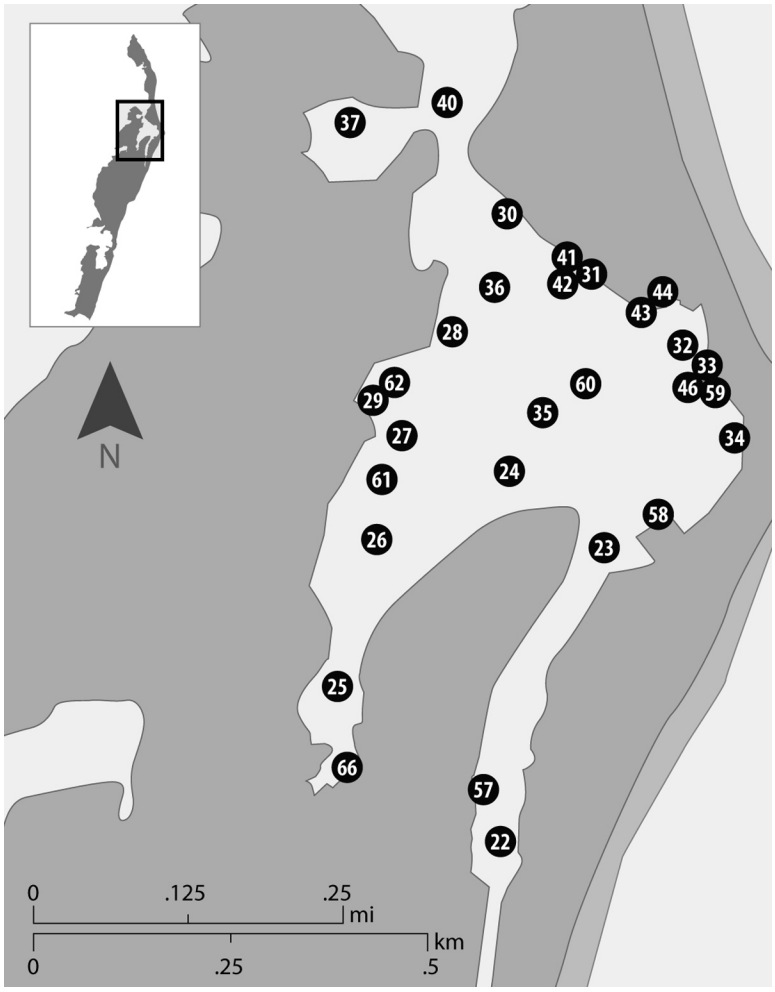


Figure B.2 – Sampling locations within White Sound. Sample numbers shown.

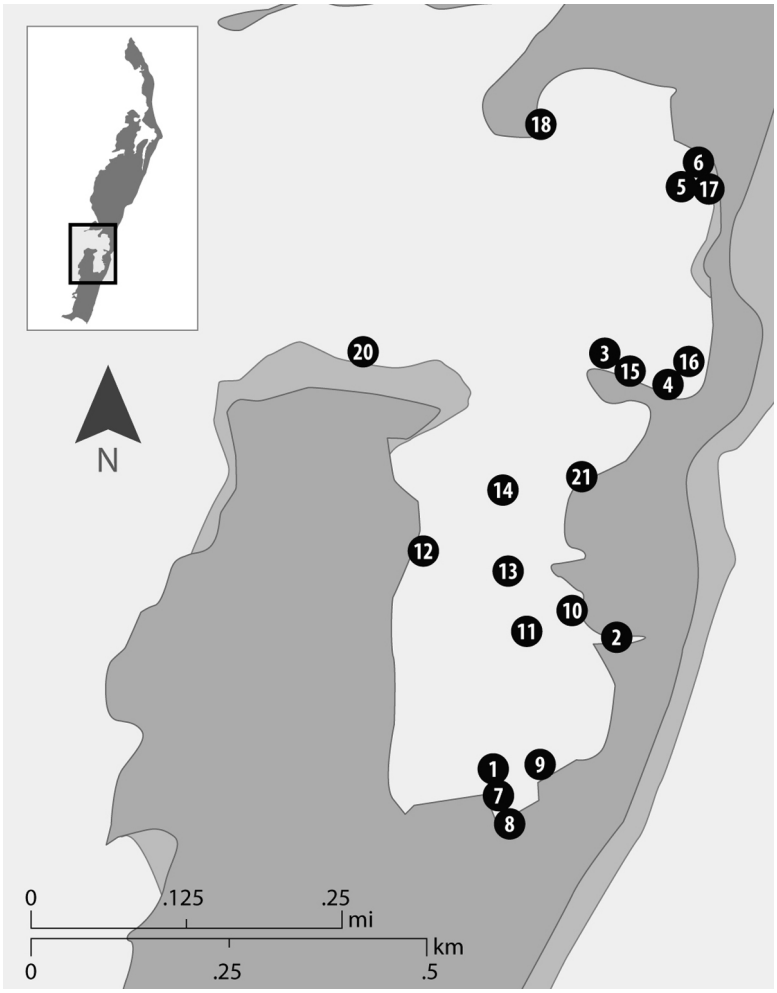


Figure B.3 – Background sampling locations. Sample numbers shown.

Appendix C – Fecal coliform data

Table C.1 Fecal Coliform Counts for Hope Town Harbour					
Sample No.	Latitude	Longitude	Tide[1]	Date	Fecal Coliform Count (cfu/100 mL)
22	26.53282	76.96088	high	3/16/2009	100
23	26.53595	76.95919	high	3/16/2009	39
24	26.53693	76.96025	high	3/16/2009	462
25	26.53470	76.96280	high	3/16/2009	84
26	26.53639	76.96201	high	3/16/2009	69
27	26.53748	76.96158	high	3/16/2009	139
28	26.53857	76.96082	high	3/16/2009	233
29	26.53799	76.96169	high	3/16/2009	153
30	26.53988	76.95994	high	3/16/2009	215
31	26.53919	76.95911	high	3/16/2009	94
32	26.53808	76.95787	high	3/16/2009	83
33	26.53762	76.95759	high	3/16/2009	88
34	26.53708	76.95736	high	3/16/2009	301
35	26.53749	76.95978	ebb	3/16/2009	29
36	26.53909	76.96016	ebb	3/16/2009	66
37	26.54113	76.96175	ebb	3/16/2009	85
40	26.54123	76.96056	N/A	3/17/2009	135
41	26.58917	76.95404	low	3/17/2009	212
42	26.53918	76.95905	flood	3/17/2009	372
43	26.53821	76.95792	flood	3/17/2009	184
44	26.53825	76.95790	flood	3/17/2009	406
46	26.53769	76.95772	flood	3/17/2009	105
57	26.53338	76.96098	low	3/18/2009	203
58	26.53629	76.95842	low	3/18/2009	303
59	26.53718	76.95769	low	3/18/2009	14
60	26.53787	76.95914	flood	3/18/2009	360
61	26.53712	76.96178	flood	3/18/2009	191
62	26.53800	76.96169	flood	3/18/2009	330
66	26.53383	76.96235	flood	3/18/2009	393

[1] Tides are described by dividing the tidal cycle into quarters. High tide refers to the quarter of the tidal cycle when water levels are highest. Ebb tide refers to the quarter of the tidal cycle when water levels are decreasing. Low tide is the quarter of the cycle in which water levels are lowest. Flood tide refers to the quarter of the cycle in which water levels are increasing.

Table C.2 Fecal Coliform Counts for White Sound					
Sample No.	Latitude	Longitude	Tide	Date	Fecal Coliform Count (cfu/100 mL)
1	26.50947	76.97517	ebb	3/15/2009	5
2	26.51120	76.97327	ebb	3/15/2009	28
3	26.51413	76.97310	ebb	3/15/2009	440
4	26.51379	76.97233	ebb	3/15/2009	517
5	26.51613	76.97183	ebb	3/15/2009	252
6	26.51620	76.97176	ebb	3/15/2009	30
7	26.50934	76.97523	low	3/16/2009	144
8	26.50915	76.97520	low	3/16/2009	19
9	26.50980	76.97466	low	3/16/2009	296
10	26.51137	76.97431	low	3/16/2009	100
11	26.51119	76.97467	low	3/16/2009	77
12	26.51228	76.97585	low	3/16/2009	32
13	26.51184	76.97490	low	3/16/2009	41
14	26.51280	76.97481	low	3/16/2009	10
15	26.51405	76.97314	low	3/16/2009	26
16	26.51386	76.97234	low	3/16/2009	17
17	26.51602	76.97181	low	3/16/2009	2
18	26.51698	76.97370	low	3/16/2009	6
20	26.51459	76.97633	flood	3/16/2009	9
21	26.51283	76.97376	flood	3/16/2009	44

Table C.3 Fecal Coliform Counts for background sites					
Sample No.	Latitude	Longitude	Tide	Date	Fecal Coliform Count (cfu/100 mL)
19	26.51850	76.98055	low	3/16/2009	1
38	26.54432	76.96175	ebb	3/16/2009	9
39	26.53428	76.96861	low	3/17/2009	5
63	26.54536	76.96226	flood	3/18/2009	1
64	26.55496	76.96489	flood	3/18/2009	< 1
67	26.53452	76.96659	flood	3/18/2009	7