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Bathing Beach Monitoring for New Indicators 44 pp

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Narragansett Bay Estuary Program

BATHING BEACH MONITORING

FOR NEW INDICATORS

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Final Report for the
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FOREWORD

The United States Congress created the National Estuary Program in 1984, citing its concern for the "health and ecological integrity" of the nation's estuaries and estuarine resources. Narragansett Bay was selected for inclusion in the National Estuary Program in 1985 and the Narragansett Bay Project (NBP), a multi-year study of the Bay and its resources, was established. Under the joint sponsorship of the U.S. Environmental Protection Agency and the Rhode Island Department of Environmental Management, the NBP has involved participation by local, state, and federal agencies, the academic community, and local interest and user groups. The purpose of the Narragansett Bay Project is first to identify and evaluate pollution problems and causes in the Bay through a five-year plan of scientific research. Based on the results the NBP will then develop a comprehensive management plan by December, 1990, which will recommend actions to improve and protect the Bay from further degradation.

In March, 1988, the Administrator of EPA and the Governor of Rhode Island signed an agreement officially designating Narragansett Bay as an "estuary of national significance". The State of Rhode Island pledged to make a good faith effort to institute whatever corrective actions are recommended by the management plan as necessary to protect the Bay. The EPA will continue to support the NBP through 1995 for the express purpose of overseeing implementation of the recommended actions and monitoring their effectiveness. After 1995, the State of Rhode Island will assume responsibility for implementation of the management plan to protect the Bay and its resources for future generations.

The NBP has established the following seven priority issues for Narragansett Bay:

* management of fisheries
* nutrients and potential for eutrophication
* impacts of toxic contaminants
* health and abundance of living resources
* health risk to consumers of contaminated seafood
* land-based impacts on water quality
* recreational uses

The NBP is taking an ecosystem approach to address these problems and has funded research that will help to improve our understanding of various aspects of these priority problems. The Project is also working to expand and coordinate existing programs among state agencies, governmental institutions, and academic researchers in order to apply research findings to the practical needs of managing the Bay and improving the environmental quality of its watershed.

This report represents the technical results of an investigation performed for the Narragansett Bay Project. The information in this document has been funded wholly or in part by the United States Environmental Protection Agency under assistance agreement #CX812768 to the Rhode Island Department of Environmental Management. It has been subject to the Agency's and the Narragansett Bay Project's peer and administrative review and has been accepted for publication by the Management Committee of the Narragansett Bay Project. The results and conclusions contained herein are those of the author(s) and do not necessarily represent the views or recommendations of the NBP. Final recommendations for management actions will be based upon the results of this and other investigations.

EXECUTIVE SUMMARY

The U.S. EPA has recently recommended that a new water quality standard based on the enterococci group be used as a replacement for the fecal coliform standard presently used by most states. The objective of this study was to examine Rhode Island beaches regularly monitored by the RI Department of Environmental Management and compare indicator levels at these beaches with present RI standards (total and fecal coliforms, Table 1) and the newly recommended enterococci standard.

Results of the beach survey for 1986 indicated that the majority of RI beaches actually look better under the enterococci standard than the present total and fecal criteria, even under conditions of a comparatively wet Summer. However, results strongly imply that the enterococci standard may be a poorer indicator of water quality under certain conditions.

A closed beach (Riverside, E. Providence), located in an area receiving effluents from several major wastewater treatment plants, never exceeded the EPA recommended single-sample maximum of 104 for enterococci nor the recommended geometric mean criteria of 35 for 13 sample dates. Analyses of these same samples indicated that the present total coliform standard was exceeded on four occasions, and the fecal standard was exceeded on six dates. The discrepancy may be due to the high chlorine residual entering this area from the wastewater treatment effluents.

Because the present Rhode Island bathing standards appear to show a more conservative response to potential water quality fluctuations (especially for saltwater beaches), it is recommended that the present standard be retained, at least for the saltwater beaches threatened by sources of chlorinated wastes, and more research be performed to examine the sensitivity of the enterococci group to chlorinated effluents in both SW and FW.

INTRODUCTION

The RI Dept. of Environmental Management, Div. of Water Resources performs a water quality check of public freshwater (FW) and saltwater (SW) beaches in RI once a year, just prior to the bathing season. Water samples from twenty-three freshwater and thirty-four saltwater bathing beaches are tested for total coliform and fecal coliform levels. Results are compared with state water quality standards for swimmable, fishable waters ("B" for FW or "SB" for SW).

After initial sampling, five saltwater and three freshwater beaches which are considered susceptible to various sources of bacterial input are monitored over the bathing season. Olney Pond, Lincoln Woods (FW) and Warren Town Beach (SW) are monitored weekly. The former suffers from bather loading and occasional nonpoint runoff input, while the latter is in close proximity to numerous inputs, including effluents from a secondary wastewater treatment plant and a seafood processing plant, along with storm drains and other runoff sources. For comparative purposes, a closed beach (Riverside, East Providence) on the Providence River, an area known for poor water quality, was added to the weekly sampling during this study.

Bi-weekly sampling normally occurs at Barrington Town Beach, Buttonwoods, and Goddard State Park in Warwick (all SW), and WW II Memorial State Park in Woonsocket (FW). These beaches are considered to have sporadic fluctuations in water quality due to various input sources. Barrington Town Beach is located in the upper Bay, an area which can be impacted by low quality water from the Providence River, and Goddard State Park is located close to Greenwich cove, an area which receives effluent from the East Greenwich Wastewater Treatment Facility. Buttonwoods and WWII State Park are thought to be impacted mainly by nonpoint sources and/or bather loading. Kingspoint Park beach, Newport (SW) is sampled following heavy rain events (> 0.5" within 24h) due to its close proximity to combined sewer overflows discharging into Newport Harbor.

Recently, the EPA has recommended that a new indicator organism be utilized (Table 1). EPA urges the use of a membrane filter (MF) method to measure the geometric mean density of either *E. coli* or the enterococci group, rather than the previously recommended total and fecal coliform groups (EPA, 1986; Fed. Reg. Notice, 1986). The present state bathing beach standards are based on median densities of total and fecal coliforms as measured by a 3-tube serial dilution Most Probable Number (MPN) enumeration method (Table 1). The objective of this project was to examine the RI beaches in relation to present bathing criteria and the new EPA recommended enterococci standard.

METHODS

All water samples were obtained by RI DEM personnel between 0800 and 1500 h . Each sample was taken by wading from a point approximately midbeach out to a depth of approximately 1 m, submerging a 250 ml autoclaved polycarbonate bottle in an inverted position to a depth of 0.3 m below the surface, and tipping the bottle into an upright position to fill it. The sample was carefully sealed with the autoclaved screw top of the sample bottle, and immediately placed into an insulated carrier containing ice packs. Following completion of the day's sampling, all samples were transported to the RI Department of Health sanitary microbiology laboratory.

Upon arrival at the laboratory, samples were logged in. Each sample was shaken 25 times over a distance of 0.3 m for a period of 7 seconds, then split into two equal-volume subsamples for separate enterococci and coliform analyses. The total and fecal coliform analyses for the most probable number method (MPN) with a 3-tube dilution followed the procedures given by Standard Methods (1985). Enterococci analyses followed the procedures given by EPA Test Methods (1985).

RESULTS

Initial Sampling

Salt Water Beaches

None of the initially-sampled salt water beaches exceeded the EPA-recommended single-sample maximum enterococci count of 104 (Table A1, Appendix A).

Total and fecal coliform levels did not correlate well with the enterococci levels. Initial single-sample values for the saltwater beaches showed two beaches to have fecal coliform levels exceeding the SB fecal standard of 50 MPN: the East end of Mackeral Cove, Jamestown (fecal = 230); and the North end of Wickford Town beach, North Kingstown (fecal = 93, Table A1). Of these, only the Wickford beach sample also had an elevated enterococci level (ent. = 77). Although elevated, it did not exceed the single sample enterococci maximum criteria. Both beaches were resampled, and showed low fecal and enteroccoci counts on the second sample (Table A1).

No sources of sewage input are known for either of these beaches. Besides sewage, potential sources for such elevated levels of indicator organisms may come from nonpoint runoff sources and/or wastes from any warm-blooded organisms, including waterfowl.

A sample from the Tiverton Yacht Club exceeded both total and fecal coliform standards (tot. = 2300; fecal = 90). However, enterococci were very low (=3) for this same sample (Table A1). This beach is located very close to several large storm drains which release significant runoff volume following rainstorms. The above sample was taken soon after a significant rain event (>1" in 24h). A second sample taken on a "dry" day showed low values for all indicator organisms (Table A1).

Fresh Water Beaches

The initial single-sample values for FW beaches indicated that one beach exceeded the enterococci single-sample maximum of 61: Lake Belair in No. Smithfield (=74, Table A2). This same sample did not exceed total or fecal standards. Potential input of indicator organisms into this area is from nonpoint sources.

Total and/or fecal standards were exceeded for 2 of the initially sampled FW beaches: Waterman Lake Assoc. beach, Glocester (tot. coli. = 2400); and Little Pond, Warwick (tot. & fecal = 2300 each, Table A2). At Waterman Lake, the fecal and enterococci levels were very low (9 and 8 respectively), suggesting that the source of these counts was probably of low sanitary significance.

The Little Pond data has a total:fecal ratio of 1:1, suggesting a potential input of sewage into the area. However, the enterococci level is low (=28), and within a range found at other FW beaches having much lower total and fecal levels. This pond is located in an urbanized area which is only partially sewered, and would be expected to receive nonpoint source impacts from runoff, with a possible contribution from septic systems in areas with a high water table. This is therefore an area of suspected bacterial problems, but the enterococci values contradict this. More will be discussed below concerning interpretation of indicator levels.

Beaches Monitored Through the Bathing Season

Summary statistics and raw data for beaches sampled weekly or biweekly are given in Tables B1 - B2 and A3 - A4 respectively. As noted previously, these beaches are considered to have the greatest potential for fluctuations in water quality, and are therefore monitored on a more frequent basis.

Saltwater Beaches

The only SW beach that exceeded state standards was Warren Town beach (fecal median = 93, Table B1 and Fig 1). Extreme fluctuations in indicator organism levels suggested a sporadic input of these organisms (Table A4 and Fig 2). This is an area of concern because effluents of sanitary concern do occur here, both fecal coliform and enterococci geometric means and medians exceeded standards, and the maximum total coliform count of 4300 (Table B1 and Fig 2) was high in comparison with other open beaches in the survey, although the median total coliform count did not exceed standards.

A special shoreline survey was performed in this area in an attempt to locate the major input(s), but water samples taken from effluents, drainage input, etc., were not successful at pinpointing the source in 1986. Further sampling surveys performed in 1987 by both the State and personnel of the Warren wastewater treatment facility have located what is believed to be the major source of this material (discussed below).

The other Rhode Island SW (open) beaches appeared to be in better shape. None exceeded the state median standards, and only two (Buttonwoods and Kingspoint Park, Tables A4 & B1) exceeded the single-sample maximum of 104 for enterococci on a single sample date.

Samples from Kingspoint Park, Newport indicated that, as expected, this area is affected by rain events. Sources would be expected to include a combined sewer overflow located nearby. Levels for all 3 indicator organisms were elevated on 3 dates following heavy rains (Table A4). However, this beach did not exceed the standards for the geometric means or medians for any of the indicators (Table B1).

At Buttonwoods, Warwick, the enterococci exceeded the single-sample maximum on one sample date (Table A4), but both total and fecal coliforms were very low. The geometric means and medians did not exceed standards for any indicator (Table B1).

Closed Beach Results

Samples from the closed SW beach, Riverside, E. Providence, reflect sporadic poor water quality. Inputs to the Providence River include effluents from several wastewater treatment plants, combined sewer overflows, and numerous nonpoint sources.

Both total and fecal coliform counts exceeded single-sample standards on several dates (Table A4 and Fig 3). Enterococci did not exceed the single-sample maximum (104) on any sampling dates. Geometric means and medians fell below the standards or recommended standards for all three indicator organisms.

There are a number of possible causes for these results. Effluents into this area (e.g., Fields Point WWTF) have fairly high disinfectant chlorine residuals (2-4 mg/l), potentially causing continued die-off of the indicator organisms. The projection of Sabin Point just North of the beach (Fig 1) may also minimize impact from the more contaminated waters in the main ship channel. Note that this does not mean that the DEM condones bathing here, since this area has known inputs of high sanitary concern, and viral pathogens, etc. may not suffer the same die-off rate as the indicator organisms measured. These results do provide a prime example of the fact that "there is no ideal indicator" for pathogens (FDA, 1986), and black-and-white interpretation of indicator density levels are highly tenuous.

Freshwater Beaches

WW II Memorial Park in Woonsocket did not open until June 20, 1986. During the period it was open and sampled, it exceeded the single-sample maximum of 61 for enterococci on one date (=360, Table A3) and the recommended enterococci geometric mean standard of 33 (geo. mean = 43, Table B2). This beach, which is man-made and chlorinated, suffers from bather loading and runoff from the adjacent park and vicinity. It was closed in August 1986 due to mud slides, which interfered with chlorination and the filtration system.

Olney Pond in Lincoln exceeded the single-sample enterococci maximum on the East end of the beach for 2 dates (=130, 180, Table A3) and the West end on 2 dates (67, 87, Table A3). Because total and fecal coliforms were also elevated on at least one of these dates (7/21/86, a "dry" date), there is a possibility of bather loading. Nonpoint source runoff is the only other known source of input for this area. Geometric means and medians did not exceed standards for any indicators(Table B2 and Fig 5).

Spring Lake, Burrillville, did not exceed median and geometric mean standards for any indicators (Table B2 and Fig 5). It did exceed the single-sample fecal maximum on 2 dates, and single-sample maximum for total coliforms on one of those dates (Table A3). Although elevated, enterococci never exceeded the recommended single-sample maximum. This lake is impacted by nonpoint sources.

Simple (Pearson) Correlations Between Indicator Organism Values

Simple correlation coefficients between indicator organisms were calculated using the geometric means of the three indicator organisms measured (Table C1). For a pooled data set of SW and FW beaches (n = 10), a significant positive correlation occurred between the log means of the total and fecal coliforms. Analysis of SW beaches alone (n = 6) indicated a significant correlation between the log means of fecal coliforms and enterococci. No significant correlations between any indicator levels occurred for the FW beaches, most likely due to the small sample size (n = 4).

When indicator levels were analyzed for correlations within data sets for individual beaches, 5 of the 6 SW beaches showed a significant positive correlation between the logs of the total and fecal coliform values (Table C2). Two of the 6 showed a correlation between logs of fecal coliforms and enterococci. Only one of the 6 showed any correlation between logs of the total coliforms and enterococci.

For the FW beaches, 4 out of 4 beaches showed significant positive correlation between logs of the total and fecal coliform values (Table C3) Two of the four reflected a significant positive correlation between the logs of the fecal coliform and enterococci values. Only one of the 4 showed a correlation between the logs of total coliform and enterococci values.

These results suggest that there is a strong positive correlation between the values of total and fecal coliforms found at most beaches. This is not unexpected since fecal coliforms are a subgroup of the total coliforms. Correlations between enterococci and the two coliform indicators are less frequently observed, indicating poor overall correlation between these indicators. One would therefore be less likely to find enterococci levels tracking closely with the coliform values.

It should be noted here that there are constraints to this interpretation due to the statistical assumptions involved. The simple (Pearson) correlation coefficient requires a random sampling from a bivariate normal population . The assumptions may be violated since the actual population distributions for these indicators is not known. Therefore, I have also examined the data using a nonparametric method: the Spearman rank difference correlation coefficient. This coefficient can be used to indicate whether the rank order (lowest to highest counts) of samples is significantly correlated between two variables measured. (Note: this coefficient can only provide information on how ranking the samples may be affected by which parameter is used, not the degree of any quantitative relationship between the measured parameters).

Rank correlations between indicators were calculated for the data sets from each beach (i.e., samples were ranked by indicator level for individual beaches). Results indicated that there was a significant positive correlation between ranks for total and fecal coliform values for 5 out of the 6 SW beaches and 2 of the 4 FW beaches (Table C4). Ranking by total coliform levels showed little correlation with ranks based on enterococci, with only one beach (Kingspoint Park) producing a significant correlation between these indicators. There was evidence of a slight correlation between ranks based on fecal coliforms and enterococci, with 2 SW and 2 FW beaches having significant coefficients (Table C4).

This information provides evidence that total and fecal coliforms will, in most cases, track each other, at least in terms of direction (as one goes up or down, the other should also follow that trend). Enterococci are less likely to follow the relative trends in coliform levels measured at a particular beach.

When beaches are ranked by their geometric means, this relationship is seen again. Although the number of beaches sampled is too low to calculate the rank coefficient for SW and FW groups separately, a pooled data set of SW + FW beaches (n = 10) showed a significant positive correlation between ranks based on total and fecal coliforms only (Table C4). Once again, all evidence suggests that enterococci trends at a beach will not follow coliform levels.

Comparing Criteria

It may be useful to ask how conservative each indicator organism is as a gross indicator of water quality. (Note: This is not the same as a quantitative health risk estimate.) One possible way is to examine the frequency with which samples exceed the single-sample criteria. A review of the 1986 beach data (Tables C5 & C6) indicates that the SW and FW beaches differ in this measure.

For a pooled data set from all SW beaches, the fecal coliform single-sample criteria is more likely to be exceeded than the other standards. A chi-square analysis presents a significant difference between the number of samples which exceed the fecal coliform criteria and the other two indicator groups (Table C5). For SW beaches, enterococci appear to be the least conservative of the three, showing the lowest number of samples exceeding the relevant criteria..

Using this same approach, there are no significant differences between the indicator organisms used for FW beaches. This is most likely due to the higher levels used for the total and fecal coliform standards for FW as compared with SW standards (Table 1).

Perhaps a more valid approach for comparison of the usefulness of different bacteriological indicator organisms as general indicators of sewage contamination in an area is to concentrate on the 2 beaches which have known significant sources of human sewage located nearby: Riverside and Warren. If one looks at the number of samples exceeding the single-sample criteria for both of these beaches, it is clear that the low fecal criteria is still the most conservative measure (Table C5). It is especially disconcerting to note that the Riverside data show no samples exceeding the enterococci limit, yet this closed beach is in close proximity to an area which receives large volumes of (treated) sewage.

The Warren data shows the greatest number of samples exceeding the single-sample criteria for fecal coliform and enterococci for any beach measured (Table C5). Measurements made by the town and DEM in both 1986 and 1987 strongly suggest that the source of the indicator organisms at Warren is not the wastewater treatment effluent, and may in fact be organic material other than human sewage. DEM has isolated food processing waste effluent as a major source of non-pathogenic bacterial indicator organisms into this area, and is presently dealing with this situation. It is interesting to note that the fecal counts are consistently exceeding the single-sample criteria here, again reiterating the conservative nature of the SW fecal standard. It also indicates the potential for bacterial indicator sources other than sewage to significantly elevate the levels of indicators as measured by water samples at the beach.

DISCUSSION AND CONCLUSIONS

The major conclusion from the data concerning the recommended enterococci standards is that the vast majority of RI beaches look better under that standard versus the present total and fecal coliform standards, even under conditions of a comparatively wet Summer (1986).

Each of the above indicators suffers from a major drawback: sources other than human wastes can be found in the environment. Total coliforms include several genera which have natural sources other than sewage, and can reach high environmental levels, yet have questionable health significance (Cabelli, 1983; Chandler, 1982). Fecal coliforms include *Klebsiella*, which can reproduce in the environment and has substantial extra-fecal sources (Cabelli, 1983; Chandler, 1982; Dufour, 1984). In addition, fecal coliforms can be found in wastes of all warm-blooded organisms including naturally-occurring wildlife such as waterfowl (Chandler, 1982). The exact sanitary significance of the contribution made by such nonhuman sources of indicator levels is unknown (Chandler, 1982). Finally, the enterococci indicator also has significant extra-fecal sources, including vegetation, insects, and certain soils (EPA, 1985; Levin et.al., 1975). In fact, counts of less than 100 enterococci/100ml are often found to consist mainly of Streptococcus faecalis var. liquifaciens, a ubiquitous biotype not considered to be of sanitary significance (Geldreich, 1970; Std. Methods, 1985).

The above statistical analyses suggest that, at least for SW beaches, the fecal criteria is the most conservative measure of general bacteriological water quality. For FW, the indicators do not differ significantly in frequency of samples exceeding criteria. It would appear that reliance on the fecal coliform criteria is still warranted in areas potentially affected by chlorinated effluents, and it is recommended that, at least for saltwater beaches, a revision of the RI bathing beach standard to sole use of an enterococci criteria not be performed at this time. Enterococci would be a more accurate measure of swimming risk for freshwater beaches in RI based on the EPA epidemiological data. This will entail altering the FW criteria, and ensuring that the RIDOH laboratory has personnel and funding available to provide analyses on all three indicators for the annual State beach monitoring program. It is also recommended that the more rapid (24 h) assay method be used for the fecal determinations if at all possible. If funds and manpower are available, it would be useful to continue developing a data base which can reflect the trends for all three indicator organisms at all beaches, and most importantly, continue maintaining shoreline surveys of the beaches in pursuit of potential inputs of sanitary significance.

It is clear that research on the relationship of enterococci, total, and fecal coliform levels to chlorination treatment is necessary. It might also be highly enlightening to examine the level of these indicators within a water body that is known to receive sources of untreated sewage, such as septic (ISDS) leachate.

Because of the confounding effect due to input from natural sources of low sanitary concern for all these indicator organisms, the interpretation of results from bathing beach samples using any of the above indicators is subject to many constraints. Further research to more fully examine background levels of these indicators from other natural sources (e.g., input from nearby marshes, common waterfowl populations, major insect populations such as the gypsy moth, etc.) would greatly aid in the interpretation of results.

ACKNOWLEDGEMENTS

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REFERENCES

Cabelli, V.J. 1983. Health effects criteria for marine recreational waters. EPA-600/1-80-031. August, 1983. 97pp.

Chandler, L. 1982. Section H. Indicator Organisms. FDA Information and Training Course Manual on Growing Area Surveys. NE Technical Services Unit, FDA, Davisville, RI.

Dufour, A.P. 1984. Health effects criteria for fresh recreational waters. EPA-600/1-84-004. August 1984. 33pp.

EPA 1985. Test methods for Escherichia coli and enterococci in water by the membrane filter procedure. EPA-600/4-85/076. 25pp.

EPA 1986. Ambient waster quality criteria for bacteria - 1986. EPA-600/4-85/076. 25pp.

Federal Register Notice. March 1986. Bacteriological ambient water quality criteria; availability. March 7, 1986. pp. 8012-8016.

Geldreich, E. E.1966. Sanitary Significance of Fecal Coliforms in the Environment. U>S> Dept. of the Interior, FWPCA. November, 1966.

Levin, M.A., J.R. Fischer, and V.J. Cabelli. 1975. Membrane filter technique for enumeration of enterococci in marine waters. Applied Microbiology 30:66-71.

Standard Methods For the Examination of Water and Wastewater, 16th Edition, 1985. M.A. Franson, Managing Ed. American Public Health Association, Washington, D.C., 1268 pp.

Table 1. Present RI water quality criteria and EPA recommended criteria for full-body contact swimmable waters.

Indicator Organism	Geometric Mean * (MF)	Maximum # Median (MPN)	Other Criteria
Fresh Water :			
EPA			
E. coli	126		235 single sample maximum
enterococci	33		61 single sample maximum
RI			
Total coliforms		1000	Not more than 20% of the samples > 2400 and a single sample maximum of 1000
Fecal coliforms		200	Not more than 20% of the samples > 500 and a single sample maximum of 200
Salt Water :			
EPA			
enterococci	35		104 single sample maximum
RI			
Total Coliforms		700	Not more than 10% of the samples > 2300 and a single sample maximum of 700
Fecal Coliforms		50	Not more than 10% of the samples > 500 and a single sample maximum of 50

* $n \geq 5$ samples

per 100 ml sample

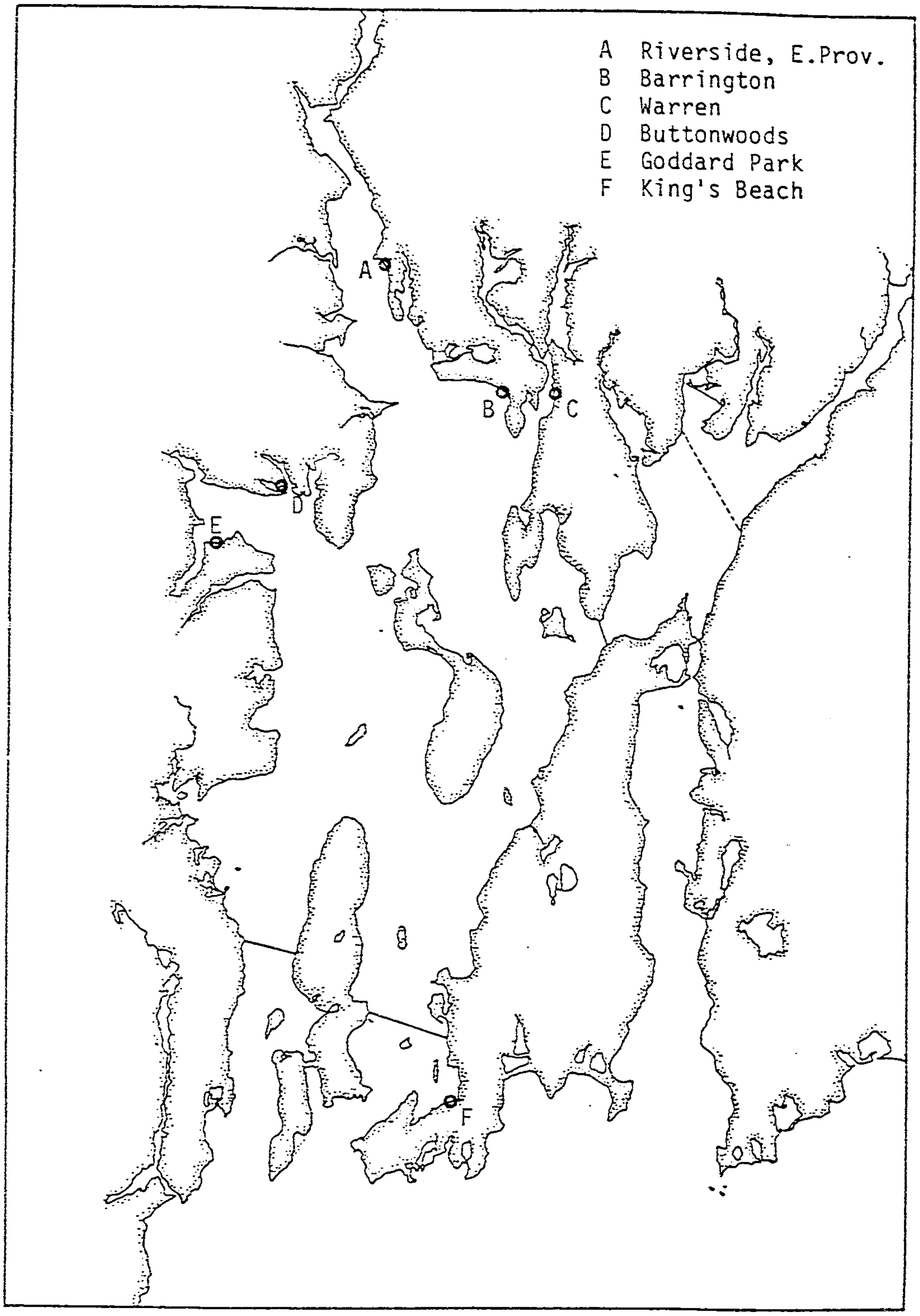

Fig. 1. Salt Water Beaches Monitored 1986

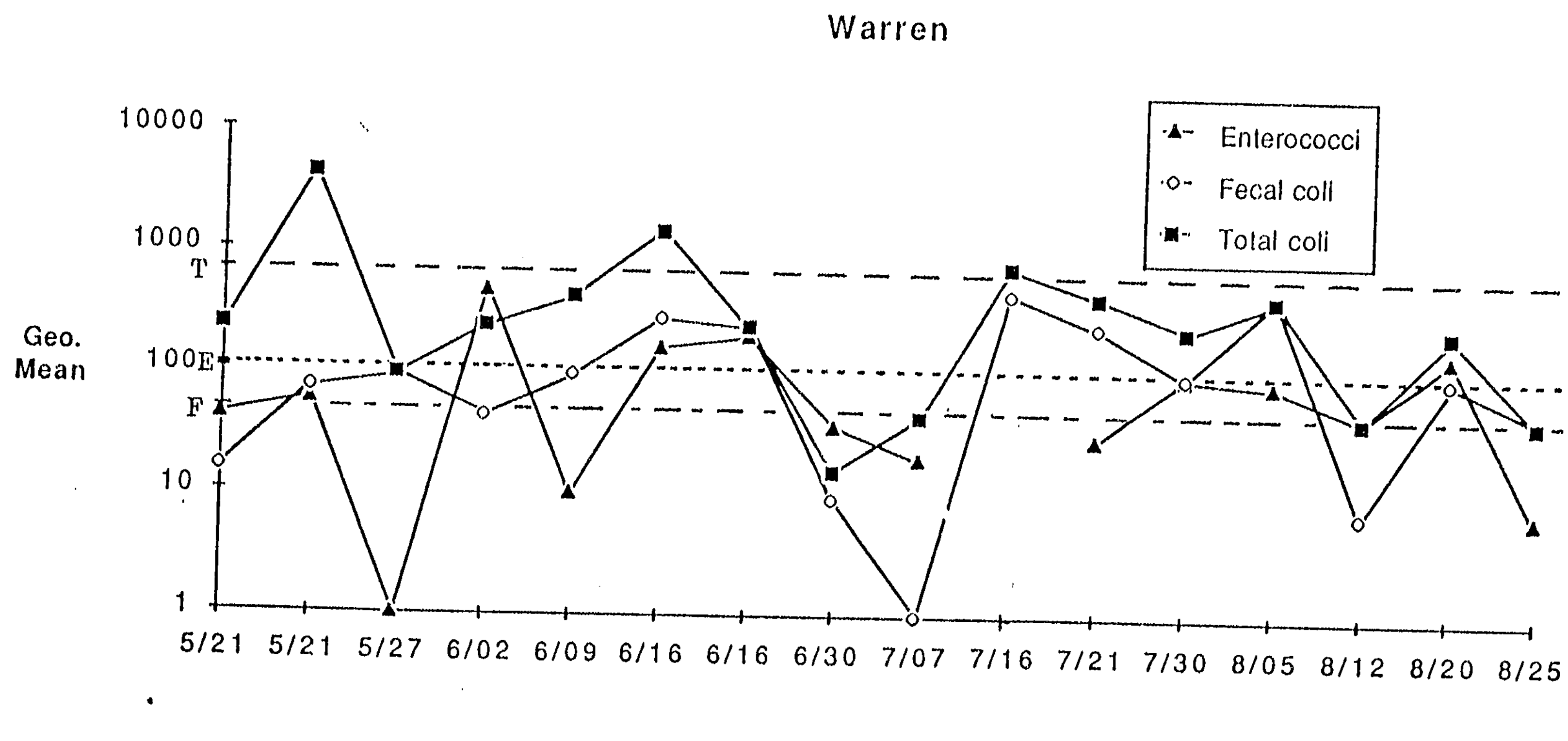

Fig. 2. Indicator Levels at Warren Town Beach 1986

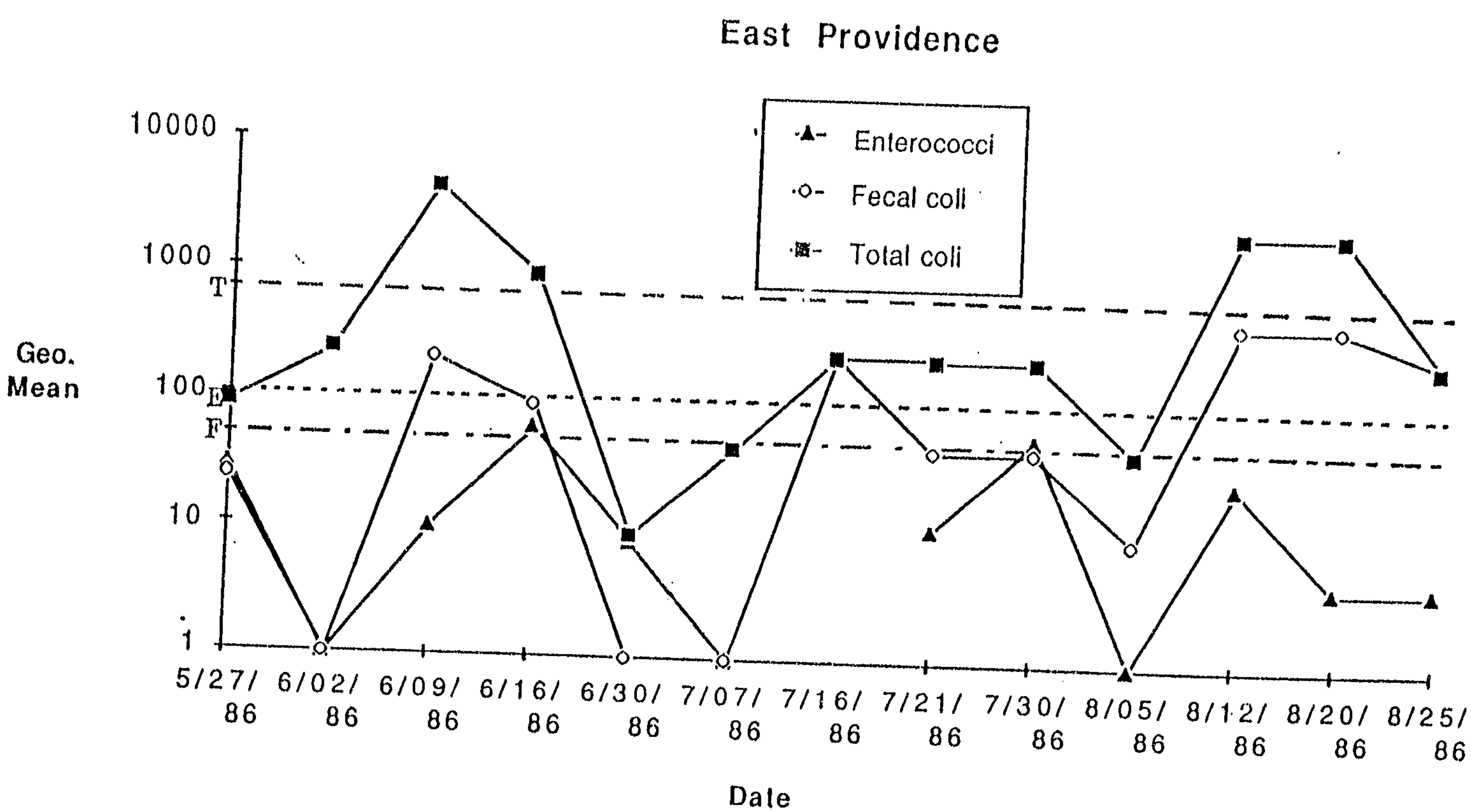

Fig. 3. Indicator Levels at Riverside Beach 1986

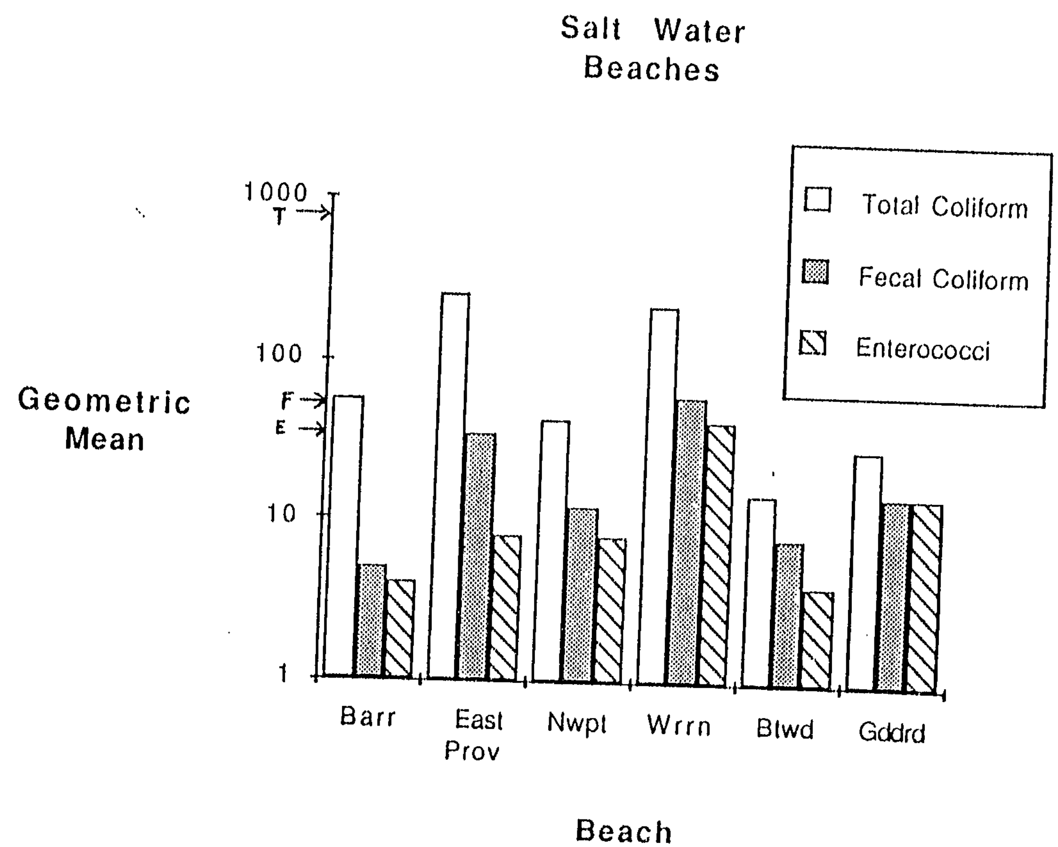

Fig. 4. Geometric means for saltwater beaches monitored 1986.

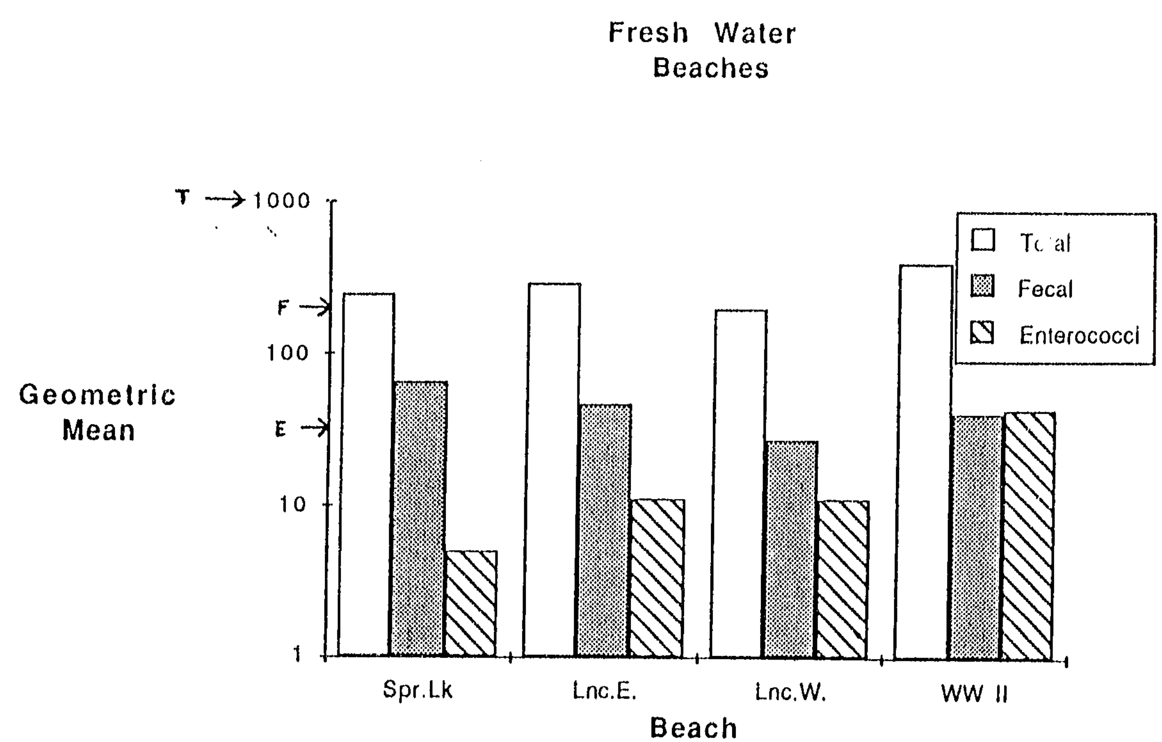

Fig. 5. Geometric means for freshwater beaches monitored 1986.

APPENDIX A

RAW DATA FOR INDIVIDUAL SAMPLES

TABLE A1. SALT WATER BEACHES - INITIAL SAMPLING 1986

BEACH	DATE	TOTAL COLIFORM	FECAL COLIFORM	ENTERO-COCCI	* RAIN	TIDE
BRISTOL Town						
Beach (No.End)	5/21/86	4	4	1	R	Ebb
(So.End)	5/21/86	30	1	<1	R	Ebb
CHARLESTOWN						
Town Beach	5/19/86	15	1	<1	D	Low
JAMESTOWN						
Mackeral Cove						
(East End)	5/12/86	230	@ 230	<1	D	High
	6/16/86	40	1	<1	R	–
(West End)	5/12/86	23	1	23	D	High
	6/16/86	1	1	1	R	–
LITTLE COMPTON						
Warren's Pt.						
Beach Club	5/21/86	130	1	<1	R	Ebb
Town Beach	5/21/86	9	4	1	R	Low
Goosewing Beach	5/21/86	1	1	<1	R	Low
Brigg's Beach	5/21/86	1	1	<1	R	Low
MIDDLETOWN						
2nd Beach	5/13/86	4	4	4	D	Flood
3rd Beach	5/13/86	9	9	18	D	Flood
Peabody's Beach	5/13/86	7	4	<1	D	Flood
NARRAGANSETT						
Sand Hill Cove						
(East End)	5/19/86	1	1	2	D	Flood
(West End)	5/19/86	1	1	<1	D	Flood
Dunes Club	5/19/86	210	1	<1	D	Flood
Scarborough						
(No.End)	5/19/86	90	1	<1	D	Flood
(Middle)	5/19/86	27	1	<1	D	Flood
(So.End)	5/19/86	160	1	<1	D	Flood
Narr.Pier Beach						
(No.End)	5/19/86	1	1	<1	D	Flood
(Middle)	5/19/86	43	4	1	D	Flood
(So.End)	5/19/86	15	7	1	D	Flood

* R = >0.5" RAIN W/IN 3DA OR > 1" W/IN 4DA ; D = DRY
@ = EXCEEDS SB STANDARDS : 700 MPN TOTAL COLI.; 50 MPN FECAL ; 104 ENT.

TABLE A1. SALT WATER BEACHES - INITIAL SAMPLING 1986 (Cont.)

BEACH	DATE	TOTAL COLIFORM	FECAL COLIFORM	ENTERO-COCCI	* RAIN	TIDE
NEWPORT						
Fort Adams	5/13/86	4	1	1	D	High
Hazard's Beach	5/13/86	15	9	14	D	High
Gooseberry Beach	5/13/86	4	4	8	D	High
Bailey's Beach	5/13/86	4	4	16	D	Flood
Easton's (1st Bch.)						
(East End)	5/13/86	9	9	5	D	Flood
(West End)	5/13/86	21	3	19	D	Flood
NO. KINGSTOWN						
Town Beach						
(Wickford)(No.End)	5/12/86	93	@ 93	77	D	Flood
	6/17/86	7	7	<3	R	-
(So.End)	5/12/86	11	7	63	D	Flood
	6/17/86	1	1	<3	R	-
PORTSMOUTH						
Sandy Point	5/13/86	23	23	10	D	Flood
SO. KINGSTOWN						
East Matunuck						
(East End)	5/19/86	1	1	<1	D	Flood
(West End)	5/19/86	39	1	<1	D	Flood
TIVERTON						
Yacht Club	5/21/86	@ 2300	@ 90	3	R	Ebb
	6/17/86	70	4	19	R	-
Town Beach						
(Grinnel's)	5/21/86	43	7	28	R	Ebb
Fogland	5/21/86	1	1	12	R	Ebb
WARWICK						
Conimicut Point						
(East End)	5/14/86	1	1	1	D	-
(West End)	5/14/86	9	4	1	D	-
Oakland Beach	6/24/86	43	4	11	D	Ebb
WESTERLY						
Misquamicut						
(East End)	5/19/86	160	1	<1	D	Low
(West End)	5/19/86	1	1	<1	D	Low
Westerly Red Cross Beach	5/19/86	4	1	3	D	Low

* R = >0.5" RAIN W/IN 3DA OR > 1" W/IN 4DA ; D = DRY
@ = EXCEEDS SB STANDARDS : 700 MPN TOTAL COLI.; 50 MPN FECAL ; 104 ENT.

TABLE A2. FRESH WATER BEACHES - INITIAL SAMPLING 1986

BEACH	DATE	TOTAL COLIFORM	FECAL COLIFORM	ENTERO-COCCI	* RAIN
BURRILLVILLE					
Pulaski State Park (Peck Pond)	5/20/86	150	1	1	D
CRANSTON					
Curran Park	5/20/86	160	9	3	D
COVENTRY					
Tiogue Lake	5/14/86	4	4	2	D
GLOCESTER					
Bowdish Reservoir (Geo.Washington Park)	5/20/86	43	3	<1	D
Waterman Lake					
-Lake Assoc.	5/20/86	@ 2400	9	8	D
	6/16/86	15	3	14	R
-Glocester C.C	5/20/86	23	23	2	D
-Steere's Beach	5/20/86	93	9	1	D
JOHNSTON					
Slacks Reservoir (North)	5/20/86	11	7	2	D
LINCOLN					
Laporte Pond	5/20/86	39	9	8	D
Scott's Pond	5/20/86	200	40	7	D
NARRAGANSETT					
Forest Lake	5/12/86	23	9	1	D
NO. SMITHFIELD					
Lake Belair	6/3/86	240	93	@ 74	R
SMITHFIELD					
Georgiaville Pond	5/20/86	43	9	1	D

* R = >0.5" RAIN W/IN 3DA OR > 1" W/IN 4DA ; D = DRY
@ = EXCEEDS B STANDARDS : 1000 MPN TOTAL COLI.; 200 MPN FECAL.; 61 ENT.

TABLE A2. FRESH WATER BEACHES - INITIAL SAMPLING 1986 (Cont.)

BEACH	DATE	TOTAL COLIFORM	FECAL COLIFORM	ENTERO-COCCI	* RAIN
SO. KINGSTOWN					
Indian Lake					
(Plat #1)	5/12/86	75	15	20	D
(Plat #2)	5/12/86	210	23	30	D
Wakefield Old					
Mtn. Field	5/12/86	43	23	1	D
WARWICK					
Gorton Pond	5/14/86	9	4	1	D
Little Pond	5/14/86	@ 2300	@ 2300	28	D
	6/10/86	430	43	9	R
Warwick Pond	5/14/86	20	4	1	D
Sand Pond	6/2/86	240	15	40	R
Posneganset Pond	6/2/86	240	9	28	R
	8/12/86	230	9	20	R
W. GREENWICH					
Mishnock Pond	5/14/86	9	4	1	D

* R = >0.5" RAIN W/IN 3DA OR > 1" W/IN 4DA ; D = DRY
@ = EXCEEDS B STANDARDS : 1000 MPN TOTAL COLI.; 200 MPN FECAL ; 61 ENT.

TABLE A3. FRESH WATER BEACHES - BEACH MONITORING 1986

BEACH	DATE	TOTAL COLIFORM	FECAL COLIFORM	ENTERO-COCCI	* RAIN
BURRILLVILLE					
Spring Lake	7/07/86	@ 2300	@ 210	22	R
	7/21/86	75	75	28	D
	7/30/86	70	9	<1	R
	8/05/86	150	43	2	R
	8/12/86	230	43	<1	R
	8/20/86	930	@ 430	50	R
	8/25/86	150	43	1	R
LINCOLN					
Olney Pond					
(East End)	5/20/86	93	23	3	D
	5/27/86	75	9	22	R
	6/03/86	93	9	3	R
	6/09/86	430	@ 430	49	R
	6/16/86	930	23	<3	R
	6/23/86	150	9	4	D
	6/30/86	230	93	48	D
	7/08/86	430	@ 230	48	R
	7/16/86	120	43	<1	R
	7/21/86	@ 11000	@ 430	@ 130	D
	7/30/86	930	93	35	R
	8/05/86	93	43	@ 180	R
	8/12/86	230	23	12	R
	8/20/86	930	93	<1	R
	8/25/86	93	23	3	R

* R = >0.5" RAIN W/IN 3DA OR > 1" W/IN 4DA ; D = DRY
@ = EXCEEDS B STANDARDS : 1000 MPN TOTAL COLI.; 200 MPN FECAL ; 61 ENT.

TABLE A3. FRESH WATER BEACHES - BEACH MONITORING 1986 (CONT.)

BEACH	DATE	TOTAL COLIFORM	FECAL COLIFORM	ENTERO-COCCI	* RAIN
Olney Pond (West End)	5/20/86	43	4	6	D
	5/27/86	460	9	30	R
	6/03/86	240	43	43	R
	6/09/86	90	23	5	R
	6/16/86	430	43	41	R
	6/23/86	150	9	31	D
	6/30/86	230	43	67@	D
	7/08/86	230	15	5	R
	7/16/86	240	43	–	R
	7/21/86	430	43	20	D
	7/30/86	430	150	87@	R
	8/05/86	93	23	<1	R
	8/12/86	230	23	10	R
	8/20/86	430	150	<1	R
	8/25/86	43	15	1	R
WOONSOCKET					
WW II Mem. Park	6/25/86	9300@	230@	–	D
	7/07/86	150	23	360@	R
	7/21/86	230	23	19	D
(Open 6/20/86)	8/05/86	75	23	12	R
(Closed 8/08/86 due mud slides)					

* R = >0.5" RAIN W/IN 3DA OR > 1" W/IN 4DA ; D = DRY

@ = EXCEEDS B STANDARDS : 1000 MPN TOTAL COLI.; 200 MPN FECAL ; 61 ENT.

TABLE A4. SALT WATER BEACHES - BEACH MONITORING 1986

BEACH	DATE	TOTAL COLIFORM	FECAL COLIFORM	ENTERO-COCCI	* RAIN	TIDE
BARRINGTON						
Town Beach						
(East End)	5/21/86	290	4	<1	R	Ebb
(West End)	5/21/86	130	9	8	R	Ebb
(Middle)	5/27/86	23	1	<1	R	High
	6/09/86	430	15	<10	R	High
	7/07/86	4	1	2	R	Ebb
	7/21/86	93	@93	11	D	Ebb
	8/05/86	9	1	<1	R	Ebb
	8/20/86	93	9	14	R	Ebb
EAST PROVIDENCE						
Riverside	5/27/86	90	23	29	R	Flood
(Closed to	6/02/86	240	1	<1	R	Low
Swimming)	6/09/86	@4300	@210	10	R	Ebb
	6/16/86	@930	@93	60	R	Flood
	6/30/86	9	1	8	D	Flood
	7/07/86	43	1	1	R	Ebb
	7/16/86	240	@240	–	R	Flood
	7/21/86	230	43	11	D	Ebb
	7/30/86	230	43	56	R	Flood
	8/05/86	43	9	<1	R	Ebb
	8/12/86	@2300	@430	26	R	Flood
	8/20/86	@2300	@430	4	R	Ebb
	8/25/86	230	@230	4	R	–
NEWPORT						
Kings Point Park						
(East End)	5/13/86	1	1	1	D	High
(West End)	5/13/86	1	1	1	D	High
(Middle)	6/10/86	9	1	<1	R	Ebb
	6/17/86	90	4	2	R	Flood
	7/14/86	@1500	@230	63	R	Flood
	7/30/86	@930	@240	@140	R	–
	8/20/86	210	@210	79	R	Ebb

* R = >0.5" RAIN W/IN 3DA OR > 1" W/IN 4DA ; D = DRY
@ = EXCEEDS SB STANDARDS : 700 MPN TOTAL COLI.; 50 MPN FECAL ; 104 ENT.

TABLE A4. SALT WATER BEACHES - BEACH MONITORING 1986 (Cont.)

BEACH	DATE	TOTAL COLIFORM	FECAL COLIFORM	ENTERO-COCCI	* RAIN	TIDE
WARREN						
Town Beach						
(No.End)	5/21/86	230	15	41	R	Ebb
	6/16/86	240	240 @	200 @	R	Flood
(So.End)	5/21/86	4300 @	70 @	58	R	Ebb
(Middle)	5/27/86	93	93 @	<1	R	High
	6/02/86	240	43	480 @	R	Low
	6/09/86	430	93 @	<10	R	High
	6/16/86	1500 @	280 @	160 @	R	Flood
	6/30/86	15	9	36	D	Flood
	7/07/86	43	1	19	R	Ebb
	7/16/86	750 @	460 @	-	R	Flood
	7/21/86	430	240 @	28	D	Ebb
	7/30/86	230	93 @	96	R	Flood
	8/05/86	430	430 @	80	R	Ebb
	8/12/86	43	7	42	R	-
	8/20/86	230	93 @	150 @	R	Ebb
	8/25/86	43	43	7	R	-
WARWICK						
Buttonwoods	5/12/86	9	4	<1	D	Ebb
(City Park)	5/28/86	4	4	-	R	Flood
	6/10/86	4	4	7	R	High
	6/24/86	23	4	190 @	D	Ebb
	7/08/86	4	4	18	R	High
	7/21/86	93	43	<1	D	Low
	8/05/86	43	43	<1	R	Ebb
	8/20/86	43	9	<1	R	High

* R = >0.5" RAIN W/IN 3DA OR > 1" W/IN 4DA ; D = DRY
@ = EXCEEDS SB STANDARDS : 700 MPN TOTAL COLI.; 50 MPN FECAL ; 104 ENT.

TABLE A4. SALT WATER BEACHES - BEACH MONITORING 1986 (Cont.)

BEACH	DATE	TOTAL COLIFORM	FECAL COLIFORM	ENTERO-COCCI	* RAIN	TIDE
Goddard Park (East End)	5/12/86	23	23	6	D	Flood
(West End)	5/12/86	430	@ 430	37	D	Flood
(Middle)	5/28/86	9	4	–	R	Flood
	6/10/86	4	4	<10	R	High
	6/17/86	9	4	17	R	–
	6/24/86	23	4	60	D	High
	7/08/86	230	@ 230	43	R	Ebb
	7/21/86	11	1	6	D	Low
	8/05/86	9	9	3	R	Low
	8/20/86	230	@ 93	26	R	Ebb

APPENDIX B

SUMMARY STATISTICS FOR BEACH DATA 1986

Table B1. Saltwater Beaches Monitored in 1986.

Beach	% Total Coliform > 2300	Total Coliform Geo. $\overline{X}$	Min-Max	% Fecal Coliform > 500	Fecal Coliform Geo. $\overline{X}$	Min-Max	% Entero-cocci > 104	Entero-cocci Geo. $\overline{X}$	Min-Max
Barrington									
Town Beach (n = 8)	0%	57 [93]	4-430	0%	5 [7]	1-93	0%	4 [5]	< 1-14
East Providence									
Riverside (CLOSED) * (n = 13)	8 (1/13)	258 [230]	9-4300	0	34 [43]	1-430	0	8 [9]	< 1-60
Newport									
Kingspoint Park (n = 7)	0	42 [90]	1-1500	0	12 [4]	1-240	14 © (1/7)	8 [2]	< 1-140
Warren									
Town Beach * (n = 16)	6 (1/16)	220 [235]	15-4300	0	60 © [93] ©	1-460	27 © (4/15)	42 © [42] ©	< 1-480
Warwick									
Buttonwoods * (n = 8)	0	15 [16]	4-93	0	8 [4]	4-43	14 © (1/7)	4 [1]	< 1-190
Goddard Park * (n = 10)	0	29 [17]	9-430	0	15 [7]	1-430	0	15 [17]	3-60

* = 1 sample less for enterococci
[x] = median
© = Exceeds SB Criteria

Table B2. Freshwater Beaches Monitored in 1986.

Beach	% Total Coliform > 2400	Total Coliform Geo.$\overline{X}$	Min-Max	% Fecal Coliform > 500	Fecal Coliform Geo.$\overline{X}$	Min-Max	% Entero-cocci > 61	Entero-cocci Geo.$\overline{X}$	Min-Max
Burrillville									
Spring Lake (n = 7)	0%	248 [150]	70-2300	0%	65 [43]	9-430	0%	5 [2]	< 1-50
Lincoln									
Olney Pond									
East End (n = 15)	7 (1/15)	290 [230]	75-11000	0	47 [43]	9-430	13 © (2/15)	11 [12]	< 1-180
West End *	0	197 [230]	43-460	0	27 [23]	4-150	14 © (2/14)	11 [15]	< 1-87
Woonsocket									
WW II Mem. Park	25 © (1/4)	394 [190]	75 9300	0	41 [23]	23 230	33 © (1/3)	43 © [19]	12-360

* = 1 sample less for enterococci
[x] = median
© = Exceeds B Criteria

APPENDIX C

CORRELATION COEFFICIENTS AND OTHER STATISTICS

Table C1 Simple (Pearson) Correlation Coefficients .

Correlation Between Geometric Means

Beach	Logs of Total Coliform: Fecal Coliform	Logs of Total Coliform: Enterococci	Logs of Fecal Coliform Enterococci
SW + FW Beaches n = 10 df = 8	.8366**	.4901	.5597
SW only n = 6 df = 4	.7678	.5279	.8435*
FW only n = 4 df = 2	.3150	.7372	-.3986

* = $p<.05$ ** = $p<.01$

Table C2.

Within Beach Correlation Between Indicators for Individual Samples for Salt Water Beaches

Beach	Logs of Total Coliform: Fecal Coliform	Logs of Total Coliform: Enterococci	Logs of Fecal Coliform Enterococci
Barrington n = 8 df = 6	.6822	.4900	.8135*
Riverside n = 13 df = 11	.7768**	.3361	.5096
Kingspoint n = 7 df = 5	.9115**	.8821**	.9928**
Buttonwoods n = 7 df = 5	.8161*	-.3852	-.5824
Goddard Park n = 9 df = 7	.9119**	.6499	.4873
Warren n = 15 df = 13	.6596**	.3474	.1956

* = $p<.05$ ** = $p<.01$

Table C3

Within Beach Correlation Between Indicators for Individual Samples for Fresh Water Beaches

Beach	Logs of Total Coliform: Fecal Coliform	Logs of Total Coliform: Enterococci	Logs of Fecal Coliform Enterococci
Spring Lake n = 7 df = 5	.8040*	.5516	.8390*
Olney Pond E n = 15 df = 13	.6948**	.2514	.5267*
Olney Pond W n = 15 df = 13	.6180*	.5342*	.1481
WW II n = 4 df = 2	.9768*	.2580	0.0

* = $p<.05$ ** = $p<.01$

Table C4. Spearman Rank Difference Correlation Coefficient

Beach	Total Coliform: Fecal Coliform	Total Coliform: Enterococci	Fecal Coliform: Enterococci
Rank Correlation Between Beaches			
SW + FW n = 10	.7212*	.4515	.4939
Within Beach Rank Correlacion For Individual Samples			
SW Beaches			
Barrington n = 8	.696	.304	.804*
Riverside n = 13	.749**	.195	.322
Kingspoint n = 7	.938**	.866*	.964**
Buttonwoods n = 8	.887**	-.670	-.634
Goddard Park n = 10	.749*	.492	.215
Warren n = 16	.730**	.381	.327

* = $p<.05$ ** = $p<.01$

Table C5 .Salt Water Beach Data 1986 - Frequency of exceeding the single-sample criteria

Beach	Total Coliform > 700	Fecal Coliform > 50	Enterococci > 104	Sum
Barrington Town Beach (n = 8)	0	1	0	1
Riverside (n = 13)	4	6	0	10
Kingspoint Park (n = 7)	2	3	0	5
Warren Town Beach (n = 16)	3	10	5	18
Buttonwoods (n = 8)	0	0	1	1
Goddard Park (n = 10)	0	3	0	3
SUM (Total n = 62 samples)	9	23	6	38

X^2 (df = 1)
(with Yates Correction)

Total vs Fecal Coliform = 5.281*

Total vs Enterococci = 0.266

Fecal vs Enterococci = 8.828***

* = $p \leq .05$, ** = $p \leq .01$, *** = $P \leq .005$

Table C6 . Fresh Water Beach Data 1986 - Frequency of exceeding the single-sample criteria

Beach	Total Coliform > 1000	Fecal Coliform > 200	Enterococci > 61	Sum
Spring Lake (n = 7)	1	2	0	3
Olney Pond East End (n = 15)	1	3	2	6
West End (n = 15)	0	0	2	2
WW II (n = 3)	0	0	1	1
SUM (Total n = 41 samples)	2	5	5	12

X^2 (df = 1)
(with Yates Correction)

Total vs Fecal Coliform = 0.571

Total vs Enterococci = 0.571

Fecal vs Enterococci = 0.0