BATHING BEACH POLLUTION INDICES

THESIS FOR THE DEGREE OF M. S.

Adolf Sypien

1934

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Sea-water - Bacteriology

Bacteriology

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BATHING BEACH POLLUTION INDICES

A Thesis

Submitted to the Graduate Faculty

For the Master of Science Degree

Department of Bacteriology and Hygiene

by

Adolf Sypien
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THESIS

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BATHING BEACH POLLUTION INDICES

INTRODUCTION

Though the need of proper sanitary control of swimming pools has been recognized, and is being accomplished, no satisfactory control methods for natural bathing places have been devised.

There is no reason why the control of a natural bathing area is not as much to be desired as the one in an artificial place. Is it not illogical to insist upon rigid sanitary standards for swimming pools and none at all for bathing beaches? Cases are on record reporting disease transmission in natural bathing places, but in most instances the source of infection was suspected to be from the sewage which had been emptied into the water. As for the danger from the pollution caused by bathers there is no definite information. It is possible to control sewage pollution of outdoor bathing areas in many instances; however, this still leaves the problem of pollution by the bathers, which must be more thoroughly investigated before standards for control can be recommended.

Up to the present time no detailed studies have been made of the pollution introduced by bathers into a natural bathing place. Most of the work done has been concerned with the extent of sewage pollution. Without minimizing the value of such studies, it seems evident that in bathing areas which receive no sewage, other information is needed before effective control methods can be devised.

HISTORICAL

Attempts, based on the total count and *Escherichia coli* content, have been made to classify natural beaches as to their sanitary conditions. In most cases this was done to determine whether or not sewage was contaminating the beach.

California (1) placed a maximum of ten *Escherichia coli* per cubic centimeter as indicating a safe bathing place, while the New York City Department of Health (1) allowed a maximum of 30 *Esch. coli* per c.c.

In 1928 Winslow and Moxon (2) tested the beaches in the vicinity of New Haven. They found that the beaches known to be polluted had an *Esch. coli* content of 14 to 19 per c.c. They suggested that an average of not over one colon bacillus per c.c. might be a reasonable figure, with a maximum of not over 10 per c.c. However, they believed that much more work had to be done before a definite standard could be adopted. It will be noticed that Winslow and Moxon's investigations were carried out between the months of November, 1926 to April, 1927. Samples were not examined during the bathing season. Prescott and Winslow (3) have compiled enough data from various sources to show that bacterial count in rivers undergoes seasonal fluctuation. Therefore, Winslow and Moxon's recommendation of a bathing beach standard based on winter samples does not carry any weight.

In a survey of Connecticut's shore bathing waters, Scott (4) found that the most used bathing waters were subjected to the effects of sewage pollution because of their proximity to the harbors of large cities. He prepared the following classification of beaches:

Class	Average *Esch. coli* per 100 c.c.	Sanitary quality
A	0-10	good
A-	11-50	good
B	51-500	doubtful
C	501-1000	doubtful-poor
D	over 1000	very poor

Scott (4) was the first to make some studies of the pollution introduced by bathers. In 1930 he selected two beaches relatively remote from outside polluting influences for this study. He discovered that a slight increase in bacterial pollution occurred with dense bathing, and concluded that the pollution from the bathers did not affect his classification of beaches very seriously. He realizes that conditions may be different in some of the country's large, thickly populated areas. Scott believes that the effect of pollution of shore waters by bathers is minimized due to the great diluting influences.

The Michigan Stream Control Commission (5) in 1933 surveyed the waters of the Michigan coastline and obtained results similar to those of Scott. Beaches that were located some distance from sewage outlets often had colon indices from 0 to 100 per 100 c.c. of water. The pollution caused by the bathers was not considered in this work. The beaches on the Michigan coastline, as a rule, are not heavily congested. The bathers tend to spread over a relatively large area, so that with the diluting influences in operation a study of bathing pollution might show different results from those in a limited inland lake beach.

A method for the sanitary testing of a body of water suggests itself from Savage's work (6) on tidal mud. He believes mud samples are valuable in that they indicate pollution for the length of time that specific (typhoid bacilli) contamination is possible. This procedure should be tried on bathing areas to determine whether it would have the same merit.

The study of bacterial processes in sewage polluted streams is of interest in that it may shed some light on the factors responsible for self-purification of waters. That streams do not always give the same bacterial results from day to day is due to the fact that self-purification is in progress. Studies have been made to determine the phenomena responsible.

In his work on sewage polluted streams, Jordan, in 1900 (7), came to the conclusion that the chief reason for the bacterial self-purification was due to the "insufficiency or unsuitability of the food supply". Jordan was unable to satisfy himself that the plankton were of any significance. As for the action of sunlight, his evidence indicated that this was of no great importance. Whether the sun shone brightly or was completely obscured the same reduction in numbers of bacteria occurred. Samples taken at the surface and down to a depth of three feet revealed practically no change in the total count.

The effect of plankton animals upon bacterial death rates was also looked into by Purdy (8) who found that the diminution of bacterial population was accomplished by plankton. Later Purdy (9) made the claim that water which is recovering from sewage pollution contains large numbers of plankton and related organisms. He is of the opinion that this is one of the factors in the self-purification of streams.

The status of the streptococcus as an indicator of pollution is still in doubt. Search of the literature reveals many striking discrepancies.

The streptococcus test has been used in England for many years, and is a part of their standard procedure in bacteriological water analysis. The medium used is neutral red broth recommended by Savage and Read (10); incidentally, this medium was first used for the detection of Esch. coli, but its unreliability for this group was demonstrated by Irons (11).

In an early report of the purification of sewage Jordan (12) noted the comparative absence of micrococci in sewage effluents. Winslow and Hunnewell (13) decided that he did not use a suitable medium.

Houston (14) was the first to indicate that the search for streptococci was valuable in determining the sanitary quality of water. He isolated this organism, as well as the staphylococci, from impure water, sewage effluents, crude sewage, and polluted soils. In a subsequent report, Houston (15) stated that recent animal pollution of a dangerous character seems to coincide with the presence of streptococci. Horrocks (16) considered this group of sufficient importance to warrant a chapter in his book on water bacteriology; however, he did not believe they represented recent contamination. Later, Savage and Wood (17) confirmed Houston's contention that the streptococcus group indicated recency of contamination.

The results of the work on this group until 1902 were ignored outside of England when Winslow and Hunnewell (13) recommended that search for streptococci be made in any sanitary bacteriological water analysis. Prescott and Baker (18), also impressed by the importance of streptococci in this connection, suggested a medium for isolation.

Rivas (19) was among the first to point out that the <u>Esch</u>. <u>coli</u> test as performed in 1907 was too limited. As for a streptococcus test he claimed that it could be of no value. This he concluded for the irregularities in his work with effluent water; however, he made the suggestion that perhaps the technique employed was at fault.

The following year Rivas (20) found the most numerous organisms in feces were the "sewage streptococci or other variety of cocci", while <u>Esch</u>. <u>coli</u> was second. In sewage, the "sewage streptococci or some variety of cocci" also predominated, while in this case <u>Esch</u>. <u>coli</u> was fourth.

He further states that since the purification of water is only partial and selective, the cocci persist regardless of the relative purity of the water. Therefore, he considered that these "non-pathogens" could not be of importance as an index of pollution in water, but that the Esch. coli still remained the best.

Houston (21), in 1931, using a procedure different from that of Rivas, examined seventeen sewage specimens and found Esch. coli from a 100 to a 1000 times more numerous than the streptococci. Also, in observations of feces from different animals, approximately the same ratio of Esch. coli predominance over streptococci occurred.

More recently, the popularity of swimming pools has stimulated work of this nature. One of the pioneers in this field, Mallmann (22), disclosed that the streptococci content parallels the bathing load, while Esch. coli is not a satisfactory measure of pollution because it is able to multiply in the pool. When chlorination is applied Esch. coli are killed before the streptococci (23). A test for streptococci devised by Mallmann and Gelpi (23) is now finding wider usage. The technique will be presented later in this thesis.

At a conference of state sanitary engineers (24) it was proposed that all public bathing places, both natural and artificial, should be placed under the control of the local health authorities, and that these bathing areas should be of the same standard of bacterial quality as is required for swimming pools.

EXPERIMENTAL

The beaches in lower Michigan are generally very small, averaging from 200 to 400 feet in length. Those located close to large towns are popular bathing places during the season. Since most of them do not receive any sewage pollution they are believed to be safe for swimming.

Lake Lansing was chosen for this study because it is typical of the lakes in this region. Being located only seven miles from Lansing it receives large numbers of bathers. No sewage enters the lake. It measures approximately 1¼ miles in length by 1 mile in width. Only one beach exists on this lake and it is at the northern end. There is no inlet. An outlet is situated on the western shore.

The bathing beach area is limited as shown in Figure 2. A muck line about 220 feet from the shore separates this area from the rest of the lake. Since this muck is disagreeable to wade in, the sandy bathing area itself measures about 350 feet in length, and 200 feet in width. The deepest point is five feet. Most of the bathers stay in the vicinity of the end of the dock which extends about 150 feet from shore.

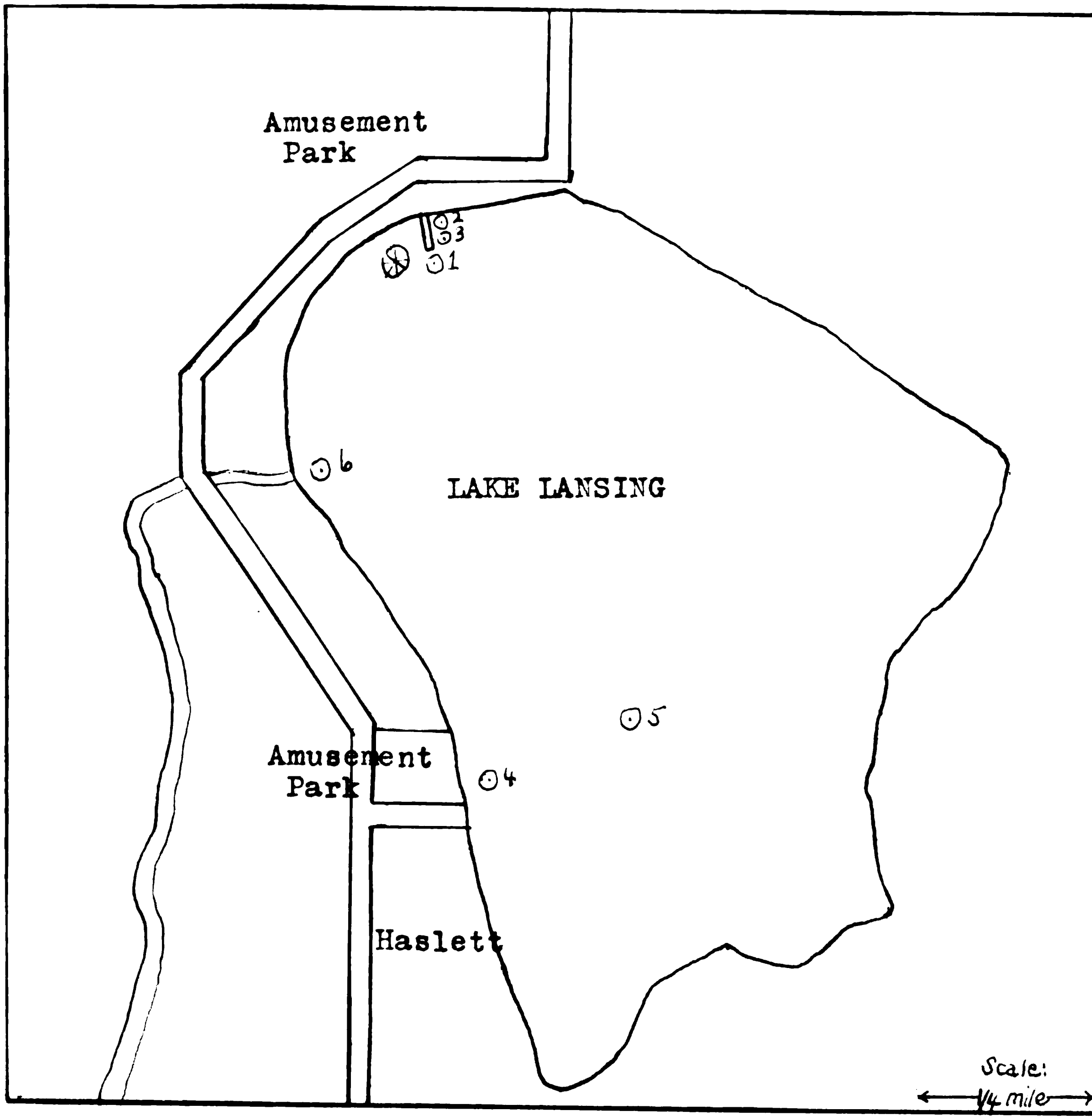
At first, samples were taken from the end of the dock (Fig 1, Point 1), near shore (Point 2), and middle of the dock (Point 3). Sand samples occasionally were obtained below those collected near shore (Point 2).

The middle of the dock sample was discontinued because it did not yield any additional significant information. The outlet (Point 6), about a half-mile from the beach, was adopted as a control point but early in the investigation it was abandoned in favor of a more convenient sampling point which is about three-fourths of a mile south of the beach (Point 4), readily accessible, and relatively distant from the polluting effects of bathers. Sometimes samples were taken from the middle of the lake (Point 5), and other points selected at random.

As a general rule, samples were collected early in the morning before bathing began, during light and heavy loads during the day, and late at night. This program was usually followed during the week-ends from Friday to Sunday, or from Saturday to Monday, depending on weather conditions. Samples were also gathered at random during the week. Most of this work was performed during the period from June 14 to July 31, 1933.

To determine whether or not the same results would be obtained at another lake, it was decided to go through the same week-end routine at Park Lake which is in the same vicinity. A fee is charged for addmittance to the beach on this lake so that the bathing loads are considerably lighter than those at Lake Lansing.

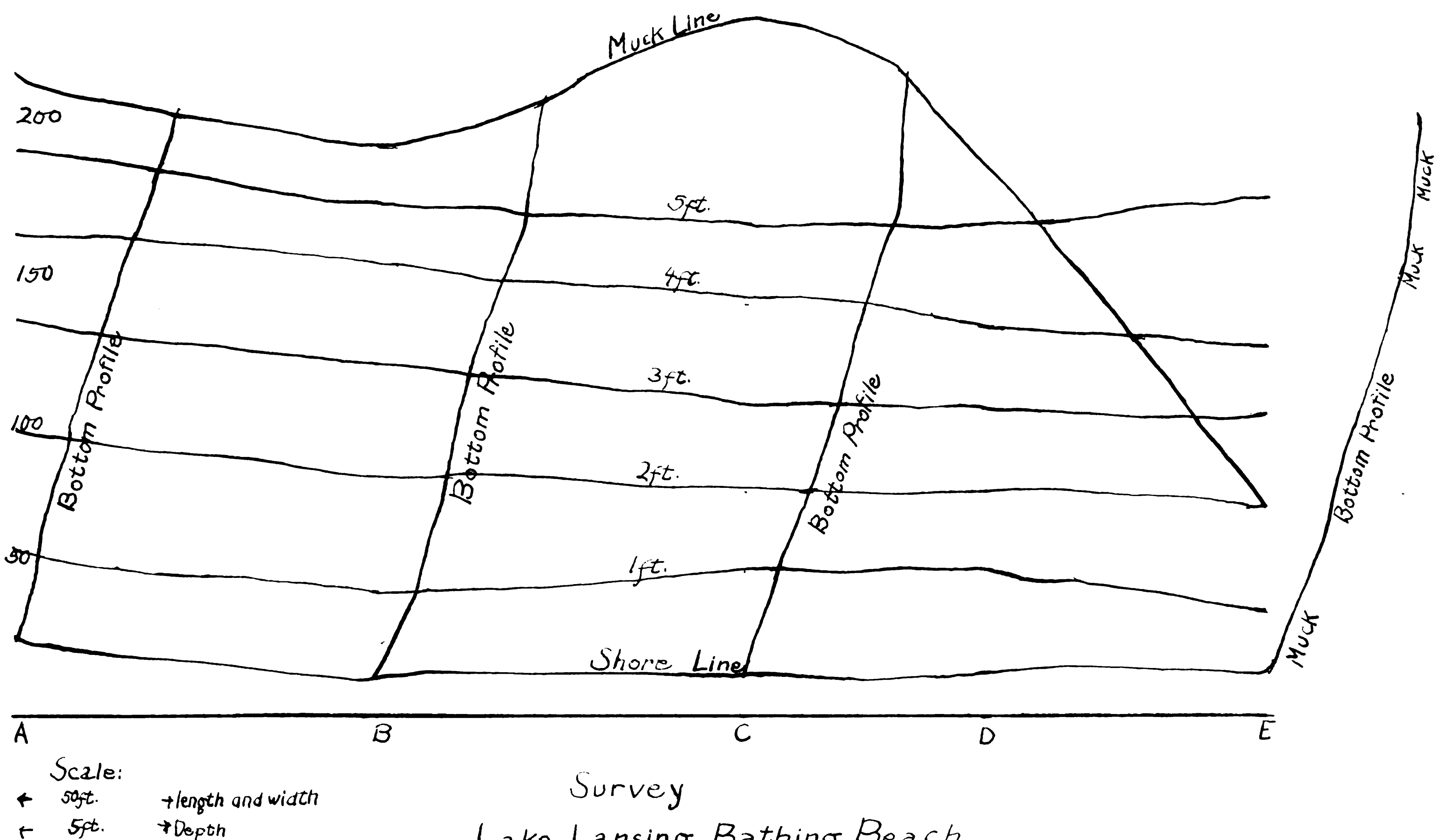
Figure 1



KEY:

⊛-Public Bathing Beach

⊙-Sampling Points
1. End of Dock
2. Near shore, and sand sampling point
3. Middle of Dock
4. Control at Lakeside
5. Middle of Lake
6. Outlet



Survey
Lake Lansing Bathing Beach

Figure 2.

TECHNIQUE

Naturally, the methods employed in testing swimming pools and drinking water were applied in this study, and since the streptococcus index has been recommended for swimming pools, this was also investigated.

The procedure was essentially the same as that recommended by the American Public Health Association (25). Ten c.c. of water was pipetted into each of five tubes of double-strength lactose broth, and in single-strength lactose broth a 1 c.c., and dilutions of 1-10 and 1-100 were used.

The calculation of the "Colon Index" was performed in practically the same manner as suggested by the Phelps method (25) in which it is assumed that the most probable number of organisms present in a sample is the reciprocal of the highest positive dilution. This gives the number per c.c. whereas in this work the figure was multiplied by 100 in order to state the result in terms of a 100 c.c. Thus, if the 1 c.c. and 1-10 tubes were positive, while the 1-100 tube remained negative, the colon index according to Phelps would be 10. This means that the most probable number of colon forms per c.c. was 10. In this study the index would read 1000 meaning that the most probable number was a 1000per 100 c.c. of sample.

For further confirmation material was taken from the positive lactose broth tube which contained the least amount of sample, and smeared on eosin-methylene-blue agar, and an inoculation was also made into brilliant-green bile broth.

Counts were obtained from nutrient agar plates incubated at 37 degrees Centigrade for 24 hours, and at 22 degrees Centigrade for 48 hours. Proper dilutions were prepared to ensure accurate counting.

The Mallmann and Gelpi (28) method for determining the streptococcus index was used. This was done by allowing the lactose broth tubes used in the regular procedure, to stand another twenty-four hours, thus giving sufficient time for the streptococci to settle down to the bottom of the tubes. Then, most of the supernatant liquid was removed by suction. The sediment was smeared on slides, stained with methyl violet, and examined microscopically.

An attempt to determine the numbers and varieties of plankton was made by the Sedgwick-Rafter method (26).

At the completion of this investigation weather reports for the entire period were obtained from the weather bureau. These were plotted on the graphs showing the weekend data in order to ascertain whether or not there were any correlations.

Table 1
Lake Lansing
May 6, 1932, 3:00 P.M.

Station A:

Distance from shore	Gas in lactose broth 10	10	10	10	10	1	0.1	Count, 37 C.
25 feet	-	-	-	-	-	±	-	18
50 feet	-	-	-	-	-	+	-	12
100 feet	-	-	-	-	-	-	-	27

Station C:

Distance from shore	Gas in lactose broth 10	10	10	10	10	10	0.1	Count, 37 C.
25 feet	+	-	-	+	-	-	-	8
50 feet	-	-	+	+	-	-	-	9
100 feet	+	-	±	-	-	-	-	17

Station E:

Distance from shore	Gas in lactose broth 10	10	10	10	10	1	0.1	Count, 37 C.
25 feet	-	-	+	+	-	+	-	15
50 feet	±	±	±	-	+	-	-	22
100 feet	+	-	-	-	-	+	-	17

May 23, 1932, 3:00 P.M.

Station A:

Distance from shore	Gas in lactose broth 10	10	10	10	10	1	0.1	Count, 37 C.
25 feet	+	+	+	+	+	-	-	67
50 feet	±	+	+	+	±	-	-	104
100 feet	+	+	+	-	+	-	-	88

Station C:

Distance from shore	Gas in lactose broth 10	10	10	10	10	1	0.1	Count, 37 C.
25 feet	+	+	+	+	+	-	-	100
50 feet	+	+	+	+	+	-	-	91
100 feet	+	+	+	+	+	-	-	48

Station E:

Distance from shore	Gas in lactose broth 10	10	10	10	10	1	0.1	Count, 37 C.
25 feet	+	+	-	+	-	-	-	163
50 feet	+	+	+	+	+	-	-	74
100 feet	+	+	+	+	+	-	-	55

Table 2a

Week-end, Friday-Sunday
Location: End of Dock, Lake Lansing

No.	Time	Load	Colon Index	Strep. Index	Counts 37 C.	22 C.
7	Friday 1:40PM	62	1000	100	140	---
8	5:00	77	10000	8	230	3000
9	9:00	95	1000	10	780	---
10	Saturday 1:00AM	0	10000	10	2000	---
11	8:30	4	100	2	175	---
12	1:30PM	58	1000	10	500	---
13	5:00	48	100	6	397	486
14	11:30	4	100	10	720	1290
15	Sunday 9:30AM	4	100	0	820	780

---=Count omitted.

Table 2b

Week-end, Friday-Sunday
Location: Near Shore, Lake Lansing

No.	Time	Load	Colon Index	Strep. Index	Counts 37 C.	Counts 22 C.
7	Friday 1:40PM	62	1000	2	273	---
8	5:00	77	10000	8	19000	---
9	9:00	95	100	10	600	---
10	Saturday 1:00AM	0	100	2	500	---
11	8:30	4	1000	0	328	---
12	1:30PM	58	100	0	166	---
13	5:00	48	100	4	452	485
14	11:30	4	1000	10	1300	1420
15	Sunday 9:30AM	4	10000	0	1810	2450

--=Count omitted

Table 2c
Week-end, Friday-Sunday
Location: Control at Lakeside

No.	Time	Load	Colon Index	Strep. Index	Counts 37 C.	22 C.
7	Friday 1:40PM	0	1000	0	90	---
11	Saturday 8:30AM	0	100	0	150	---
15	Sunday 9:30AM	0	100	0	1660	1240

Location: Near Shore, Sand Samples

8	Friday 5:00PM	77	1000	0	8000	---
11	Saturday 8:30AM	4	1000	5	3500	4250
15	Sunday 9:30AM	4	10000	8	1500	3040

--=Counts omitted

Table 3a
From Monday-Thursday
Location: End of Dock

No.	Time	Load	Colon Index	Strep. Index	Counts 37 C.	22 C.
1	Monday 10:30AM	0	1000	0	5000	7080
2	4:20PM	28	100	4	10000	14500
3	Tuesday 9:30AM	0	100	0	220	260
4	Wednesday 3:30PM	45	100	0	61	500
5	8:50	30	100	4	72400	76400
6	Thyrsday 7:30PM	31	1000	0	425	1300

Table 3b
Location: Near Shore

1	Monday 10:30AM	0	1000	0	117	1140
2	4:20PM	28	100	0	180	690
3	Tuesday 9:30AM	0	10000	0	5960	8000
4	Wednesday 3:30PM	45	10000	0	1300	4000
5	8:50PM	30	1000	0	381	1870
6	Thursday 7:30PM	31	1000	0	780	2240

Table 3c
From Monday-Thursday
Location: Control

No.	Time	Load	Colon Index	Strep. Index	Counts 37 C.	Counts 22 C.
1	Monday 10:30AM	0	1000	0	129	1100
2	Tuesday 9:30AM	0	1000	0	5850	10000

Sand Samples:

1	Monday 10:30AM	0	1000	0	3450	11000

Outlet:

1	Monday 10:30AM	0	100	0	500	2500

Table 4a
Week-end, Friday-Sunday
Location: End of Dock

No.	Time	Load	Colon Index	Strep. Index	Counts: 37 C.	22 C.
1	Friday 1:45PM	70	100	10	300	800
2	5:00	54	1000	10	360	970
3	Saturday 12:30AM	0	1000	6	16000	---
4	10:00	4	100	0	1580	2360
5	2:00PM	30	100	0	5000	8700
6	5:00	67	1000	4	820	1560
7	Sunday 10:00AM	0	10	0	300	380
8	3:45PM	200	100	100	127,000	156,000
9	5:00	250	100	6	600	1090
10	11:00	0	10000	4	420	1480
11	Monday 8:30PM	65	10000	4	242	1680

---=Count omitted

Table 4b
Week-end, Friday-Sunday
Location: Near Shore

No.	Time	Load	Colon Index	Strep. Index	Counts: 37 C.	22 C.
1	Friday 1:45PM	70	100	8	500	850
2	5:00	54	10	8	100000	innum.
3	Saturday 12:30AM	0	100	6	1600	---
4	10:00	4	1000	0	270	1000
5	2:00PM	30	100	0	1100	1050
6	5:00	67	10000	0	148000	71120
7	Sunday 10:00AM	0	100	0	211	340
8	3:45PM	200	1000	4	12000	9715
9	5:00	250	10000	8	1000	2000
10	11:00	0	100	10	240	1940
11	Monday 8:30PM	65	1000	0	500	3360

innum.=innumerable
--=Count omitted

Table 4c
Week-end, Friday-Sunday
Location: Control at Lakeside

No.	Time	Load	Colon Index	Strep. Index	Counts: 37 C.	Counts: 22 C.
1	Friday 1:45PM	0	1000	0	950	1540
4	Saturday 10:00AM	0	100	0	67	410
7	Sunday 10:00AM	0	10	0	700	1500
10	11:00PM	0	10000	0	175	770

Sand Samples:

No.	Time	Load	Colon Index	Strep. Index	Counts: 37 C.	Counts: 22 C.
2	Friday 5:00PM	54	100	5	9000	15600
4	Saturday 10:00AM	4	1000	0	2000	7500
7	Sunday 10:00AM	0	100	0	22400	30000
10	11:00PM	0	10000	0	innum.	innum.

Middle of Lake:

No.	Time	Load	Colon Index	Strep. Index	Counts: 37 C.	Counts: 22 C.
7	Sunday 10:00AM	0	8	0	139	360

innum.=innumerable

Table 5a
Week-end, Saturday-Tuesday
Location: End of Dock

No.	Time	Load	Colon Index	Strep. Index	Counts: 37 C.	22 C.
1	Saturday 2:00PM	60	1000	10	312	1170
2	5:00	3	1000	2	490	1630
3	Sunday 11:00AM	13	100	4	272	410
4	5:00PM	60	100	100	83	440
5	Monday 11:00AM	0	1000	0	44	224
6	Tuesday 3:00PM	56	10000	6	7800	---

---=count omitted

Table 5b
Week-end, Saturday-Tuesday
Location: Near Shore

No.	Time	Load	Colon Index	Strep. Index	Counts: 37 C.	Counts: 22 C.
1	Saturday 2:00PM	60	100	4	275	870
2	5:00PM	3	100	6	5100	7400
3	Sunday 11:00AM	13	1000	0	167	460
4	5:00PM	60	1000	4	480	610
5	Monday 11:00AM	0	1000	0	1500	7600
6	Tuesday 3:00PM	56	100	6	7040	---

Table 5c
Week-end, Saturday-Tuesday

Location: Control at Lakeside:

No.	Time	Load	Colon Index	Strep. Index	Counts: 37 C.	22 C.
1	Saturday 2:00PM	0	1000	1000	342	2220
3	Sunday 11:00AM	0	10000	0	210	400
4	5:00PM	0	1000	4	243	1340
6	Tuesday 3:00PM	0	1000	0	1203	---

Location: Middle of Lake:

3	Sunday 11:00AM	0	100	0	96	300
6	Tuesday 3:00PM	0	10000	0	1500	---
7	Wednesday 9:15PM	0	10000	0	11	---

Location: Near Shore, Sand Samples:

1	Saturday 2:00PM	60	10000	10000	850	3000
3	Sunday 11:00AM	13	1000	2	480	4450
5	Monday 11:00AM	0	10000	0	3800	15100

Table 6a
Week-end, Friday-Sunday
Location: End of Dock

No.	Time	Load	Colon Index	Strep. Index	Count, 37 C.
1	Friday 2:00PM	55	100	4	393
2	Saturday 10:00AM	55	8	2	52
3	2:00PM	45	1000	100	345
4	5:30	102	10	1000	127
5	11:15	50	10	100	18600
6	Sunday 10:30AM	31	100	6	1230

Table 6b
Week-end, Friday-Sunday
Location: Near Shore

No.	Time	Load	Colon Index	Strep. Index	Count, 37 C.
1	Friday 2:00PM	55	100	6	440
2	Saturday 10:00AM	55	10	0	380
3	2:00PM	45	10	2	131
4	5:30	102	100	100	54000
5	11:15	50	10	100	850
6	Sunday 10:30AM	31	10	0	950

Table 6c
Week-end, Friday-Sunday
Location: Control at Lakeside

No.	Time	Load	Colon Index	Strep. Index	Count, 37 C.
1	Friday 2:00PM	0	100	0	1100
2	Saturday 10:00AM	0	100	0	140
3	2:00PM	0	100	0	3100
4	5:30PM	0	100	0	280
5	11:15	0	10	0	410
6	Sunday 10:30AM	0	100	0	200

Table 6d
Week-end, Friday-Sunday
Location: Middle of Lake

No.	Time	Load	Colon Index	Strep. Index	Count, 37 C.
1	Friday 2:00PM	0	100	0	116
3	Saturday 2:00PM	0	6	0	30
4	5:30	0	100	0	122
5	11:15	0	10	0	75
6	Sunday 10:30AM	0	10	0	500

Table 6e
Week-end, Friday-Sunday
Location: Park Lake

No.	Time	Load	Colon Index	Strep. Index	Count, 37 C.
1	Friday 2:00PM	30	100	6	435
2	Saturday 10:00AM	0	10	0	166
3	2:30PM	26	10	6	234
5	11:30	10	100	10	560
6	Sunday 10:30AM	8	100	0	230

DISCUSSION

A bacteriological study of Lake Lansing was made by W.L.Mallmann in May,1932 before the swimming season (Table 1). On May 6th samples taken at distances of 25, 50, and 100 feet from shore at stations A,C, and E (Fig. 2) showed counts well below 100 per c.c. and gas production was negligible (Table 1). There is no appreciable difference in count or gas production in samples obtained from the various sampling points. On May 23rd, after the bathing season was started, samples obtained from the same points revealed a definite increase in total count as well as in gas production. No examination for streptococci was made. These results indicate a safe bathing place under most of the standards recommended up to this time. In the present work the pollution introducted by the bathers is considered.

The data are presented in tabulated form in the tables from 1 to 6 inclusive. The same results, with the exception of those recorded in Table 1, are plotted in Graphs 2 to 6 but more strikingly presented because the general trends are much easier to follow. The data in Table 2, "a" and "b" series are plotted on Graph 2, "a" and "b" series, Table 3 on Graph 3, and so on through Table 6, "a" and "b". These are all based on week-end sampling, with the exception of the data in Table 3 which represents samples from Monday to Thursday. Graphs 7 to 11 show the comparisons among the different sampling points.

The indices are plotted logarithmically, while the bathing loads, as indicated by the rod-like blocks, are plotted on a uniform scale.

By studying one of the week-end graphs of samples taken from the end of the dock or from near the shore it will be noted that results obtained in the afternoon and early evening samples usually showed an increase which often reached its height about midnight but seldom revealed a marked decrease. This is especially true of the streptococcus index. Next morning, when samples were obtained before bathers entered the water, the streptococcus index was zero, or if a few bathers were present, this index was comparatively low.

The total counts and colon index did not go down to zero over night or at any other time during the period of study. Usually a decrease in these two indices was noted in the early morning samples though occasionally increases were noted. All indices are fairly representative of pollution introduced by bathers, but if the total counts and colon indices for the entire period are compared with the control on Graphs 8 and 10 it will be observed that there is not much difference. The control samples were not always taken every time a sample was collected at the beach, however, so that if this is considered in reading the graph the above statement will be found to be essentially correct.

When the streptococcus is considered (Graph 11) a striking fact is revealed--there are no streptococci at a point free from bathers, while at the other two sampling points where bathers are present, the streptococcus index parallels the bathing load. At other points free from bathing pollution there are also no streptococci.

Nevertheless, there are two exceptions to the above statement that streptococci do not occur at points free from bathing pollution (Table 5c). When this happened a search was immediately made to find if any sewage was being dumped from the houses and restaurants bordering the lake at the control point. This was unsuccessful. Therefore, in order to determine the source of this organism a number of samples were taken from the lake at points opposite suspected houses and a restaurant. From then on to the end of this investigation no more streptococci were obtained from any point in the vicinity of the control.

Since sewage is not allowed to be emptied into this lake, and because the streptococci were found only on two occasions, it is natural to conclude that their occurrence at this particular time is of no significance. A sufficient number of samples was taken at different points outside the bathing area to strengthen the opinion that streptococci in a lake of this type are found only in the immediate vicinity of bathers. Because of this viewpoint the two exceptions are not shown in Graph 11.

In the "c" series of Graphs 2 to 6 the comparisons between the end of the dock and shore are given. The colon index and total count comparisons for the whole five weeks are presented in Graphs 7 and 9 respectively. These reveal very little difference between the two sampling points, but in the "c" series of Graphs 2 to 6 it will be observed that the total counts and colon indices are somewhat higher near the shore, while the streptococcus index is higher at the end of the dock, also shown on Graph 11. This further proves that the streptococcus index is a good indicator of bathing pollution because a more complete immersion of the body takes place at the end of the dock and, in this area, we have the greatest concentration of bathers.

It seems that the streptococci disappeared overnight because they were not present in the morning before bathing began, and they did not settle down to the sand because the latter samples revealed no streptococci unless some bathers were present.

The streptococcus index seldom rises above 10, the colon index and total count rarely go below a 100. In a swimming pool the opposite is often found due to the fact that the more susceptible colon organisms are destroyed by chlorination before the streptococci.

Agar plate counts, incubated at 22 C. for 48 hours, were discontinued after the fourth week-end because they did not yield any additional information outside of the fact that they gave slightly higher counts.

Often, sand samples were taken at the same point from which the shore samples were obtained. Total counts and colon indices gave slightly higher results than at any other sampling points. Occasionally streptococci were observed (Tables 2c, 4c, 5c) although in only one instance was the index high. As mentioned above, no streptococci were observed unless the bathing load was above zero.

The Mallmann and Gelpi macroscopic examination for streptococci (23) was not applicable to these tests because of the high turbidity produced by the growth of the organisms.

Due to the inability to investigate any additional factors concerned in this problem because of the large numbers of samples handled in the regular procedure, much study was not devoted to plankton and their influences. Enough, however, was accomplished to enable one to state that the total plankton population was high, the most common forms present being the rotifers and water fleas. Two samples examined, one from the bathing area and the other from a point outside this area, manifested no difference in numbers or species.

Weather conditions such as prevailing winds, temperature, and amount of sunshine had no discernible effects on the results presented.

A close inspection of the data reveals that a "catch" sample would be just as apt to give a false idea of the condition of a beach as it would be to give a correct one. For example, in Table 4a, sample 8 the total count at 37 C. was 127,000, the load being 200; one hour and fifteen minutes later the load increased by 50 (sample 9) but the total count dropped to 600. In table 4b, sample 8, a load of 200 gave a count of 12,000, while in sample 6, with a load of 67 the count was 148,000. Such discrepancies have been observed at least once in each week-end table. Bacteriological examinations of a beach conducted in about the same time intervals as those presented here give a more satisfactory picture of the condition of a bathing place.

During the last week-end the same routine was performed at Park Lake, which yielded the same general results as those depicted from Lake Lansing (Table 6e, Graph 6e).

These results on streptococci confirm the conclusions of Savage and Wood (17) which were that: "In particular the finding of streptococci in any numbers can be accepted as indicating considerable and recent contamination. We consider that the streptococcus determination is very valuable on its positive side as an indication of recent contamination. As a means of judging the recency of the contamination it is even more valuable than the Esch. coli enumeration."

These workers also compared the viability of streptococci and Esch. coli in sterile water and reported that the former organisms were practically eliminated at the end of two weeks but Esch. coli, multiplied over fifty-fold of the original number at the end of eleven weeks.

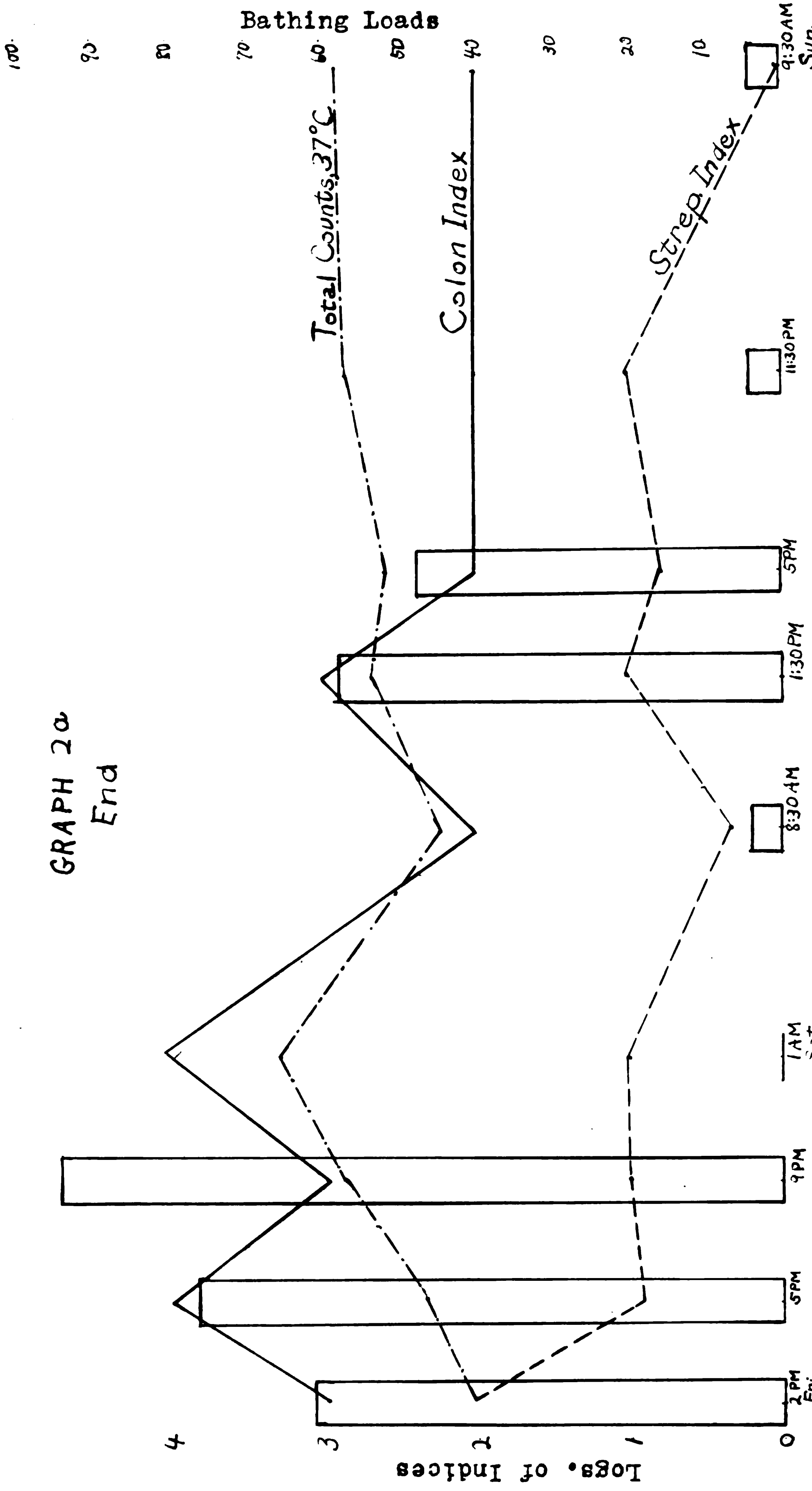
Mallmann (22) has presented evidence that Esch. coli tends to multiply in the swimming pool, while streptococci do not. He obtained these data from a non-chlorinated pool of the recirculation type in which the water turnover occurs about every nine hours. Since some of the organisms were removed through the filters the increase in their numbers in the pool could only be accounted for by their multiplication. This was not true of the streptococci.

These conditions are very similar to those in a limited bathing beach like the one at Lake Lansing. In case of streptococcus, it has been shown in the data that they disappeared over night, while Esch. coli and total count sometimes remained stationary or even increased. That Esch. coli remains viable and tends to multiply during the warmer months seems to be borne out when it is considered that in the month of May the numbers were very low while in summer they were much higher. This was also true when practically no bathers were present for several days.

It is evident from the data presented that in a limited bathing beach the conditions are similar to those in an untreated artificial pool. Therefore, there is no reason why the same bacterial standards employed in swimming pools should not be applied to a beach of this sort. Disinfection with chlorine has been tried in the Washington tidal basin (26) with good success as judged by the regular colon test. From a total count of over 175,000 bacteria per c.c. in the entering water from the Potomac River . the reduction by the treatment lowers the count to less than 100 bacteria per c.c., _Esch_. _coli_ is likewise reduced, from 500 per c.c. to its occasional presence in two or three of the five 10 c.c. portions.

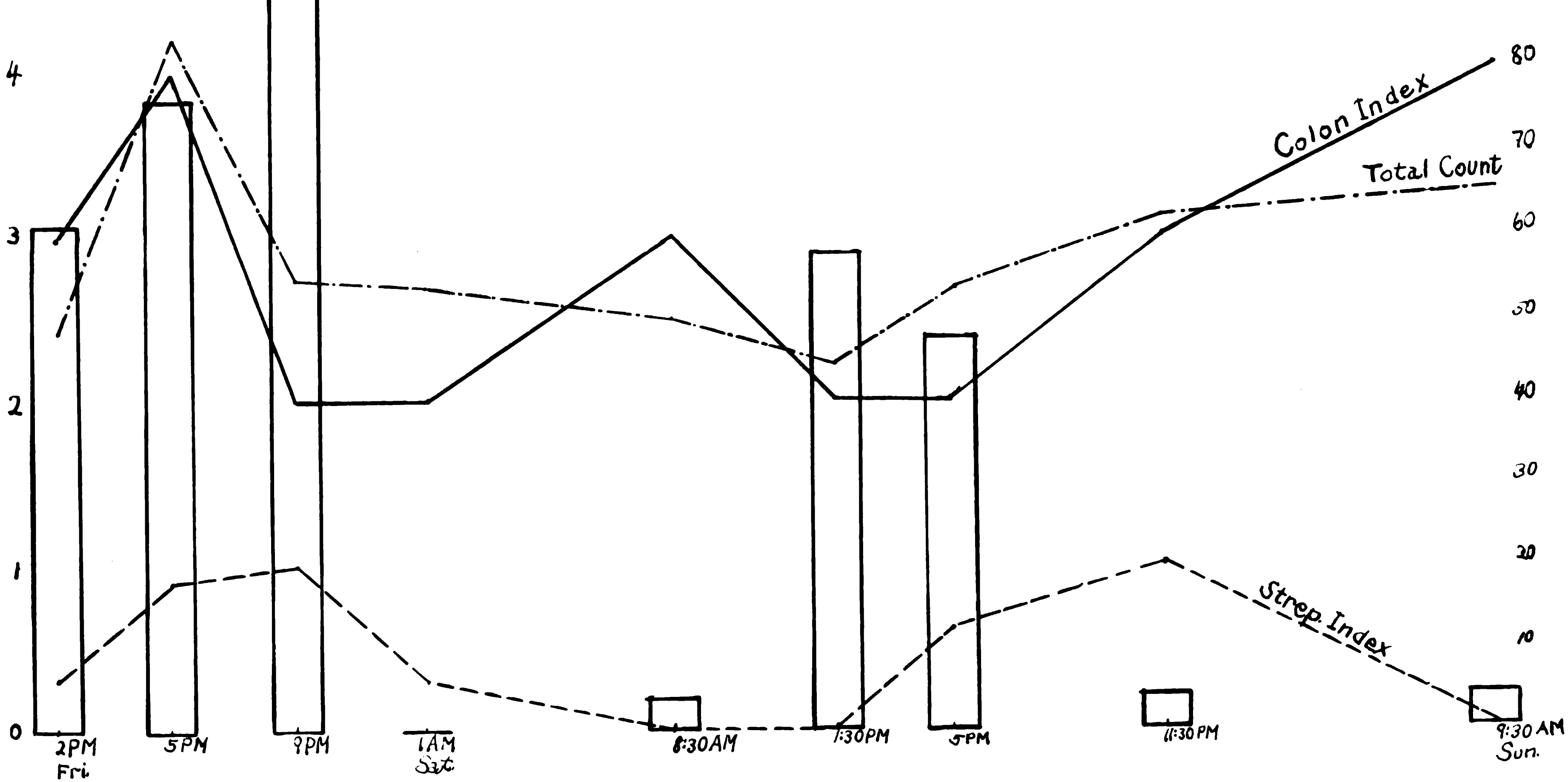
The proposal of sanitary engineers (24) that all public bathing places be of the same standard of bacterial quality as is required for swimming pools, seems justified.

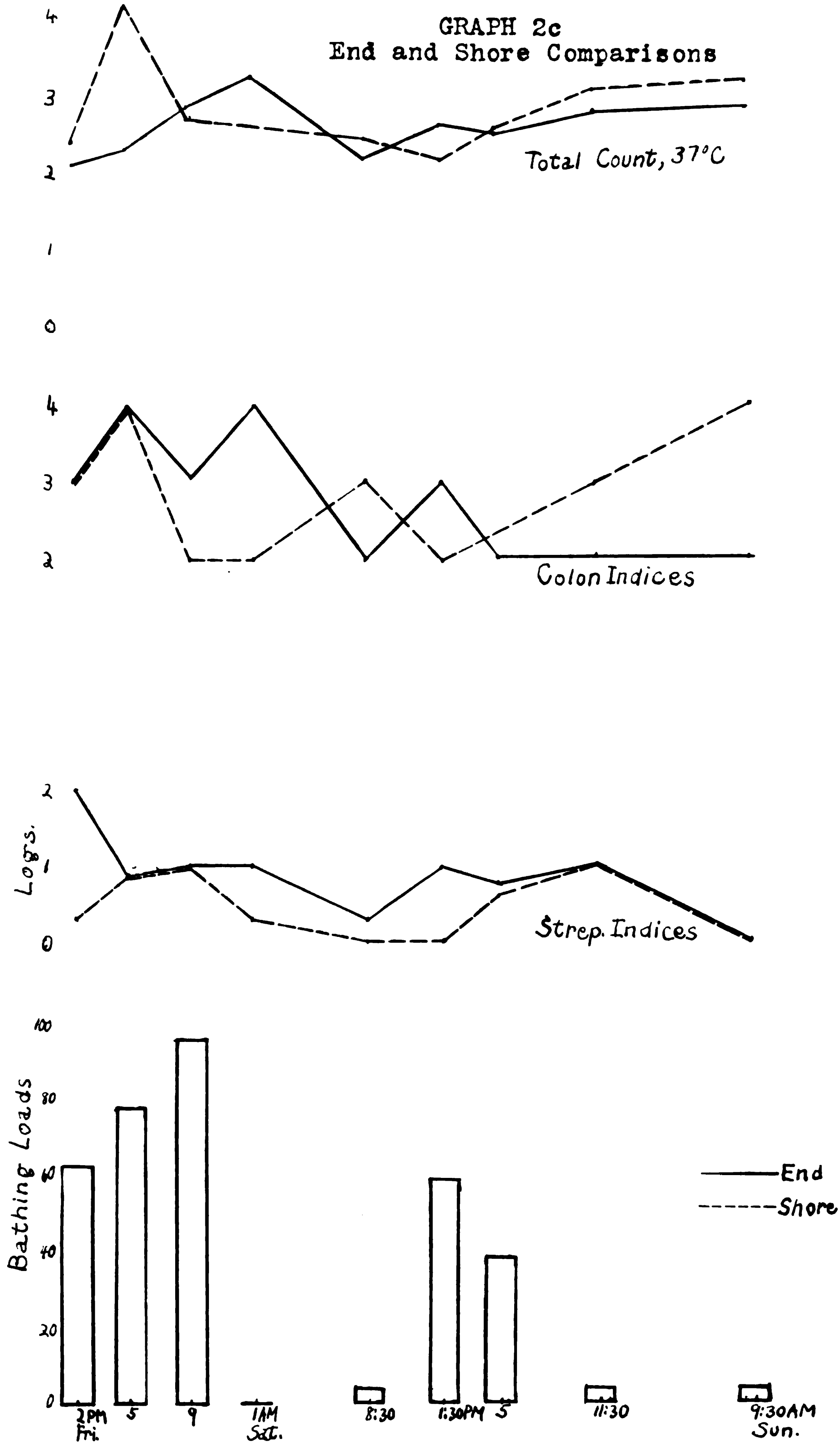
In order to meet swimming pool standards it may be necessary to chlorinate the water by use of chloroboats, by having the area fenced off so that the bathing loads can be limited, or by a combination of such methods.

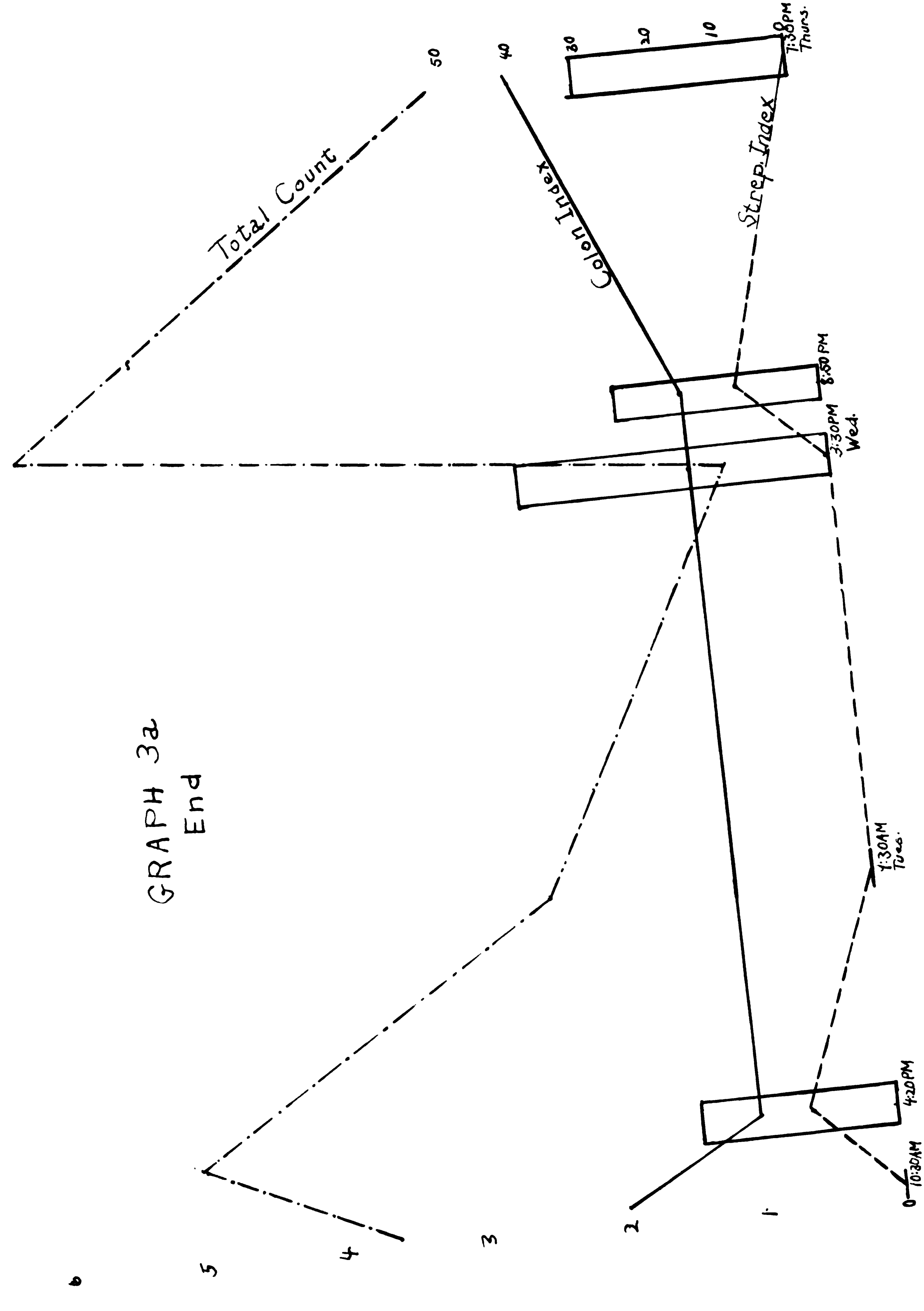

Bathing Loads
100
90
80
70
60
50
40
30
20
10
Total Counts, 37°C
Colon Index
Strep Index
Logs. of Indices
4
3
2
1
0
2PM Fri
5PM
9PM
1AM Sat.
8:30AM
1:30PM
5PM
11:30PM
9:30AM Sun.

GRAPH 2a
End

GRAPH 2b
Shore

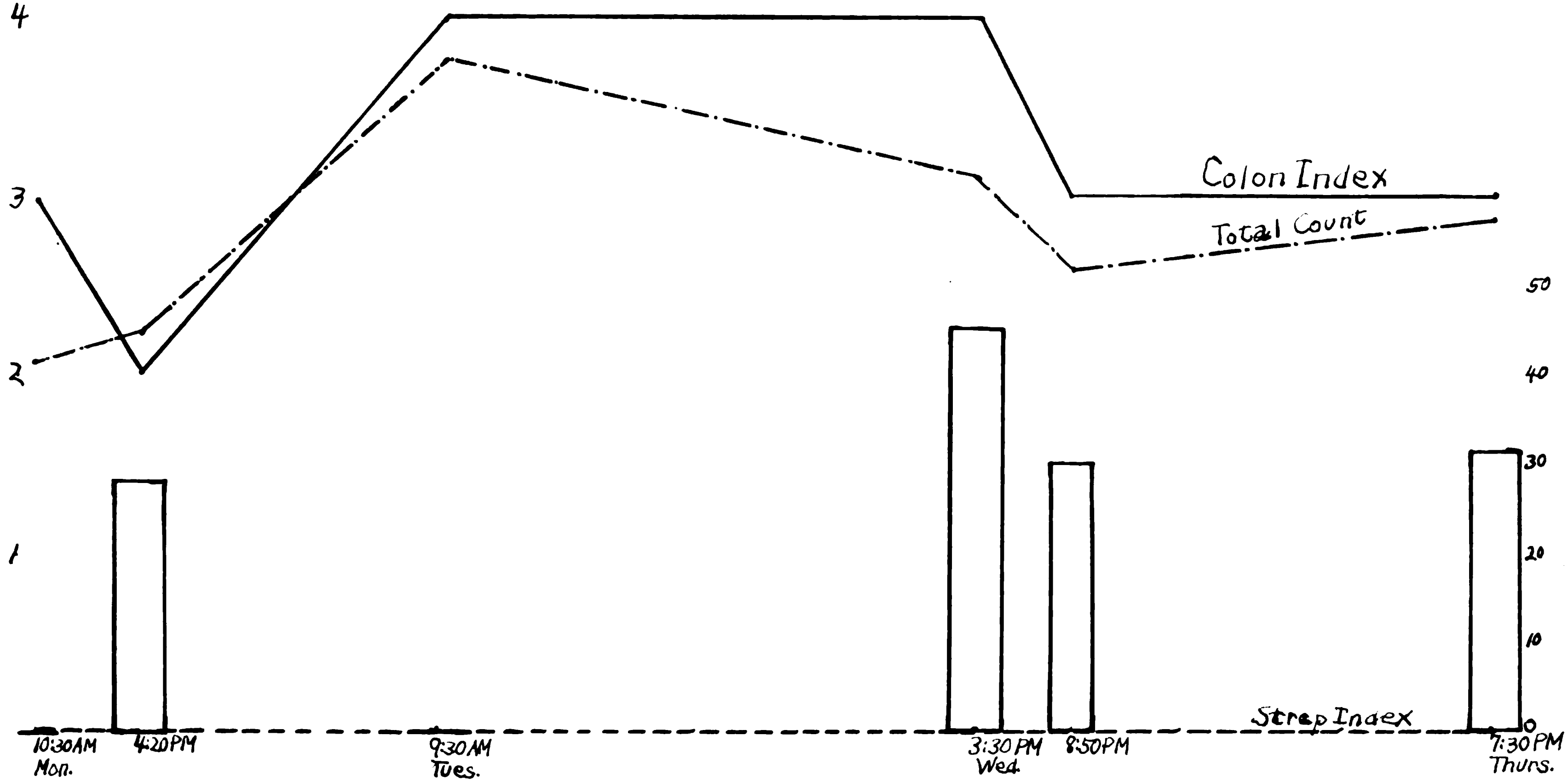



GRAPH 2c
End and Shore Comparisons
Total Count, 37°C
Colon Indices
Strep. Indices
Logs.
Bathing Loads
End
Shore
2PM Fri.
5
9
1AM Sat.
8:30
1:30PM
5
11:30
9:30AM Sun.
4
3
2
1
0
100
80
60
40
20


Total Count
Colon Index
Strep Index
50
40
30
20
10
0
7:30PM Thurs.
8:50PM
3:30PM Wed.
7:30AM Tues.
4:20PM
10:30AM
5
4
3
2
1
0

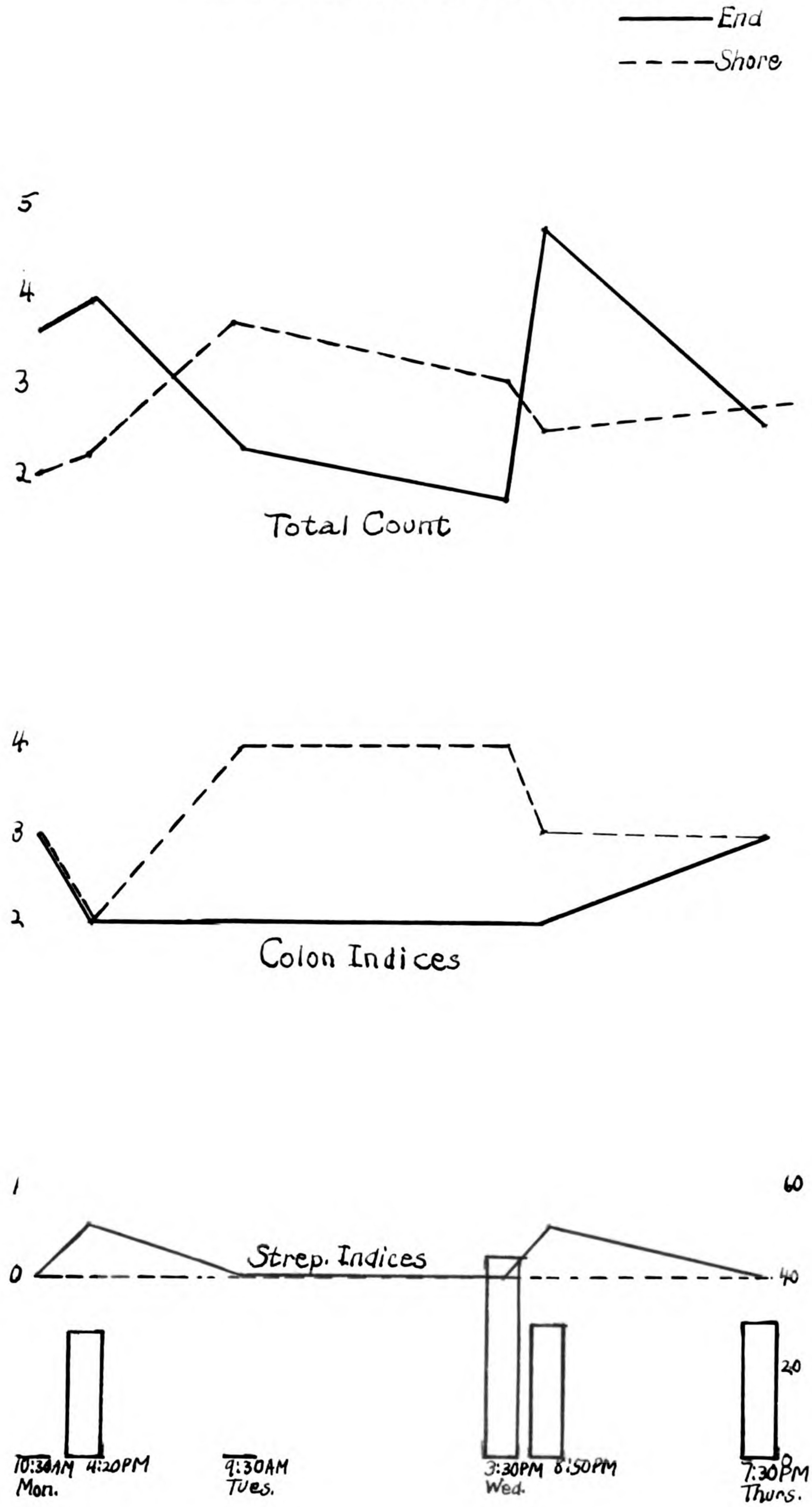
GRAPH 3a
End

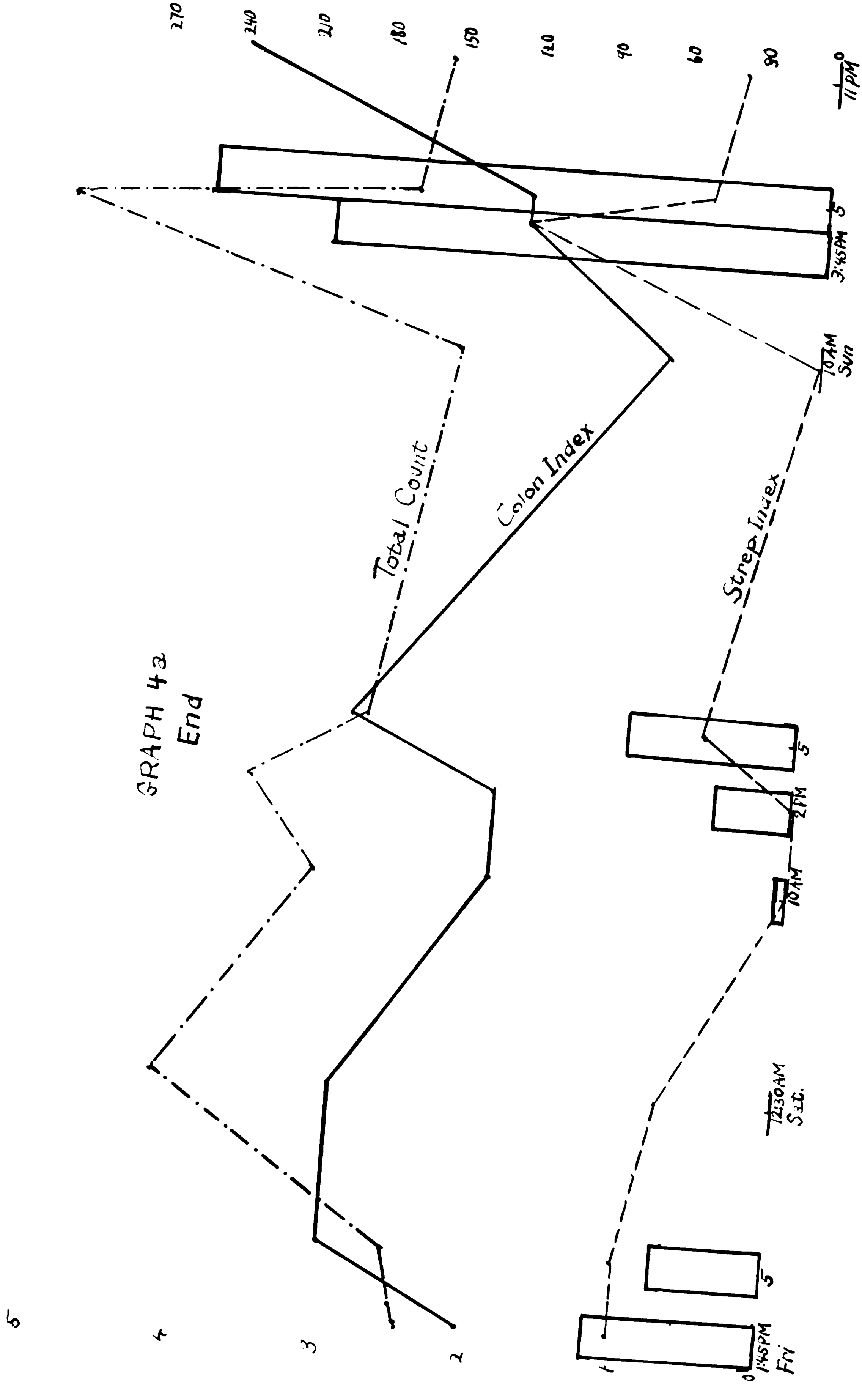
GRAPH 3b
Shore

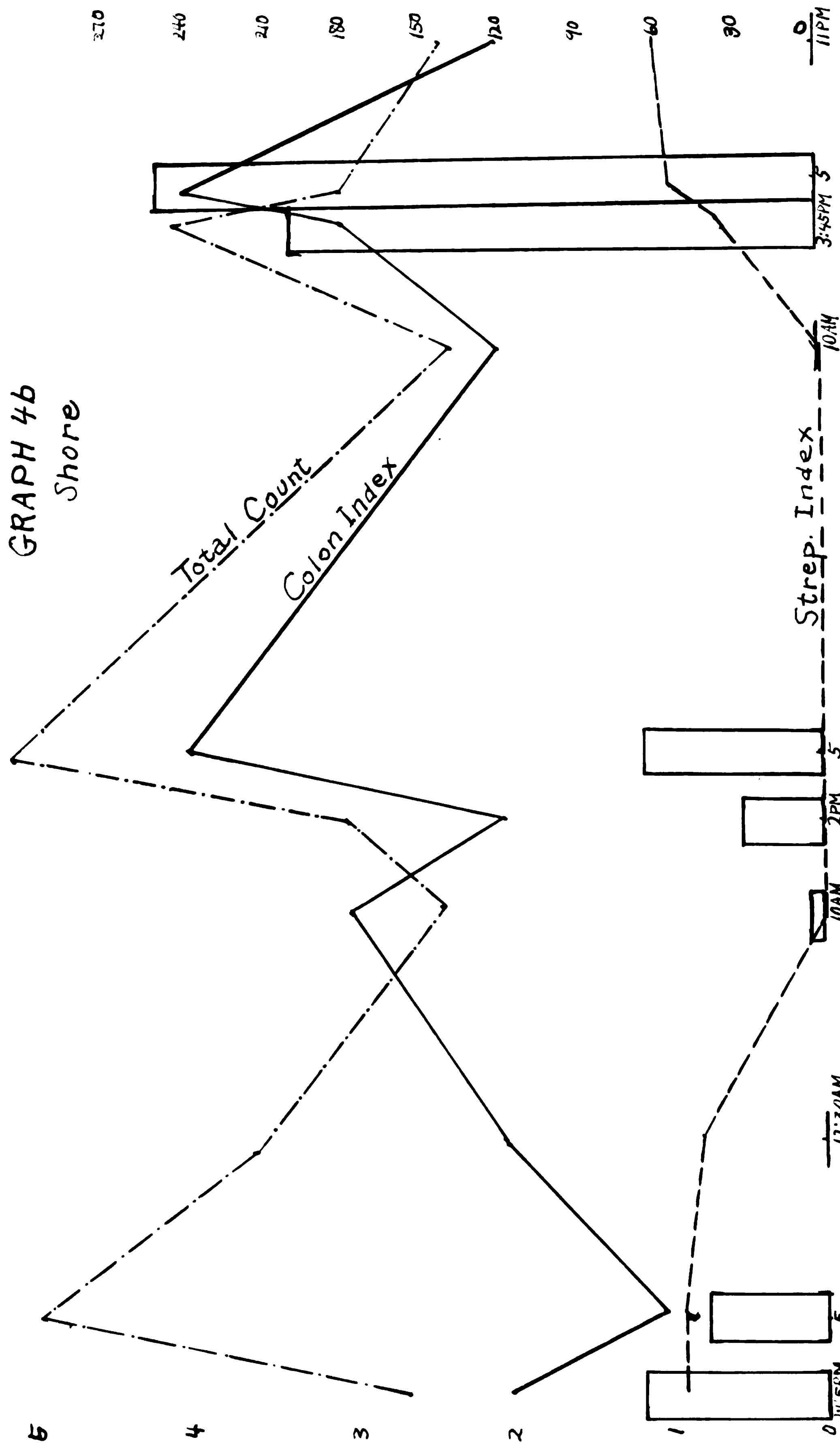


GRAPH 3c

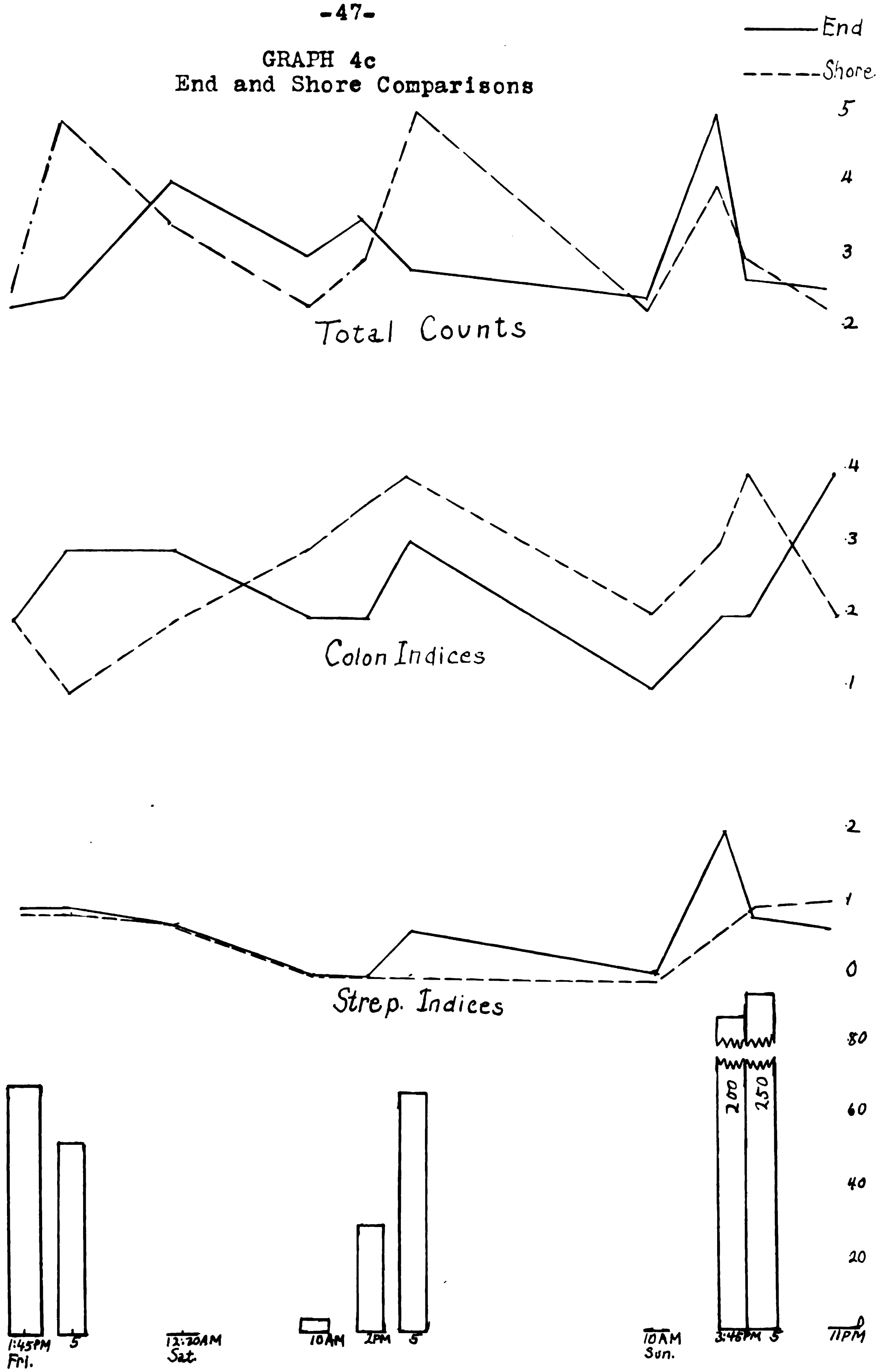
End and Shore Comparisons



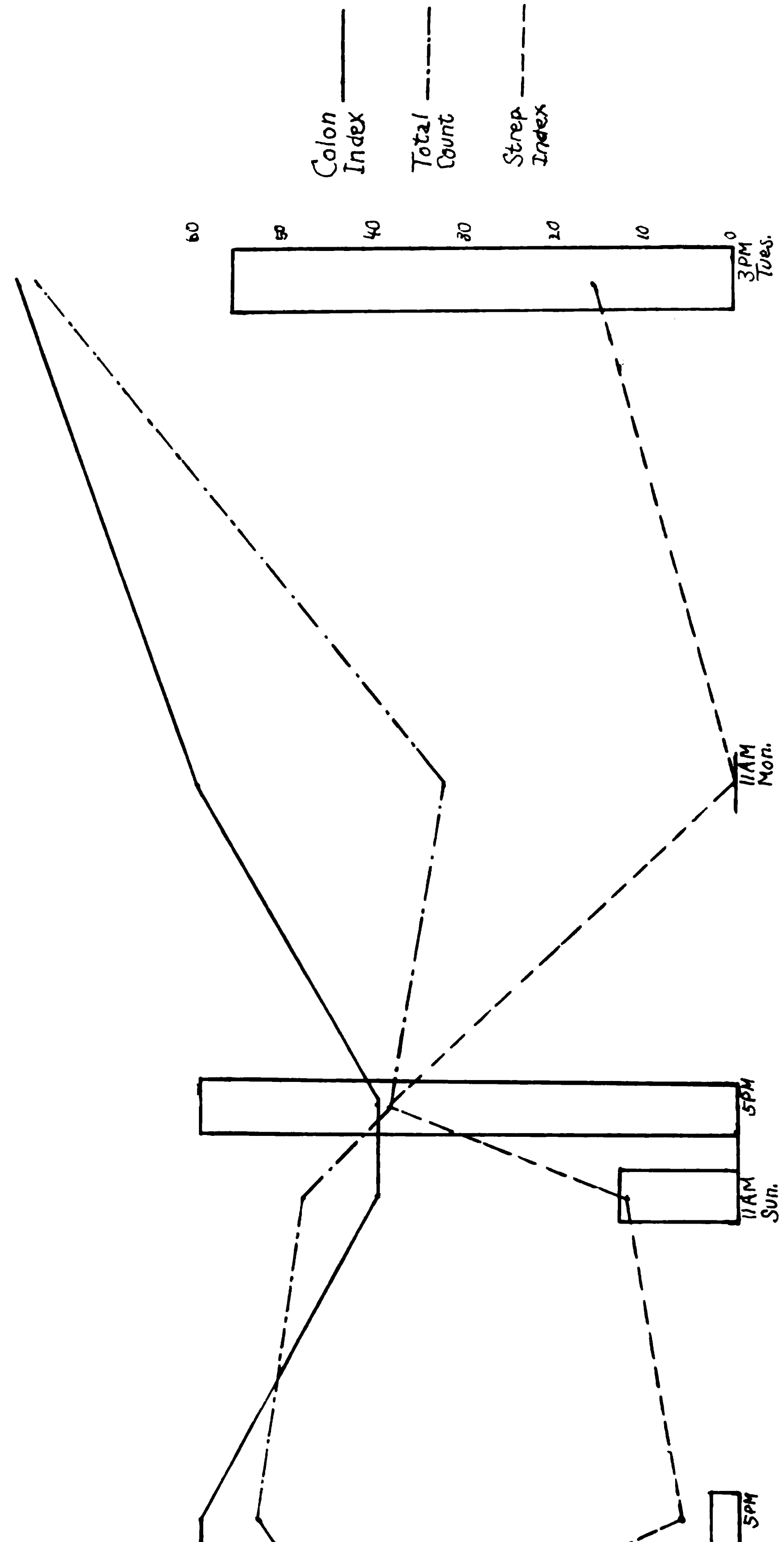

GRAPH 42
End
Total Count
Colon Index
Strep Index
270
240
210
180
150
120
90
60
30
0
11 PM
5
3:45PM
10AM
Sun
5
2PM
10AM
12:30AM
Sat.
5
1:45PM
Fri
0
1
2
3
4
5

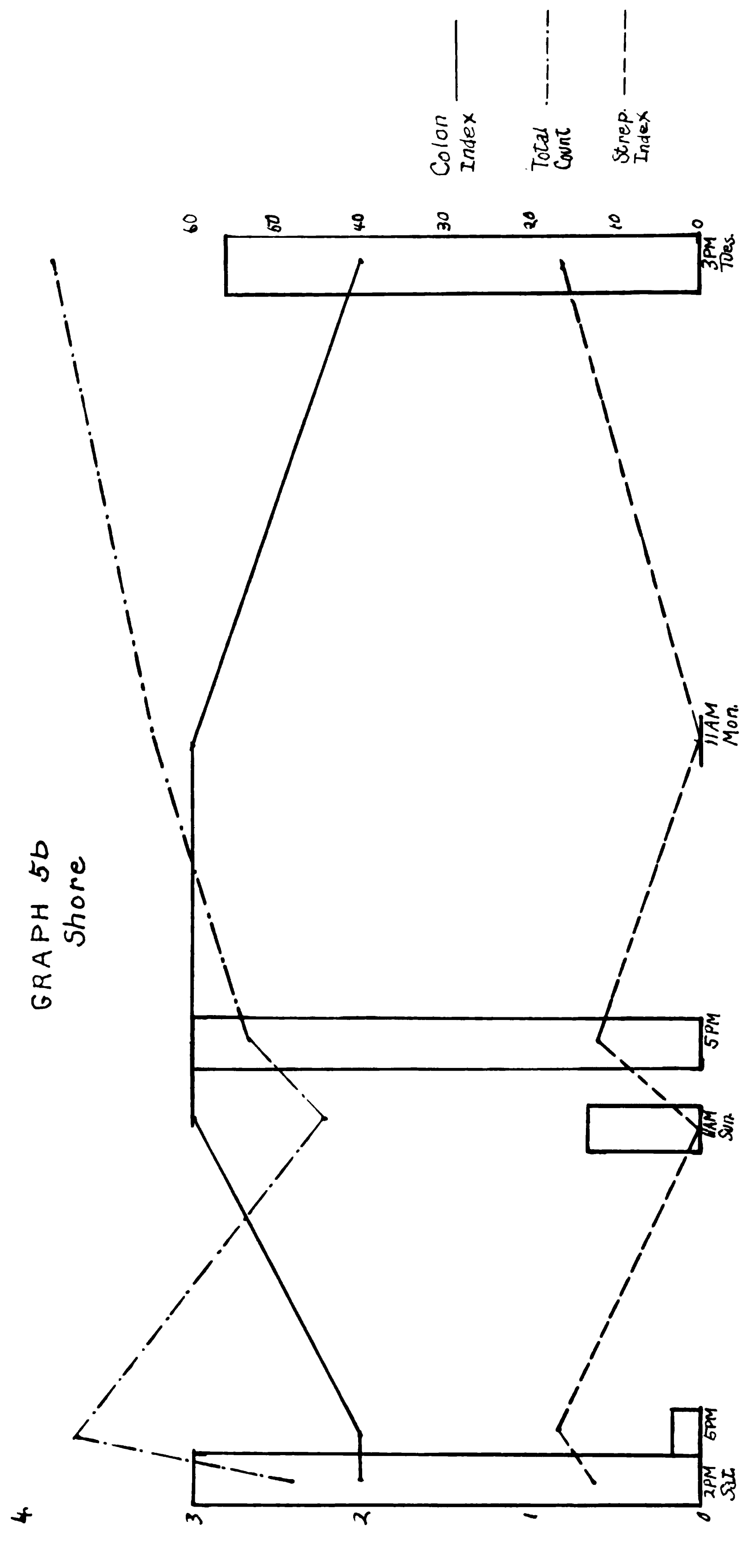

GRAPH 4b
Shore
Total Count
Colon Index
Strep. Index
270
240
210
180
150
120
90
60
30
0
11PM
5
3:45PM
10AM
Sun.
5
2PM
10AM
12:30AM
Sat.
6
1:45PM
Fri
0
1
2
3
4
5

GRAPH 4c
End and Shore Comparisons

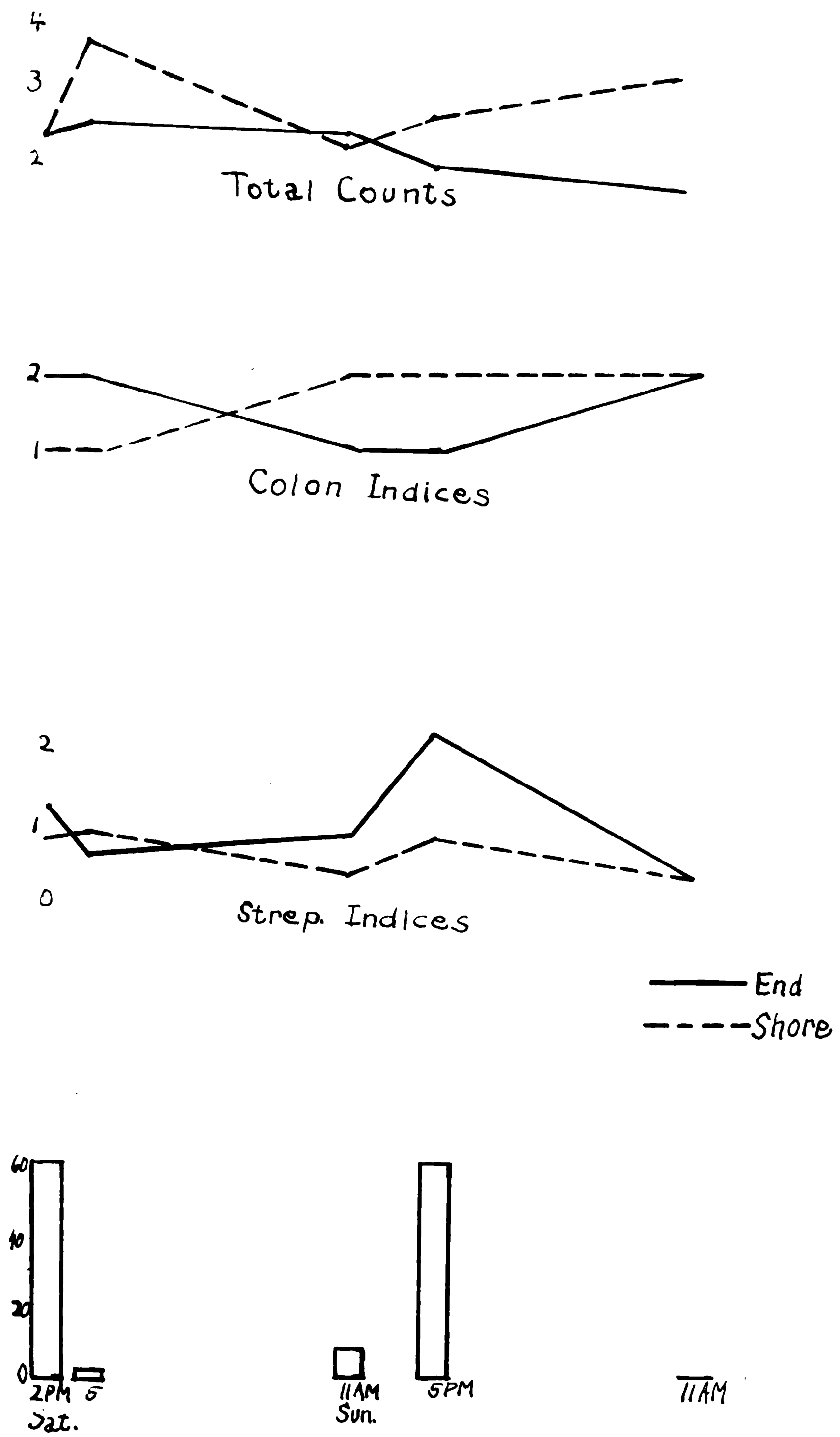


GRAPH 5a
End

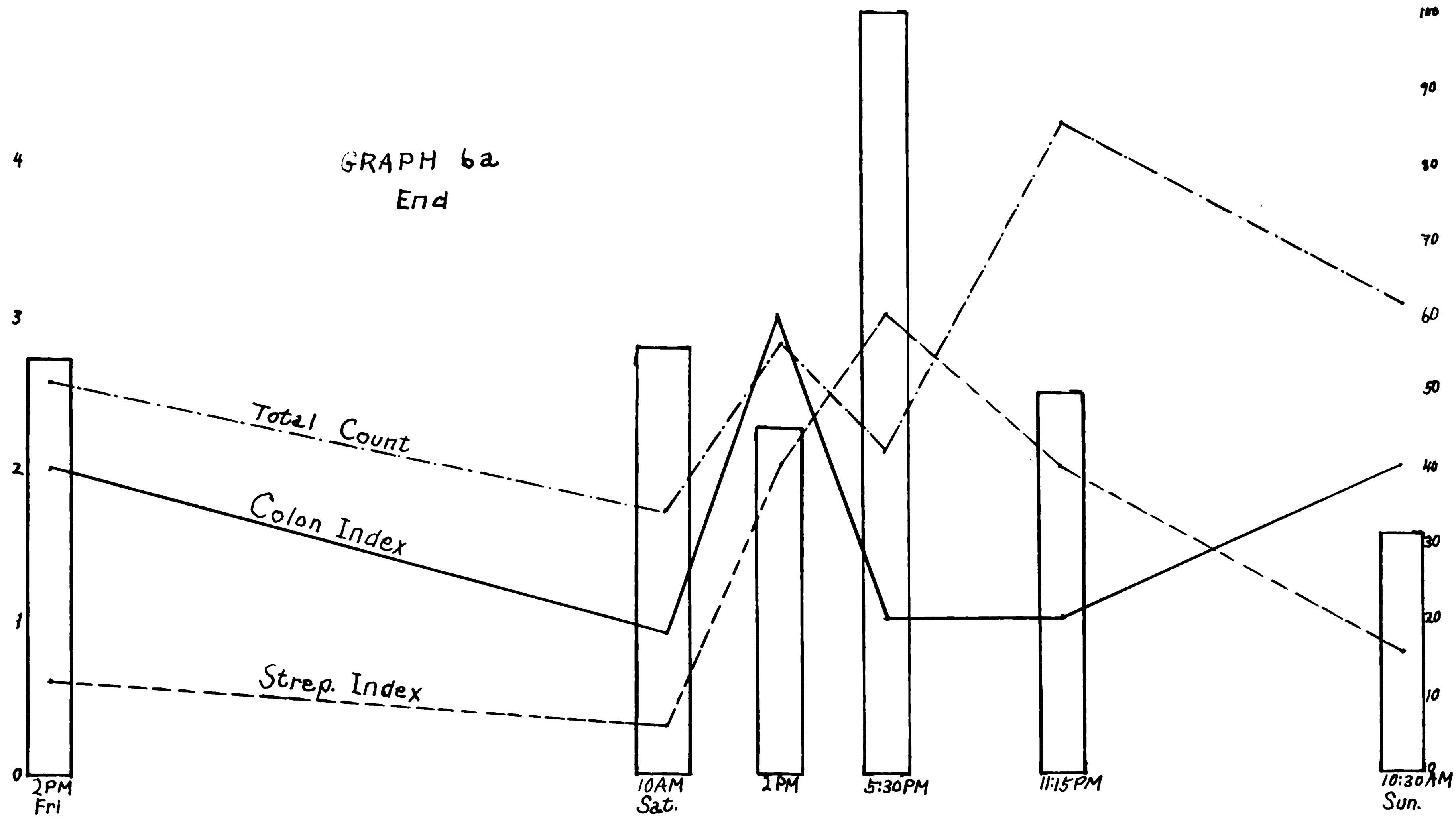

Colon Index
Total Count
Strep Index
0
1
2
3
4
0
10
20
30
40
50
60
2PM Sat.
5PM
11AM Sun.
5PM
11AM Mon.
3PM Tues.

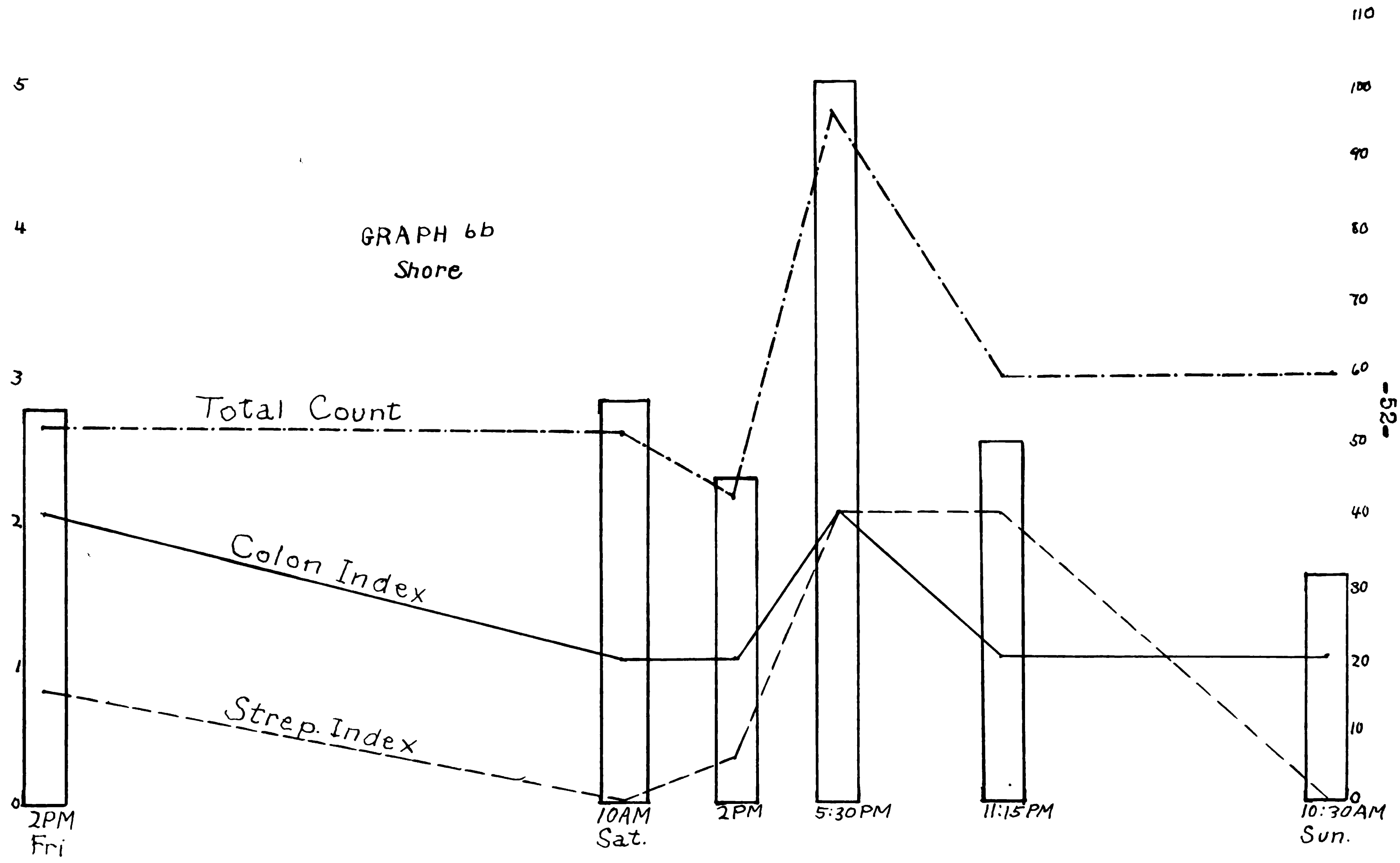

GRAPH 5b
Shore
Colon Index
Total Count
Strep. Index
60
50
40
30
20
10
0
4
3
2
1
0
3PM Tues.
11AM Mon.
5PM
11AM Sun.
5PM
2PM Sat.

GRAPH 5c
End and Shore Comparisons

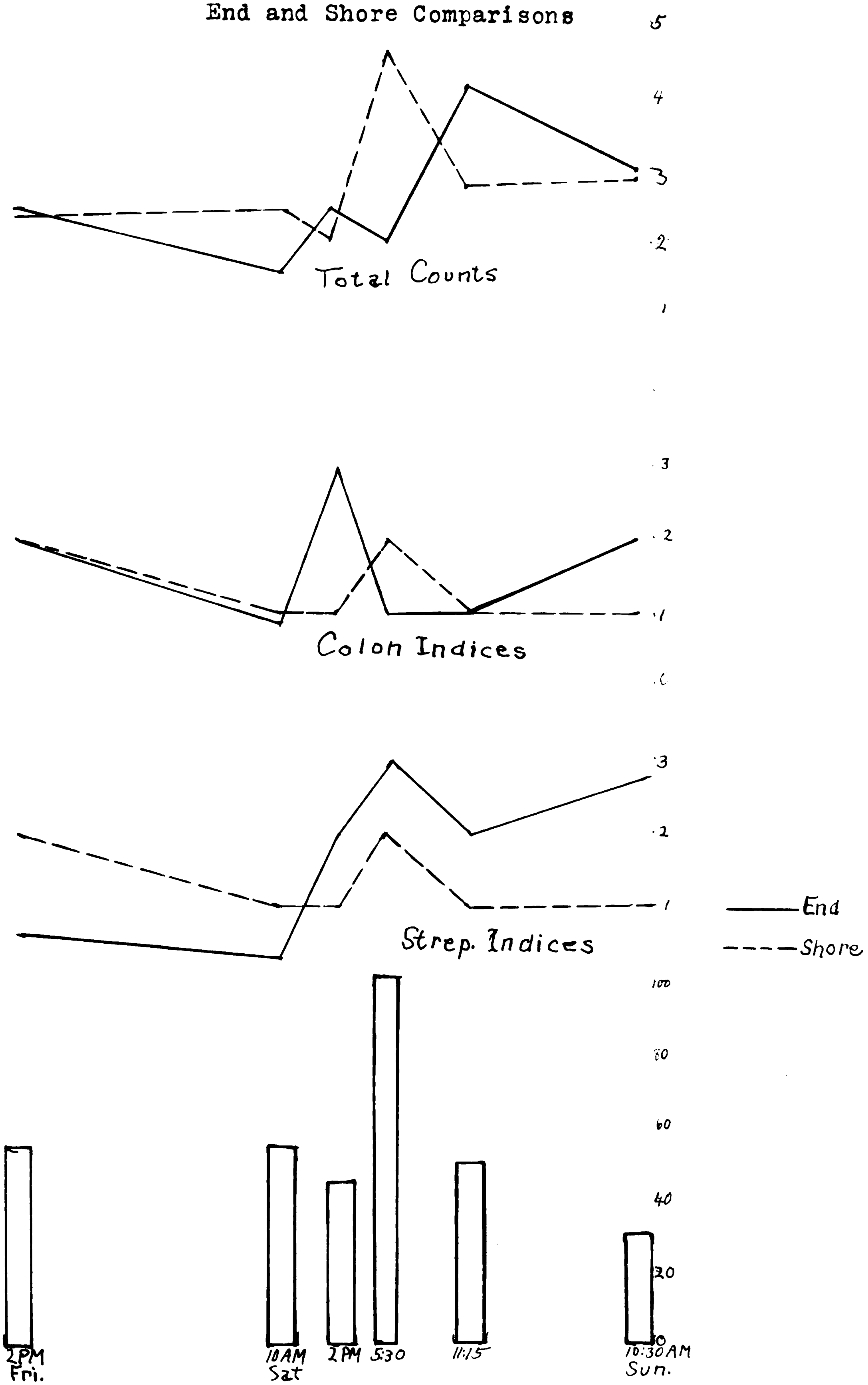


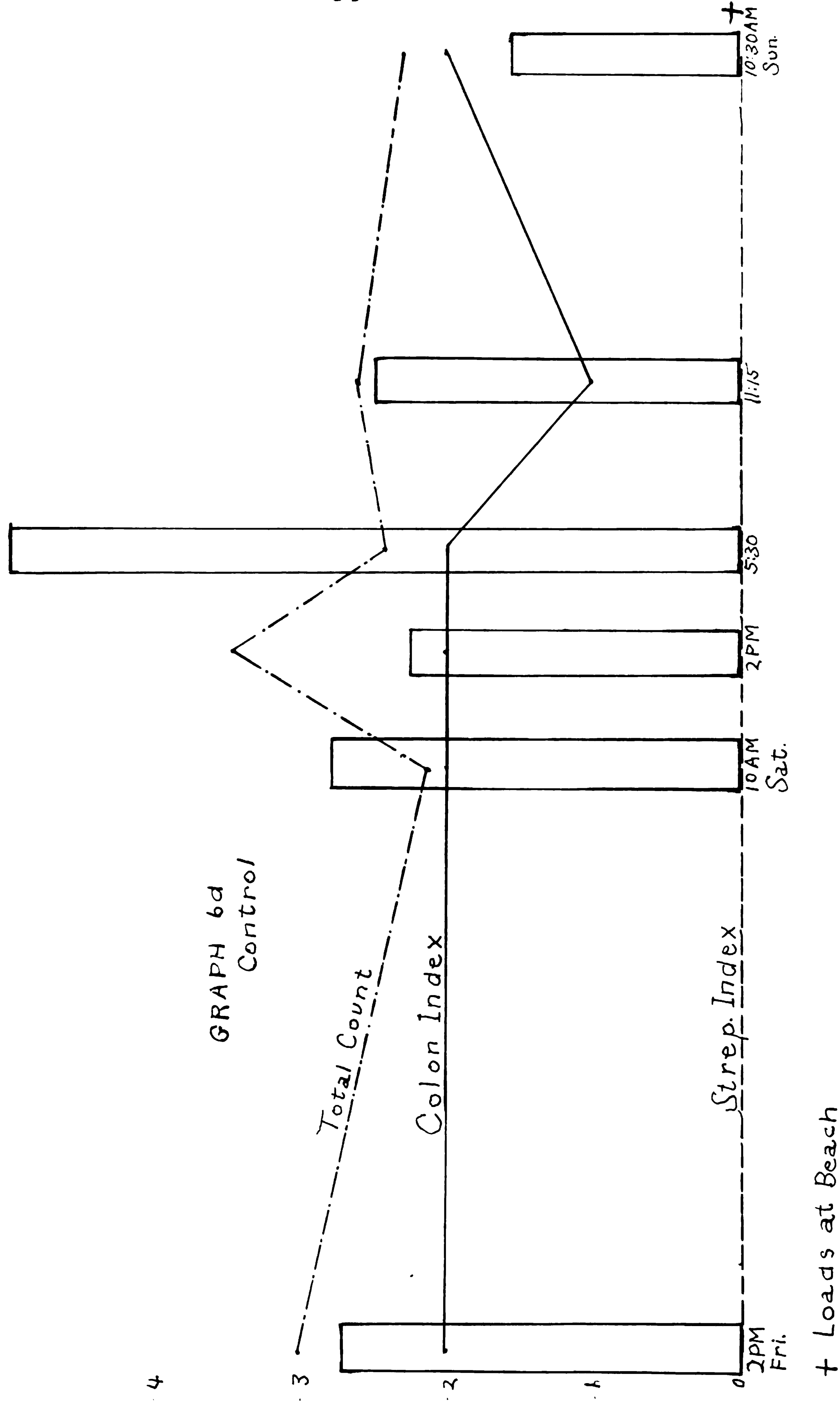
GRAPH 6a
End


Total Count
Colon Index
Strep. Index
0
1
2
3
4
2PM
Fri
10AM
Sat.
2PM
5:30PM
11:15PM
10:30AM
Sun.
0
10
20
30
40
50
60
70
80
90
100

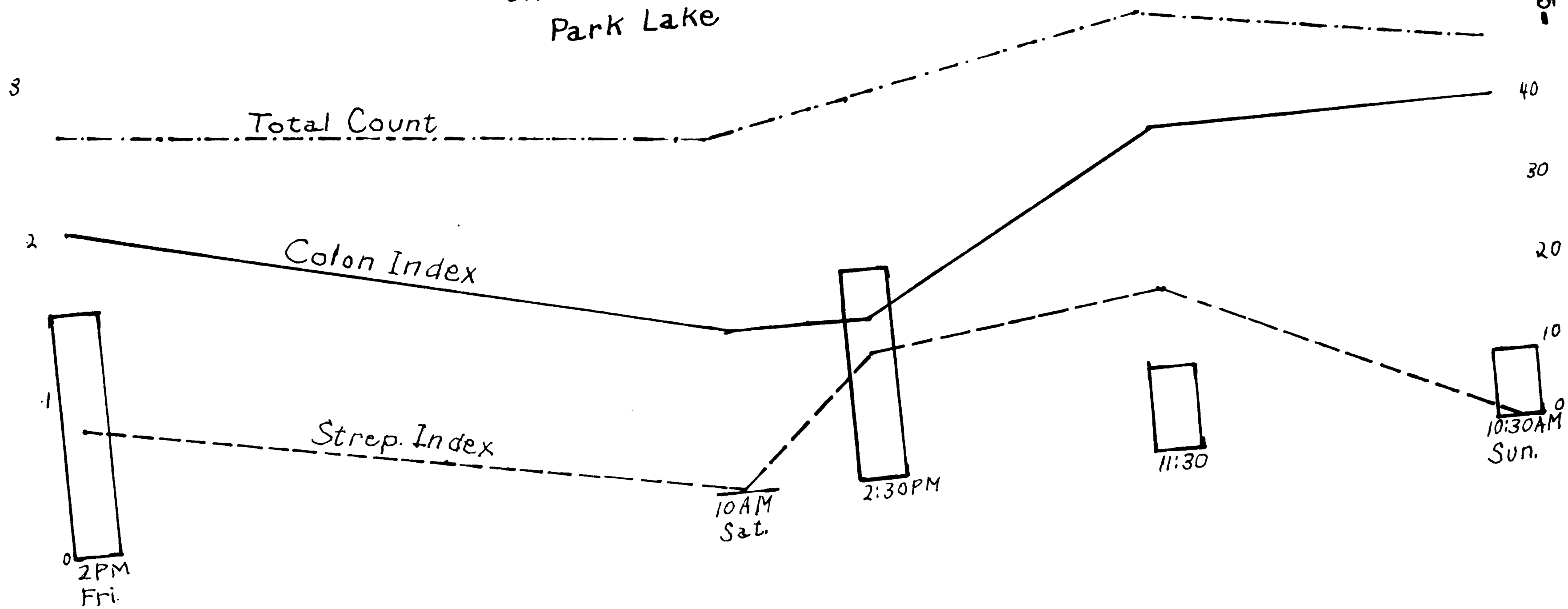

GRAPH 6b
Shore
Total Count
Colon Index
Strep. Index
5
4
3
2
1
0
110
100
90
80
70
60
50
40
30
20
10
0
2PM
Fri
10AM
Sat.
2PM
5:30PM
11:15PM
10:30AM
Sun.

GRAPH 6c
End and Shore Comparisons



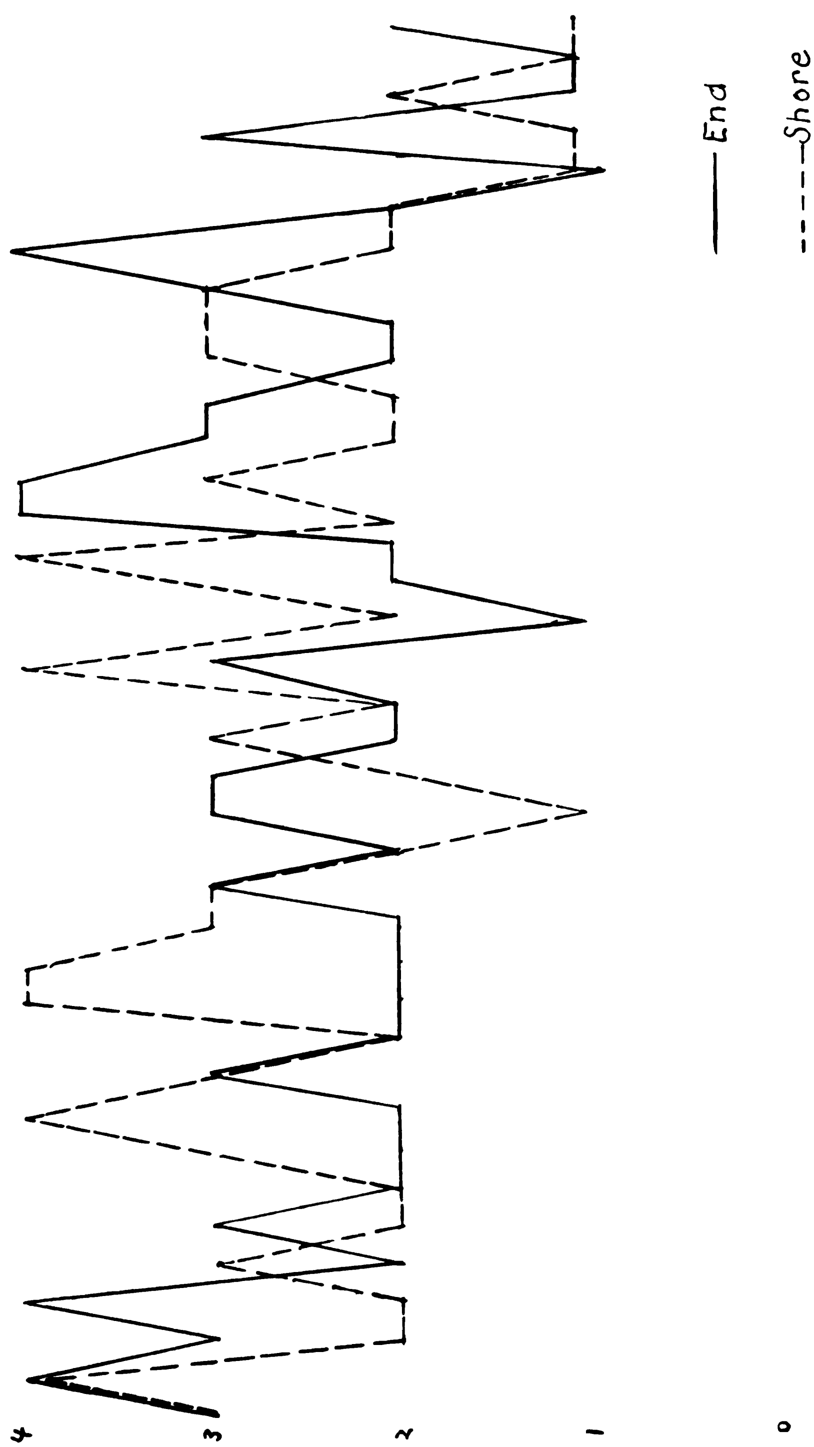

GRAPH 6d
Control
Total Count
Colon Index
Strep. Index
+ Loads at Beach
0
1
2
3
4
2PM Fri.
10AM Sat.
2PM
5:30
11:15
10:30AM Sun.
+

GRAPH 6e
Park Lake



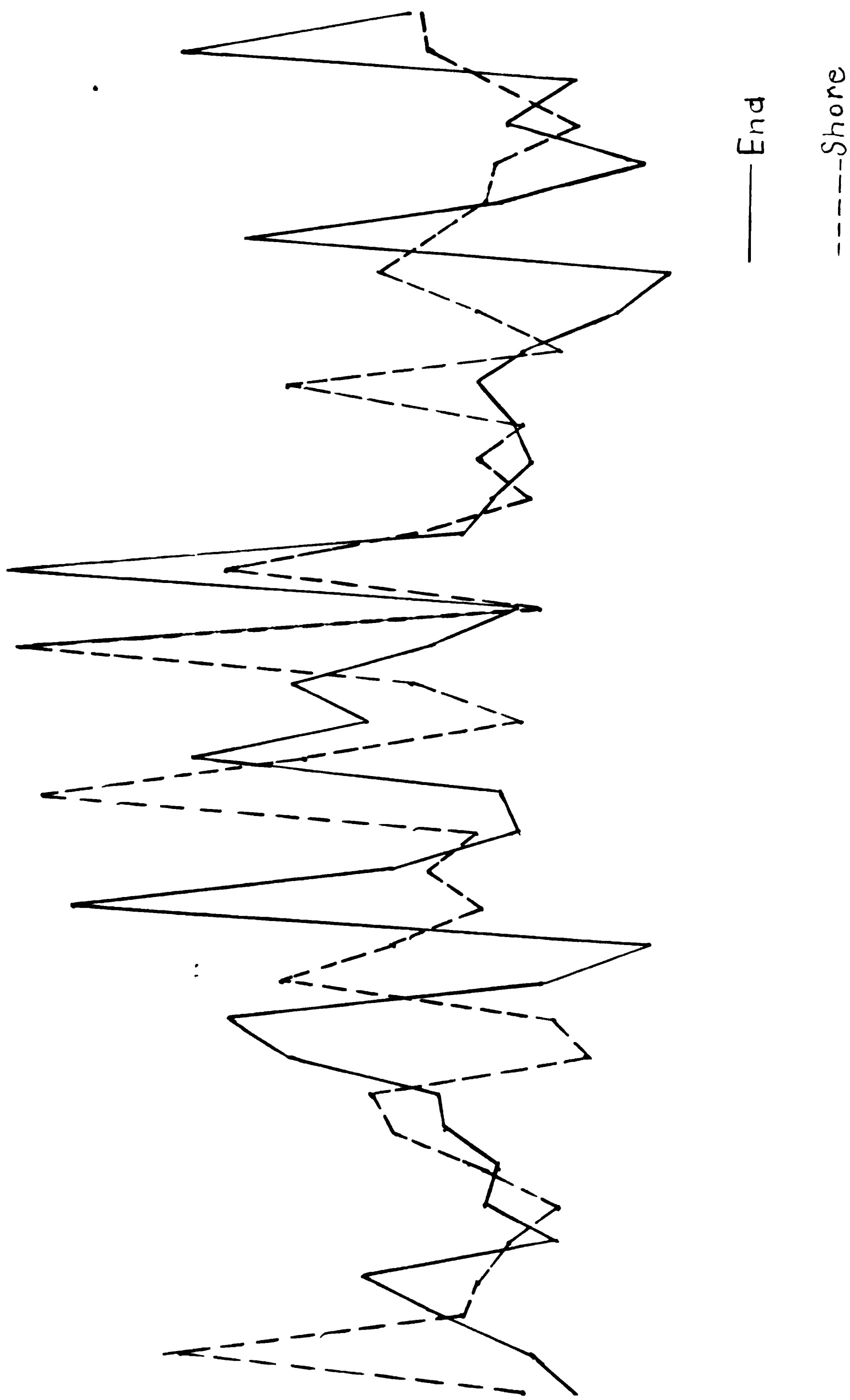
GRAPH 7

Comparison of Colon Indices at End of Dock and near Shore



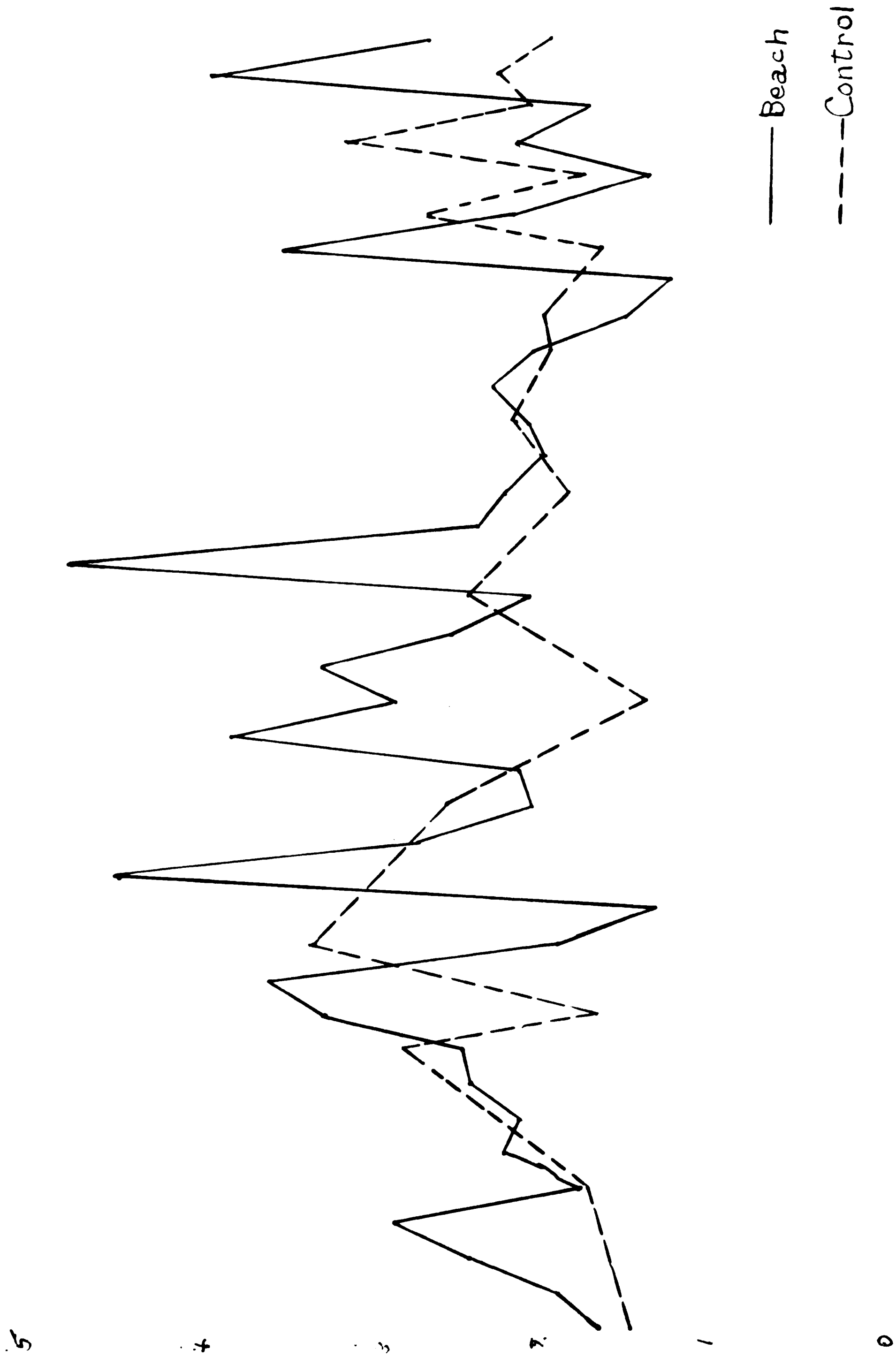
GRAPH 9

Comparison--Total Counts of End and Shore



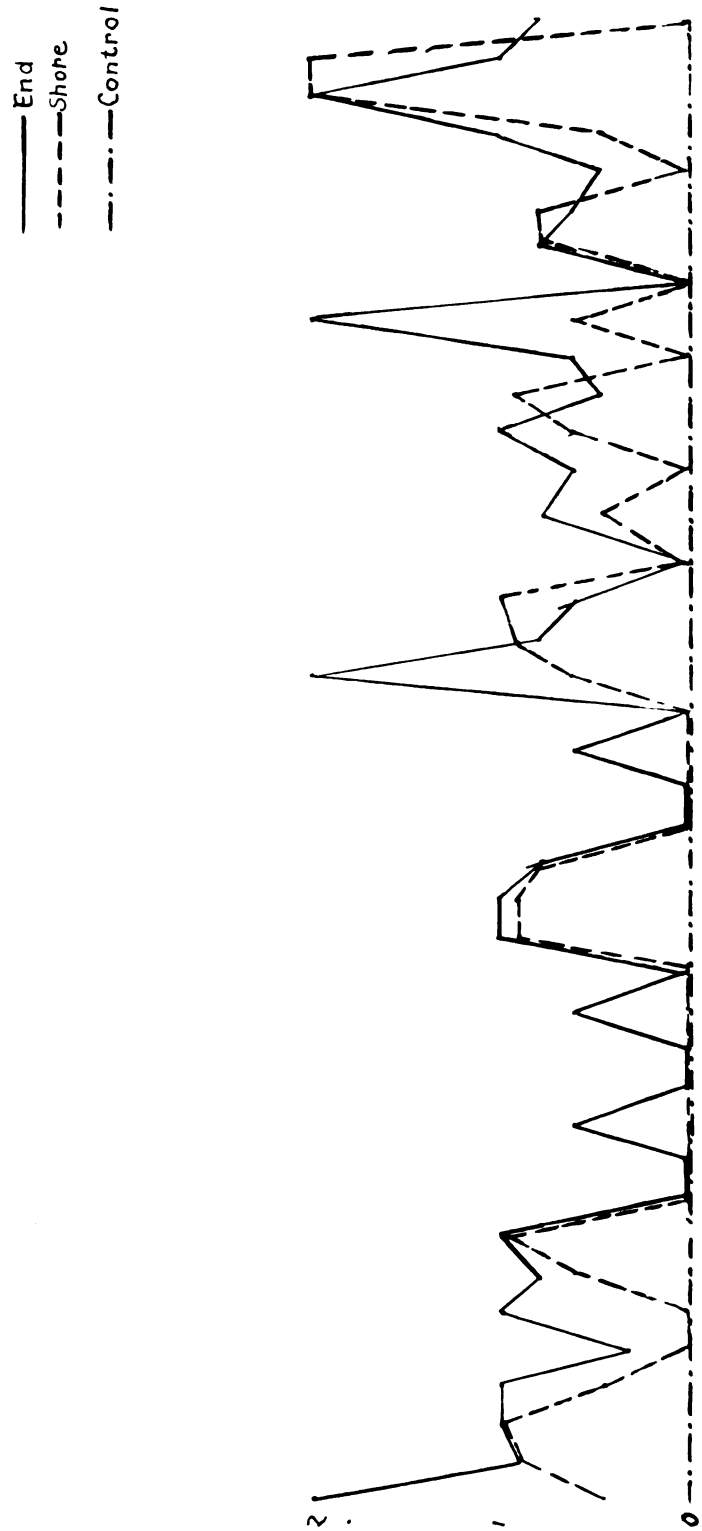
GRAPH 10

Comparison--Total Counts of Bathing Beach and Control



GRAPH 11

Comparison--Streptococcus Indices of End, Shore, and Control



CONCLUSIONS:

1. The total count and colon index did not parallel the bathing loads in a natural bathing place as closely as did the streptococcus index.
2. The most reliable measure of pollution was obtained in the area of the most dense bathing.
3. Places free from bathing pollution showed no streptococci.
4. The streptococci disappeared over night.
5. *Esch. coli* did not disappear from the lake during the warmer months.
6. Sand samples did not give information concerning pollution introduced by bathers.
7. Total counts and colon indices usually decreased over night, though occasionally increases were noted.
8. Total counts and colon indices did not differ materially from those obtained in areas free from pollution.
9. The streptococcus is recommended as an index of the pollution introduced by bathers into a natural bathing place.
10. Natural bathing areas should conform to swimming pool standards.

LITERATURE CITED

1. 1932 Report of Joint Committee on Swimming Pools and Bathing Places. American Public Health Association and Conference of State Sanitary Engineers.

2. Winslow, C.E.A. and Moxon, David.
Bacterial Pollution of Bathing Beach Waters in New Haven Harbor.
Am. Jour. Hyg.8:no.3,299,1928.

3. Prescott, S.C. and Winslow, C.E.A.
Elements of Water Bacteriology,
5th Edition, 1931.

4. Scott, W.J.
Survey of Connecticut's Shore Bathing Waters.
Am. Jour. Public Health 22:no.3,316,1932.

5. Michigan Stream Control Commission.
Coastline Pollution Surveys of Michigan,
June 1933.

6. Savage, W.G.
Bacteriology of Tidal Mud.
Jour. Hyg.5:143,1905.

7. Jordan, E.O.
The Bacterial Self Purification of Streams.
Jour. Exp. Med.5:271,1900.

8. Purdy, W.C.
Activities of Plankton in the Natural Purification of Polluted Waters.
Am. Jour. Public Health 18:468,1928.

9. Purdy, W.C. and Butterfield, C.T.
The Effect of Plankton Animals upon Bacterial Death Rates.
Am. Jour. Public Health 8,499,1918.

10. Savage, W.G. and Read,W.J.
Significance of Streptococci in Water Supplies.
Jour. Hyg.15:334,1916.

11. Irons, E.E.
Neutral red in Routine Examination of Water.
Jour. Hyg.2:314,1902.

12. Jordan, E.O.
Special Report of Mass. State Board of Health on Purification of Sewage and Water, 1890.

13. Winslow, C.E.A. and Hunnewell,M.P.
Streptococci Characteristic of Sewage and Sewage-polluted Waters, apparently not hitherto Reported in America.
Science,15:827,1902.

14. Houston, A.C.
Bacterioscopic Examination of Drinking Water, with Particular Reference to Relations of Streptococci and Staphylococci with Waters of this Class.
Report of the Medical Officer to Local Government Board for 1898-1899,page 467. London, England.

15. Houston,A.C.
On the Value of Examination of Water for Streptococci and Staphylococci with a view to detection of its Recent Contamination with Animal Organic Matter.
Report of Medical Officer of Local Government for 1899-1900,London,,England.

16. Horrocks, W.H.
Bacteriological Examination of Water.
London, 1901.

17. Savage,W.G. and Wood,D.R.
The Vitality and Viability of Streptococci in Water.
Jour. Hyg.16:No.3,227,1917.

18. Prescott, S.C. and Baker, S.K.
The Cultural Relations of Bacillus coli and Houston's Sewage Streptococci and a Method for the Detection of these Organisms in Polluted Waters.
Jour. Infect. Dis.1:193,1904.

19. Rivas,D.
B. coli communis, "The Presumptive Test," and the Sewage Streptococci in Drinking Water.
Jour. Med. Res.16:85,1907.

20. Rivas,D.
Preliminary Report of the Predominating Micro-organisms in Feces and Sewage, as an Index of Pollution in Drinking Water."

21. 26th Ann. Rep. on Results of Chemical and Bacteriological Examination of London Waters.
December, 1931.

22. Mallmann, W.L.
Streptococcus as an Indicator of Swimming Pool Pollution.
Am. Jour. Public Health 18:771,1928.

23. Mallmann, W.L. and Gelpi, A.G.
Chlorine Resistance of Colon Bacilli and Streptococci in a Swimming Pool.
Michigan. Eng. Exp. Sta. Bull. No. 27,1930.

24. Report of the Joint Committee on Bathing Places of the American Public Health Association and Conference of State Sanitary Engineers.
Am. Jour. Public Health 16:1186,1926.

25. Standards Methods of Water Analysis.
7th Edition, 1933.

26. Baker, W.P.
Application of Swimming Pool Sanitation to the Public Bathing Beach.
Jour. Am. Med. Assoc. 80:No.13,907,1923.