SANITARY SURVEY OF SHELLFISH GROWING AREA ON WEST FOWL RIVER ESTUARY, MOBILE, ALABAMA

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美國 Alabama州 West Fowl River 河口 貝類棲息場에 對한 衛生學的 調査

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市販되는 굴, 담치, 백합 등 貝類는 깨끗한 水域에서 生産되어야 한다는 것은 公衆保健上 매우 重要하다. 따라서 이들 棲息海域에 對한 衛生狀態를 評價하는 것은 貝類衛生管理에 있어 가장 基本的인 일이다.

本 調査는 美國 Alabama州 West Fowl River 地域에 있어 貝類衛生管理上 養殖場의 等級分類와 關聯한 굴 (*Crassostrea virginica*) 및 그 棲息水의 衛生學的 性狀을 알기 위하여 實施되었다. 이 硏究는 美國 國際開發處 (AID) 練修計劃에 의하여 이루워 졌음을 밝혀 둔다.

調査地域에 있어서의 汚染源은 家屋, 小業体, 家畜, 물새, 野生動物 등에 의한 一般的인 廢棄物과 排泄物로 되어 있고 특별한 下水나 工業排出物은 없었다. 이 調査는 이 地方에 있어 乾燥期인 10月에 實施되었으며 調査期間中의 總 降雨量은 0.08*mm*, 平均 氣溫은 21.3℃, 바람은 東風이 優勢하였다.

底質은 뻘로 되어 있고 低潮時 平均水深은 약 1*m*이며 調査期間中 平均 水溫은 26.0℃였다. 鹽分은 調査地点에 따라 相異하였으며 바다로 向한 江의 흐름에 따라 增加하고 平均 鹽分은 18.0～28.7‰의 範圍에 있었다.

海水 및 굴 兩者의 Coliform 含量은 Fecal coliform 보다 시종 높았으며 Coliform 및 Fecal coliform의 數는 바다로 向한 江의 흐름에 따라 점차 減少하였다. 이것은 海水의 汚染은 주로 地表水의 流入에 의한다는 것을 말하고 있다. 굴의 Coliform 및 Fecal coliform MPN은 海水의 그것보다 11～12배 높았다.

調査水域에 設定한 7개소 Sampling station 중 오직 Station 7만이 貝類養殖場 許可海域의 細菌學的 水質基準에 合當하였으며 굴의 Fecal coliform MPN은 市販用 貝類의 細菌學的 基準을 초과하고 있었다.

EC test 陽性試驗管에서 分離된 細菌의 97.6%가 *E. coli* group로 나타나 EC test는 *Echerichia coli* 試驗에 매우 效果的인 方法임을 알 수 있다.

INTRODUCTION

Oysters and other bivalve shellfish are the marine food which should be carefully controlled from the sanitary viewpoint because these animals are growing in estuaries or other bodies of water where there is a high possibility of contamination by domestic and industrial wastes. Also shellfish are

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often eaten raw or only partially cooked. There are many reports describing outbreaks of intestinal diseases caused by oysters harvested from polluted areas.

The United States was the first country to establish a sanitary control program for the shellfish industry to guard the public health and to protect the consumer. Since the program was started in 1925, there has been no documentation describing a case of disease caused by oysters harvested from growing waters which meet the criteria for the approved growing area. It is very clear that the growing areas from which market oysters are harvested should be clean not only for the protection of the consumer but also to assure the prosperity of the shellfish industries.

The present survey consisted of a sanitary reconnaissance, hydrographical observations and a bacteriological study on the West Fowl River area to study the sanitary survey procedures necessary for the classification of a shellfish growing area.

This study was carried out during the period of October 14 to October 24, 1968 under the support of the U. S. Public Health Service Gulf Coast Marine Health Sciences Laboratory in Dauphin Island, Alabama as a part of study in the sanitary control of shellfish in the United States of America sponsored by the Agency for International Development of the U. S. Department of States.

MATERIALS AND METHODS

Description of Area. The West Fowl River and West Fowl River Bay drainage area ot approximately 39km^2 is located in South Mobile County and empties into the Portersville Bay area of Mississippi Sound. West Fowl River is part of a stream system which empties into Mobile Bay at the northeast end and into Portersville Bay at the southwest end. The area to the east of the stream system is known as Mon Louis Island. The entire system is tidal and the water is brackish except during floods. West Fowl River and East Fowl River are divided by the tidal node in the area known locally as "The Narrows." East Fowl River then drains in a northeasterly direction until it flows into Fowl River which then empties into Mobile Bay.

There are no stream gaging stations in the area, therefore, no records are available on fresh water inflow. Also, no quantitative salinity data could be found to define the fluctuations in salinities, although local sources indicate that at times the entire area may contain only fresh water.

The climate of the area would be classed as humid, subtropical. At the official Mobile Weather Station, approximately 49km north of West Fowl River, the annual average temperature is 20.10℃ with a range of 11.7℃ in January to 29.4℃ in July. Average annual rainfall is 1,700mm. Normally the driest months are October and November with an average rainfall of approximately 76mm per month and the wettest months are July, August, and September, with a normal rainfall of 150—250 mm per month.

Tides along this portion of the Gulf Coast are diurnal. Mean tidal range is approximately 0.6m and maximum range is approximately 1m. Normally high tides occur during the early evening and night in the winter and during the day in the summer. This tidal pattern frequently makes it very difficult to sample at the time of the most unfavorable conditions.

Water depths at mean low tide in West Fowl River are 0.9—1.8m and in the bay water depths are 0.6—0.9m. At extreme low tide there may be only 0.3—0.5m of water in West Fowl River Bay.

Pollution Sources. Potential pollution sources in the West Fowl River drainage area can be classified as (1) domestic wastes from individual homes and small businesses, (2) domestic animals, (3)

waterfowl and wild animals. There are no sources of treated sewage or industrial waste within the drainage area.

Approximately 100 houses and 2 oyster shucking houses are located within the drainage area of the study. Ten to 20 of these houses are uninhabited or serve as second homes. Forty percent of the houses are located within 100*m* of West Fowl River or one of its tributaries. The remainder of the homes are located far enough from any waterways that their effect would probably be negligible even under the worst meteorological conditions. Shoreline inspections did not reveal any improperly functioning septic tanks. One direct line from a septic tank to the river was found but it was from an uninhabited house and no indications of recent use could be found. It should be emphasized that this survey was made during a period of record drought when almost any drain field would be adequate. Additional inspections should be made during the winter rainy season when septic tank systems would be most likely to malfunction. Survey by car found 30 head of cattle west of the Bellingrath Garden Road. The cattle were found in an area drained by an intermittent stream which had not carried water for several months. Light rains of the type experienced during the last month would not produce runoff from these areas which could reach a tributary to West Fowl River. However, in the winter this stream frequently carries water and runoff from these pastures which could reach West Fowl River. The only other domestic animals observed in the area were a normal population of dogs, cats, and chickens.

The drainage appears to have a normal population of wild animals and waterfowl. The wild animal population would be expected to include rabbit, squirrel, raccoon, opossum, muskrat, and the usual variety of wild birds. A few migratory ducks were seen but the normal winter population had not arrived.

On the basis of the pollution source survey the human and domestic animal populations should not be a significant source of fecal pollution during the survey period. Increased soil moisture and subsequent runoff could alter this conclusion and enable significant amounts of fecal pollution to reach the river. The only significant source of fecal pollution during the study period appeared to be wild animals and waterfowl.

Field and Laboratory Methods

Establishment of Sampling Stations. In consideration of the distances involved and the time required for sample collection and examination, seven carefully selected sampling stations were established as shown in Fig. 1. The locations of the sampling stations on the map were located by use of a sextant.

Hydrographical Measurements. The salinity of the water was determined by either an inductive-type salinometer or the chemical titration method. Current velocity was measured by the drogue technique. Water temperature was determined by an inductive recorder. Wind velocity was measured by a hand anemometer and the direction of the wind and water currents was determined by a hand compass. The turbidity of the water was measured by the Spectronic 20 Spectrophotometer and the readings were recorded in Jackson turbidity units.

Sampling Method. Bottom water samples were collected at each sampling station. It was possible to collect oyster samples only at Stations 2 and 3 because of the sparse distribution of oysters in the study area. The water samples were collected by the bottom water sampling device being used by the Gulf Coast Marine Health Sciences Laboratory and the oyster samples were collected by dredging. The sampling procedures applied adhered to the method described in APHA Recommended Procedures

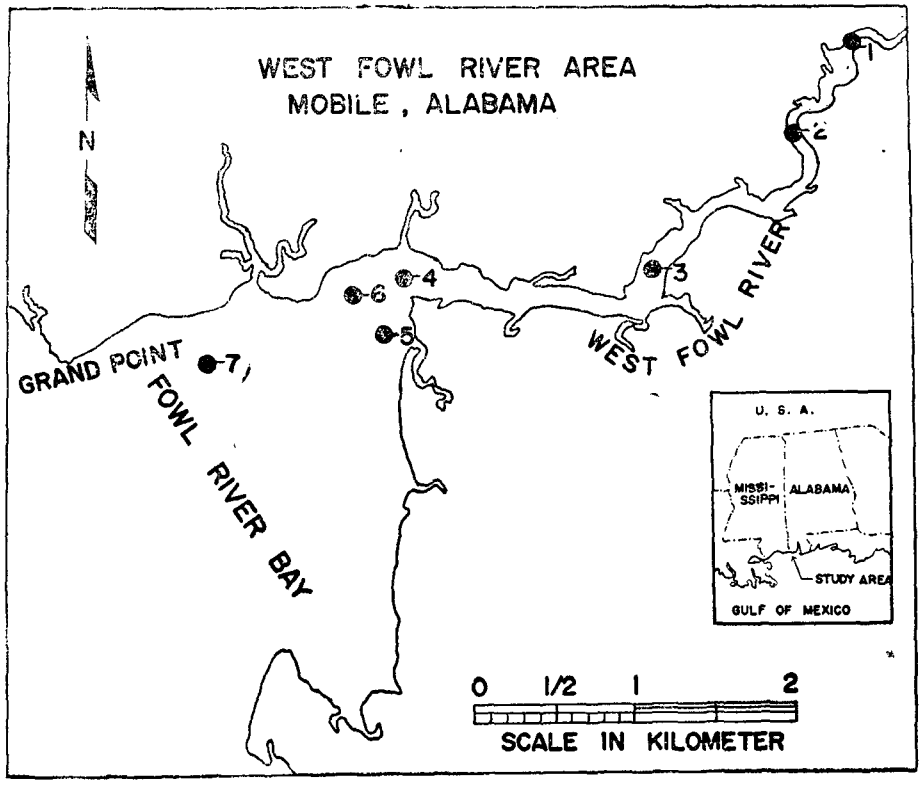

Fig. 1. Location of sampling stations.

for the Bacteriological Examination of Sea Water and Shellfish [1]. The sampling tours were conducted twice a day, in the morning and afternoon, spaced approximately 3 to 4 hours apart.

Bacteriological Examination. All water and oyster samples were submitted to bacteriological examinations to determine coliform and fecal coliform densities. In addition, oyster samples were submitted to the 35°C plate count method. Coliform cultures from all EC gas tubes were purified by streaking on eosin methylene blue (EMB) agar and classified by the indol, methyl red, Voges-Proskauer, citrate (IMViC) tests. All bacteriological tests were conducted according to APHA Recommended Procedures for the Bacteriological Examination of Sea Water and Shellfish [1].

RESULTS AND DISCUSSION

All bacteriological, hydrographical, and sanitary survey data are presented in the appendix. According to the survey, the oyster resources in this study area were insufficient for commercial operation. The oysters were only sparsely distributed, probably due to the prevalence of muddy bottom areas. At present oyster growing is centered around the middle section of the river (Stations 2 to 3).

Air temperature and rainfall data collected during the period of the survey are summarized in Table 1. The rainfall during the survey period was 0.08*mm*. This represents the rainfall of only one rainy day (October 16). The rainfall of this month was very low being only one-third that of the average normal rainfall for the season in this region. The total rainfall of 28.7*mm* recorded for October 1968

was much lower than the average normal rainfall of 76.2*mm* of precipitation expected in the month of October in this region.

Table 1. Air temperature and rainfall in Mobile, Alabama during October 1968

Survey period (15—23 Oct.)				October 1968			
Temp. ℃		Rainfall		Temp. ℃		Rainfall	
Range	Average	Rainfall *mm*	Day	Range	Average	Rainfall *mm*	Day
17.8—26	21.3	0.08	1	12.2—27.2	21.2	28.7	9

Table 2. Temperature, salinity and turbidity of water in West Fowl River Area

Station	Temperature ℃				Salinity‰		Turbidity * JTU	
	Surface		Bottom					
	Range	Average	Range	Average	Range	Average	Range	Average
1	21.0—28.1	25.7	20.6—27.9	25.8	12.2—21.8	18.0	36—80	53
2	21.0—28.0	26.0	20.7—28.0	26.0	10.1—22.7	17.2	30—77	50
3	21.0—28.3	26.1	20.8—28.1	26.2	15.7—27.1	21.8	42—150	70
4	20.2—28.2	25.7	20.0—28.0	25.7	19.0—28.0	23.3	36—84	60
5	20.2—28.1	25.7	20.2—28.3	25.7	22.3—28.0	25.5	42—101	62
6	20.0—28.2	25.7	20.2—27.7	25.6	20.1—30.1	26.1	39—84	54
7	19.0—28.0	25.3	19.0—27.7	25.2	23.6—31.0	28.7	22—84	44

* Turbidity of bottom water samples.

Table 2 summarizes the water temperature, salinity, and turbidity data collected during the survey. There was no marked variation in water temperature among the stations and between surface and bottom, but water temperature had a tendency to decrease toward the bay side from the river. The water temperature, both surface and bottom, of the area during the study period ranged from 19.0℃ to 28.3℃ and averaged approximately 26℃. The salinity gradually increased toward the bay side. The average salinity through all stations ranged from 18.0 to 28.7‰. The difference of salinity between the uppermost (Station 1) and the lowest water (Station 7) was approximately 11‰ in average value. The range of average turbidity through all stations was from 44 to 70 JTU. Station 3 showed the highest value of 70 JTU.

Direction and velocity of the wind was measured at Station 7. The prevailing wind was easterly at a velocity ranging from 8.5 to 34.7*km/h*.

The direction and velocity of the current was measured at Station 4 at approximately dead low tide. At the date and time of measurement (October 22, 12:56 p.m) the tidal amplitude was 0.6*m*, current direction was 328°W and current velocity was 0.6*km/h*.

For the purpose of summarization of bacteriological results, the bacteriological data obtained from the sampling stations were plotted on the logarithmic probability paper according to the method described by Velz [2]. All of the data showed a normal pattern of distribution. As examples, probability plots of coliform and fecal coliform MPN's in water and oyster samples from Station 2 are

shown in Fig. 2, 3, 4 and 5. Fig. 2. and 3. compare, respectively, the coliform and fecal coliform MPN's derived from water and oyster samples. Fig. 4. compares the coliform MPN's derived from water and oyster samples and Fig. 5. compares the fecal coliform MPN's derived from water and oyster samples.

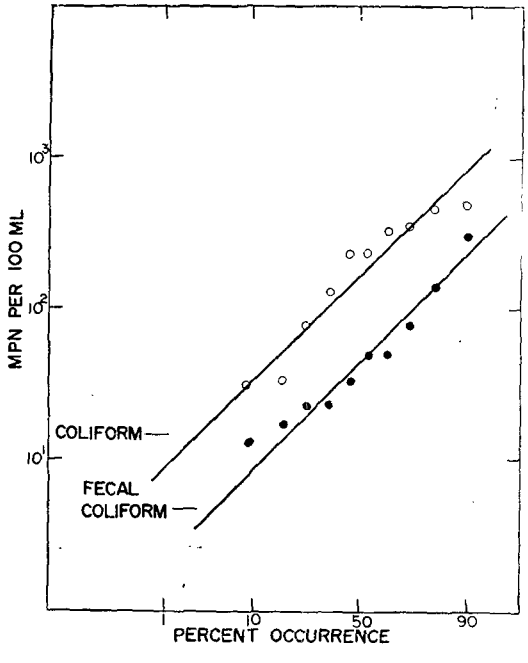

Fig. 2. Coliform and fecal coliform MPN's of water from station 2.

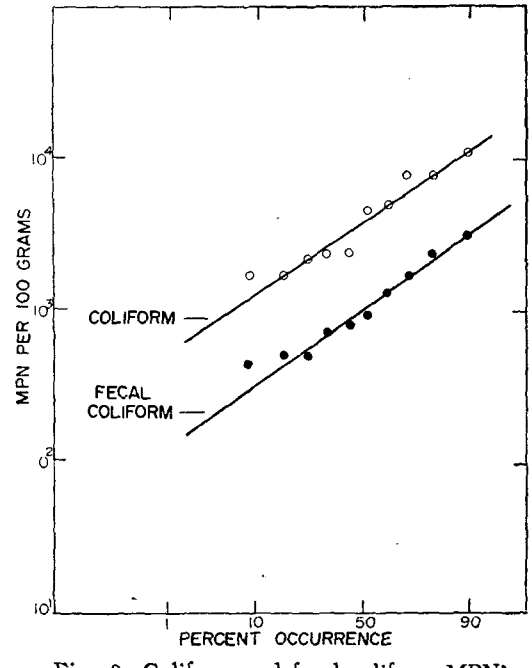

Fig. 3. Coliform and fecal coliform MPN's of oyster fom station 2.

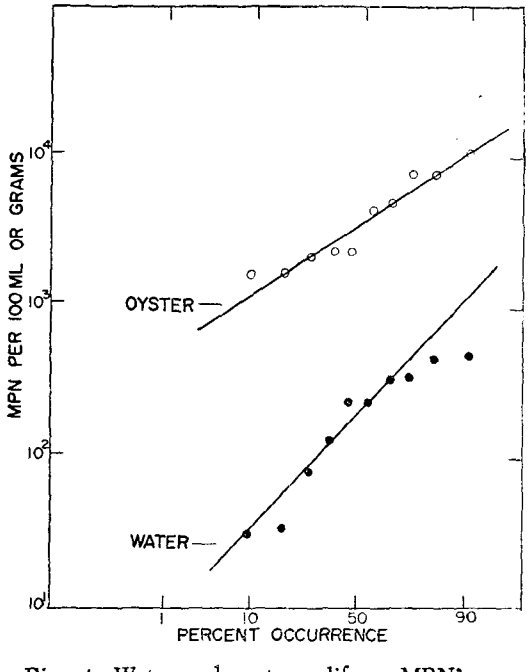

Fig. 4. Water and oyster coliform MPN's from station 2.

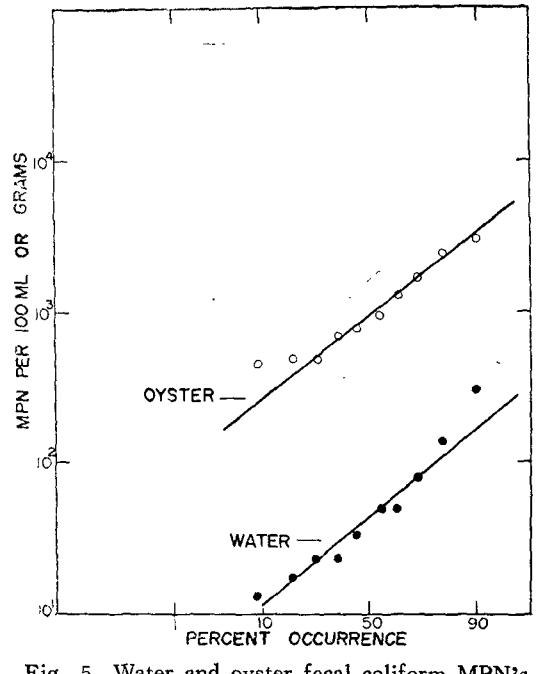

Fig. 5. Water and oyster fecal coliform MPN's from station 2.

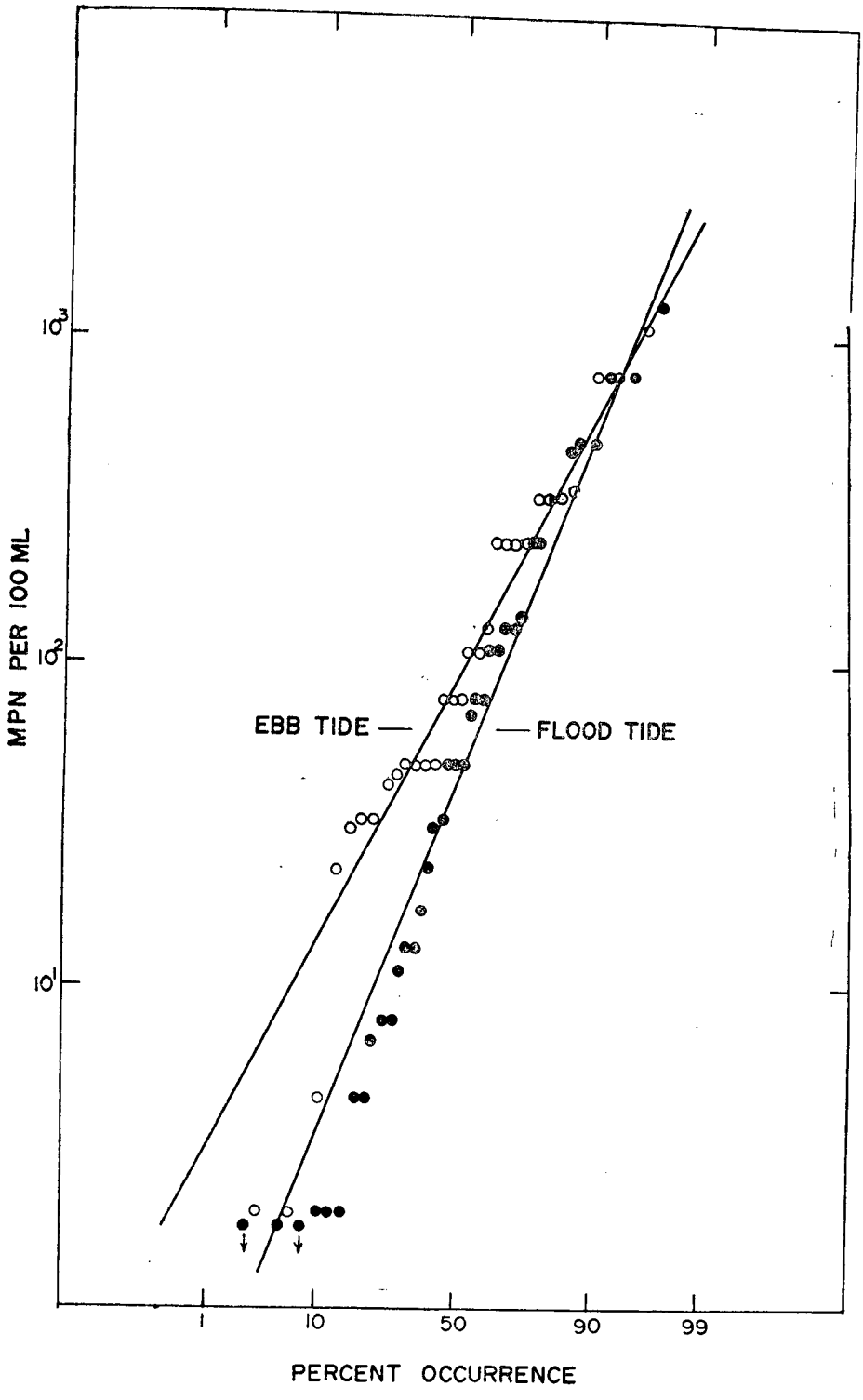

Fig. 6. Water coliform MPN's during flood and ebb tide,

Bacteriological results from all water and oyster samples collected from all stations are summarized in Tables 3 and 4, respectively. As shown in Table 3, water coliform MPN's were consistently higher than the fecal coliform MPN's derived from water samples.

Table 3. Coliform and fecal coliform MPN's of water at 10, 50 and 90 percentile at the stations 1 through 7

Station	Coliform *			Fecal coliform *			Number of samples
	10	50	90	10	50	90	
1	50	190	720	7.2	53	390	9
2	34	170	880	8.2	44	230	10
3	19	130	980	4.4	33	250	10
4	5.5	48	420	2.3	25	260	10
5	1.8	33	600	0.9	13	190	10
6	2.3	42	760	0.9	20	450	10
7	1.4	3.7	10	1.2	1.9	2.2	10

* Derived from plots on log probability paper.

Table 4. Bacteriological level of oyster at 10, 50 and 90 percentile at the stations 2 and 3.

Station	Coilform MPN *			Fecal coliform MPN *			Plate count at 35℃ *			Number of samples
	10	50	90	10	50	90	10	50	90	
2	1,300	3,700	11,000	310	1,000	3,200	2,800	3,600	4,600	10
3	180	1,300	8,800	26	380	5,200	2,800	3,200	3,600	10

* Derived from plots on log probability paper.

Table 5. Water coliform MPN during flood and ebb tide in West Fowl River area

Tide	Coliform MPN					Number of samples
	Range	Median	Percentile *			
			10	50	90	
Flood	∠1.8—1,300	49	3.7	43	500	39
Ebb	2.0—1,100	79	15	92	570	30
Ratio **		1.6	4.1	2.1	1.1	

* Derived from plots on log probability paper.
** Ebb tide/flood tide colifom ratio.

The average water coliform MPN's at the 50 percentile were 2.8 times greater than the fecal coliform MPN's at this level. Coliform and fecal coliform densities varied from station to station, and the density decreased gradually to the bay side. The coliform and fecal coliform densities showed a negative correlation with the salinity of the water as indicated by a decrease in the density of indicator microorganisms in accordance with an increase in salinity. This observation agrees with previously published data collected on the Gulf Coast [3]. Between Stations 5 and 6, the higher bacterial content of the water at Station 6 probably resulted from Station 6 being influenced more by the fresh water stream than Station 5. The difference in bacterial density of the waters at Stations 5 and 6 can be explained hydrographically. The current direction measured at Station 4 was

westerly and the wind was primarily from the east during this survey period, therefore, the flow of the West Fowl River toward Station 6 would be accelerated. From the standpoint of geometric mean coliform MPN's values, the area could be classified generally in to two areas with the division line located near the mouth of the river at Station 4. Waters on the river side had geometric mean coliform MPN's in excess of 70/100*ml* and waters from the bay side had geometric coliform MPN's of less than 70/100*ml*. From Table 4 it can be seen that the coliform MPN's were consistently higher than the fecal coliform MPN's derived from oysters. The average oyster coliform MPN's at the 50 percentile level were 3.6 times greater than the fecal coliform MPN's at this level. To evaluate the correlation between tide and the bacteriological quality of the water, the coliform MPN's of the waters at both flood and ebb tide were plotted on logarithmic probability paper Fig. 6. The median coliform MPN's and the coliform MPN's at the three percentiles (10, 50, and 90) are summarized in Table 5. The coliform density of samples collected at ebb tide was higher than that of samples collected at flood tide. The coliform MPN of ebb tide samples at the 50 percentile level was 2.1 times greater than that of flood tide samples. To completely evaluate the relationship between indicator microorganisms and water temperature and turbidity would require an expanded survey period and the collection of many more samples.

A comparison of coliform and fecal coliform densities of oysters and the overlying waters is presented in Table 6. The values presented in the table were derived from probability plots. The bacteriological contamination of oysters was much higher than that of water, and the oyster/water ratios varied according to location.

Table 6. Comparison of coliform and Fecal coliForm MPN of water and oyster at 10, 50 and 90 percentile

Station	Description	Percentile						Number of samples
		Coliform MPN			Fecal coliform MPN			
		10	50	90	10	50	90	
2	Water	34	170	880	8.2	44	230	10
	Oyster	1,300	3,700	11,000	310	1,000	3,200	10
	Ratio	38.2	21.8	12.5	37.8	22.7	13.9	
3	Water	19	130	980	4.4	33	250	10
	Oyster	180	1,300	8,800	26	380	5,200	10
	Ratio *	9.5	10.0	8.9	5.8	11.5	20.8	

* Oyster/water coliform and fecal coliform MPN ratio.

At Stations 2 and 3, the geometric mean values of both coliform and fecal coliform MPN's of oysters were 22 and 11 times greater, respectively, than those of the overlying water. Results of the present study show that the extent of bacterial accumulation by oysters at Station 2 was twice as great as the extent of accumulation by oysters at Station 3. Because the feeding action of oysters is affected by turbidity of the surrounding water [4], the oysters growing at Station 2 in low turbidity water might have accumulated bacteria to a greater extent than the oysters growing at Station 3 where water turbidities were higher (Table 2).

A bacteriological summary of the West Fowl River area data based on the classification of shellfish growing waters is presented in Table 7. In the United States, shellfish growing areas are classified into four classes on the basis of sanitary survey information: Approved, Conditionally Approved, Restricted and Prohibited. The National Shellfish Sanitation Program Manual of Operation[5] provides

that the approved area shall not be reached by dangerous concentrations of pathogenic microorganisms, radionuclides, and/or harmful industrial wastes.

Table 7. Summary of bacteriological results of water from the West Fowl River study area

Station	Period	MPN per 100*ml*								Number of samples
		Coliform				Fecal coliform				
				%				%		
		Range	Median	>230	>700	Range	Median	>23	>230	
1	10/15—10/23/68	49 —1,300	130	44	22	7.8—790	33	88	22	9
2	〃	31 — 490	240	60	0	13 —310	41	80	10	10
3	〃	17 — 790	110	40	20	2.0—220	41	70	0	10
4	〃	4.5— 240	79	10	0	2.0—240	23	70	10	10
5	〃	<1.8—1,100	46	20	10	<1.8—280	13	20	20	10
6	〃	2.0— 490	33	30	0	<1.8—490	14	50	20	10
7	〃	<1.8— 790	3.3	10	10	<1.8—790	<1.9	10	10	10

According to the regulation of the operation manual, the median coliform MPN of an approved area must not exceed 70 per 100*ml* and not more than 10 percent of the samples shall ordinarily exceed an MPN of 230 per 100*ml* for a 5-tube decimal dilution test. Among the seven sampling stations established in the West Fowl River area, only waters from Stations 5, 6, and 7 had median coliform MPN's of less than 70/100*ml*. However, more than 10 percent (20 and 30%) of the samples from Stations 5 and 6 had median coliform MPN's in excess of 230 per 100*ml*. In the West Fowl River area, only Station 7 could have been approved for the harvesting of market oysters according to the bacteriological results of this survey. Under normal conditions of rainfall there is the possibility that the pollution would be expanded to such an extent that not even Station 7 could be approved. This could be determined by extending the survey to include periods of increased runoff.

Table 8. Summary of bacteriological results of oysters from the West Fowl River study area

Station	Period	MPN per 100g meats								Plate count/g at 35℃			Number of samples
		Coliform				Fecal coliform							
				%				%				%	
		Range	Median	>2,300	>16,000	Range	Median	>230	>2,300	Range	Median	>500,000	
2	10/15—10/23/68	1,700—11,000	3,500	70	0	460—3,100	870	100	20	<3,000—4,600	3,600	0	10
3	〃	170—13,000	1,100	40	0	23—4,900	520	60	20	<3,000—4,200	<3,000	0	10

A bacteriological summary of oyster results from West Fowl River based on wholesale market standards is presented in Table 8. The National Shellfish Sanitation Program Manual of Operations[5] lists the following bacteriological criteria for fresh and frozen oysters at the wholesale market level: (1) Satisfactory-fecal coliform density of not more than 230 MPN per 100g and 35℃ plate count of not more than 500,000 per g. (2) Conditional-fecal coliform density of more than 230 MPN per 100g and/or 35℃ plate count of more than 500,000 per g.

Table 9. Coliform types from EC gas positive tubes

No. of EC gas positive tubes	Tube positive for *E. coli* group		No. of cultures	*E. coli* group		Aerogenes group		Freundii group		Miscellaneous	
	No.	%		No.	%	No.	%	No.	%	No.	%
83	81	97.6	146	134	91.78	6	4.11	0	0	6	4.11

Table 10. Composition of the variety of the coliform group from EC gas positive tubes

Group	No. of cultures	Variety Ⅰ		Variety Ⅱ		Variety Ⅲ		Variety Ⅳ	
		No.	%	No.	%	No.	%	No.	%
E. coli	134	130	97.01	1	0.75	1	0.75	2	1.5
Aerogenes	6	4	66.67	0	0	0	0	2	33.33
Freundi	0		0	0					

Table 11. Comparison of IMViC reactions and type of colony on EMB agar plate

Type of colony	No. of colonies	*E. coil* group									
		No.	%	Variety Ⅰ		Variety Ⅱ		Variety Ⅲ		Variety Ⅳ	
				No.	%	No.	%	No.	%	No.	%
Sheen	69	69	100	68	98.6	0	0	0	0	1	1.5
Wine	61	61	100	58	95.1	1	1.6	1	1.6	1	1.6
Mucoid	12	0	0								
Pink	4	4	100	4	100	0	0	0	0	0	0
		134	100	130	97.0	1	0.7	1	0.7	2	1.5

Type of colony	No. of colonies	Aerogenes group				Miscellaneous	
		No.	%	Variety Ⅰ		Variety Ⅳ			
				No.	%	No.	%	No.	%
Sheen	69								
Wine	61								
Mucoid	12	6	50	4	66.7	2	33.3	6	50
Pink	4								
		6	50	4	66.7	2	33.3	6	50

On the basis of fecal coliform MPN's none of the oysters from Station 2 and only 40 percent of the oysters from Station 3 would have been acceptable at the wholesale market level. The 35℃ plate counts of the oyster samples were relatively low and did not exceed a determinative count of 4,600 organisms/g.

Some Findings on Coliform Classification. The classification of the coliform group isolated from the liquid confirmatory EC gas positive tubes is summarized in Tables 9, 10, and 11.

Eighty-one (97.6%) of the EC gas positive tubes contained organisms belonging to the *E. coli* group (Table 9). A total of 146 cultures were isolated from 83 EC gas positive tubes. Of these, 91.8% belonged to the *E. coli* group (Table 9). Ninety-seven percent of the cultures constituting the *E. coli* group were *E. coli* type 1 (Table 10).

From Table 11 it can be seen that all colonies producing sheen or a wine or pink color in EMB agar belonged to the *E. coli* group. Of these 97% were *E. coli* type 1. Six (50%) of the mucoid colonies in EMB belonged to the *Aerobacter aerogenes* group. Of these 66.7% were *A. aerogenes* variety I and 33.3% were *A. aerogenes* variety IV. The remaining six mucoid colonies were classed as miscellaneous IMViC types.

SUMMARY AND CONCLUSION

A sanitary and bacteriological survey on the West Fowl River area of South Mobile County in the State of Alabama, U. S. A. to determine the sanitary quality of shellfish and shellfish growing waters in association with classification of shellfish growing area conducted.

The drainage area of West Fowl River and Portersville Bay is approximately 39 square kilometers. The pollution sources of this area are generally composed of domestic wastes from individual homes, small businesses, domestic animals, waterfowl, and wild animals. The area is without significant sewage or industrial waste disposal. The study was conducted in October which is a dry season in this part of the country. The meteorological data collected during the survey were as follows: Total rainfall 0.08*mm*, average air temperature 21.3℃, prevailing winds easterly.

The bottom of the estuary is muddy and the average water depth is about 1*m* at low tide. The average water temperature during the survey was 26℃. The salinity differed from sampling station to station increasing as sampling proceeded downstream and into the bay. Average salinity ranged from 18.0‰ at Station 1 to 28.7‰ at Station 7.

The coliform content of both water and oysters (*Crassostrea virginica*) was consistently higher than the fecal coliform content. The density of coliform and fecal coliform microorganisms decreased gradually as sampling proceeded downstream and into the bay. This indicates that the pollution of water is mainly influenced by surface runoff.

The coliform and fecal coliform MPN's of oysters were 11 to 12 times greater than the coliform and fecal coliform MPN's of the overlying waters.

Among the 7 sampling stations established in this study area, only the water at Station 7 complied with bacteriological criteria for approved shellfish growing waters. The fecal coliform MPN's of the oysters from the survey area exceeded the criteria for oysters at the wholesale market level.

The EC test was highly specific for *Escherichia coli* with 97.6% of the organisms isolated from EC gas positive tubes being classed as belonging to the *E. coli* group.

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APPENDIX

Table 1. Hydrographical survey on West Fowl River area (1968. 10. 14—10. 23)

Station	Date	Time	Water				Wind		Reading of staff gauge
			Temp. ℃		Current		Direction	Velocity	
			Surface	Bottom	Direction	Velocity km/hr.		km/hr.	m/hr.
1	10/14/68	14 : 10	28.1	27.9					
	10/15/68	11 : 08	26.6	26.5					
	10/16/68	10 : 40	26.8	26.9					
		15 : 00	27.2	27.2					
	10/24/68	11 : 00	21.0	20.6					
2	10/14/68	14 : 20	28.1	28.0					
	10/15/68	10 : 55	26.9	26.9					
	10/16/68	10 : 25	26.8	26.9					
		14 : 48	27.3	27.3					
	10/24/68	10 : 55	21.0	20.7					
3	10/14/68	14 : 30	28.3	28.1					
	10/15/68	10 : 40	26.5	26.5					
		14 : 15	27.3	27.3					
	10/16/68	10 : 15	26.4	26.4					
		14 : 08	27.4	27.3					
	10/24/68	10 : 45	21.0	20.8					
4	10/14/68	14 : 35	28.2	28.0					0.49
	10/15/68	10 : 12	26.1	26.1					0.52
		13 : 50	27.2	27.4					0.43
	10/16/68	10 : 08	25.6	25.7					0.85
		14 : 00	26.9	26.9					0.58
	10/24/68	10 : 25	20.2	20.0					0·18
	10/21/68	10 : 20							0.40
	10/22/68	12 : 56			328°W	0.6			0.43
	10/23/68	10 : 30							0.37
5	10/14/68	14 : 40	28.1	27.7					
	10/15/68	10 : 05	25.8	25.8					
		13 : 40	27.8	28.3					
	10/16/68	10 : 00	25.6	25.4					
		13 : 59	26.8	26.7					
	10/24/68	10 : 08	20.2	20.2					
	10/22/68	12 : 40			208°W	0.36			
6	10/14/68	14 : 45	28.2	27.6					
	10/15/68	09 : 54	25.8	25.8					
		13 : 45	27.5	27.7					
	10/16/68	09 : 50	25.7	25.6					
		13 : 55	26.8	26.8					
	10/24/68	10 : 18	20.0	20.0					
	10/22/68	12 : 00			275°W	0.183			
7	10/14/68	14 : 50	28.0	27.7	245°W	0.549	80° E	13.7	
	10/15/68	09 : 43	25.2	25.2			70° E	26.3	
		13 : 30	27.4	27.2			60° E	34.8	
	10/16/68	09 : 45	25.5	25.5			76° E	23.8	
		13 : 48	26.6	26.5			87° E	22.7	
		11 : 30					55° E	19.1	
	10/21/68	12 : 15			250°W	0.183			
	10/24/68	09 : 46	19.0	19.0			0° N	16.5	

Table 2. Outfalls or potential pollution sources in West Fowl River Bay, October 1968

No.	Type	Flow	Significance	Location
1	4″ steel pipe	0	used to be sewer drain	under and near West Fowl River Bridge
2	4″ steel pipe	0	soil drain	upward sounds
3	4″ steel pipe	0	soil drain	upward sounds
4	4″ steel pipe	0	swimming pool drain	private pool
5	4″ steel pipe	0	sink drain	private house
6	12″ concrete pipe	0	street drain	near the church
7	4″ steel pipe	0	sink, drain	two-story house
8	18″ concrete pipe	0	storm drain	
9	83 houses	0	septic tank	
10	7 trailers	0	septic tank	West Fowl River Bay boundary
11	animal pen	—	27 cattle	West Fowl River Bay boundary
12	swamp area	—		east of West Fowl River Bay
13	tonging boat	—	2 boats	at Stations 3 and 2
14	sport fishing boat	—	4 boats	around West Fowl River

Table 3A. Bacteriological examination of water samples from the West Fowl River area, Mobile, Alabama

Station 1.

Date	Time	Tide	Extreme tide		Turbidity	Salinity	MPN per 100*ml.*	
			High	Low	JTU	‰	Coliform	EC pos.
10/15/68	11 : 10	H+6 : 16	1.5	0.1	36	12.2	330	33
10/16/68	10 : 40	H+4 : 52	1.4	0.2	47	15.2	130	33
〃	15 : 00	L−3 : 54			56	20.1	240	79
10/21/68	11 : 00	L+2 : 42	1.5	0.1	42	21.7	79	13
〃	14 : 10	L+5 : 52			80	19.9	49	7.8
10/22/68	10 : 45	L+2 : 21	1.8	−0.1	39	17.8	110	23
〃	13 : 55	L+4 : 37			65	21.8	130	130
10/23/68	11 : 12	L+0 : 48	—	−0.3	56	15.4	1300	790
〃	14 : 27	L+4 : 03			56	17.8	790	330

Table 3B. Bacteriological examination of water samples from the West Fowl River area, Mobile, Alabama

Station 2.

Date	Time	Tide	Extreme tide		Turbidity	Salinity	MPN per 100*ml.*	
			High	Low	JTU	‰	Coliform	EC pos.
10/15/68	11 : 00	H+6 : 06	1.5	0.1	51	12.7	240	23
〃	14 : 20	L−3 : 58			61	13.0	350	33
10/16/68	10 : 25	H+4 : 37	1.4	0.2	54	17.2	240	79
〃	14 : 48	L−4 : 06			54	10.1	330	49
10/21/68	10 : 47	L+2 : 29	1.5	0.1	42	19.9	79	13
〃	14 : 00	L+5 : 42			44	21.9	31	23
10/22/68	10 : 35	L+1 : 17	1.8	−0.1	30	19.6	130	49
〃	13 : 45	L+4 : 27			36	22.7	33	17
10/23/68	11 : 05	L+0 : 41	—	−0.3	77	16.7	490	140
〃	14 : 15	L+3 : 51			54	18.3	460	310

Table 3C. Bacteriological examination of water samples from the West Fowl River area, Mobile, Alabama

Station 3.

Date	Time	Tide	Extreme tide		Turbidity	Salinity	MPN per 100*ml*	
			High	Low	JTU	‰	Coliform	EC Pos.
10/15/68	10 : 40	H+5 : 46	1.5	0.1	150	15.7	46	7.8
〃	14 : 15	L−4 : 03			64	16.1	330	33
10/16/68	10 : 15	H+4 : 27	1.4	0.2	42	26.2	79	23
〃	14 : 08	L−4 : 46			54	18.1	790	49
10/21/68	10 : 30	L+2 : 12	1.5	0.1	61	25.3	49	2.0
〃	14 : 40	L+6 : 22			49	24.8	17	11
10/22/68	10 : 18	L+1 : 00	1.8	−0.1	42	23.4	140	49
〃	13 : 40	L+4 : 22			101	27.1	49	49
10/23/68	10 : 45	L+0 : 21	—	−0.3	84	20.1	330	170
〃	14 : 05	L+3 : 41			54	21.2	790	220

Table 3D. Bacteriological examination of water samples from the West Fowl River area, Mobile, Alabama

Station 4.

Date	Time	Tide	Extreme Tide		Turbidity	Salinity	MPN per 100*ml*	
			High	Low	JTU	‰	Coliform	EC Pos.
10/15/68	10 : 15	H+5 : 21	1.5	0.1	54	20.9	110	23
〃	13 : 50	L−4 : 28			59	19.6	79	22
10/16/68	10 : 08	H+4 : 20	1.4	0.2	36	28.0	79	23
〃	14 : 00	L−4 : 54			54	20.1	110	110
10/21/68	10 : 20	L+2 : 02	1.5	0.1	84	21.7	6.8	2.0
〃	13 : 34	L+5 : 16			68	24.8	4.5	2.0
10/22/68	10 : 10	L+0 : 52	1.8	−0.1	49	28.0	70	49
〃	13 : 30	L+4 : 12			56	19.0	23	23
10/23/68	10 : 30	L+0 : 06	—	−0.3	84	24.8	240	240
〃	14 : 00	L+3 : 36			56	25.6	110	79

Table 3E. Bacteriological examination of water samples from the West Fowl River, Mobile, Alabama

Station 5.

Date	Time	Tide	Extreme tide		Turbidity	Salinity	MPN per 100 *ml*	
			High	Low	JTU	‰	Coliform	EC Pos.
10/15/68	09 : 55	H+5 : 01	1.5	0.1	88	22.3	49	14
〃	13 : 45	L−4 : 33			49	25.3	49	17
10/16/68	10 : 00	H+4 : 12	1.4	0.2	51	25.3	43	17
〃	13 : 59	L−4 : 55			101	25.3	49	11
10/21/68	10 : 17	L+1 : 59	1.5	0.1	61	25.3	11	2.0
〃	13 : 27	L+5 : 09			54	24.8	<1.8	<1.8
10/22/68	10 : 05	L+0 : 47	1.8	−0.1	42	28.0	13	7.8
〃	13 : 20	L+4 : 02			—	—	2.0	2.0
10/23/68	10 : 18	L−0 : 06	—	−0.3	49	26.4	1,100	280
〃	13 : 50	L+3 : 26			64	26.4	240	240

Table 3F, Bacteriological examination of water samples from the West Fowl area, Mobile, Alabama

Station 6.

Date	Time	Tide	Extreme tide		Turbidity	Salinity	MPN per 100*ml*	
			High	Low	JTU	‰	Coliform	EC Pos.
10/15/68	10 : 05	H+5 : 11	1.5	0.1	84	21.8	33	4.5
〃	13 : 40	L—4 : 38			42	22.2	23	23
10/16/68	09 : 50	H+4 : 06	1.4	0.2	39	28.0	33	4.5
〃	13 : 55	L—4 : 59			59	20.1	49	49
10/21/68	10 : 10	L+1 : 52	1.5	0.1	44	25.3	13	4.5
〃	13 : 24	L+5 : 06			44	24.8	2.0	<1.8
10/22/68	10 : 00	L+0 : 42	1.8	—0.1	75	29.7	330	170
〃	13 : 25	L+4 : 07			42	31.8	7.8	<1.8
10/23/68	10 : 08	L—0 : 16	—	—0.3	47	27.2	240	240
〃	13 : 47	L+3 : 23			59	30.1	490	490

Table 3G. Bacteriogical examination of water samples from the West Fowl River area, Mobile, Alabama

Station 7.

Date	Time	Tide	Extreme tide		Turbidity	Salinity	MPN per 100*ml*	
			High	Low	JTU	‰	Coliform	EC Pos.
10/15/68	09 : 40	H+4 : 46	1.5	0.1	22	24.9	2.0	<1.8
〃	13 : 30	L—4 : 48			44	23.6	2.0	<1.8
10/16/68	09 : 45	H+3 : 57	1.4	0.2	22	27.1	4.5	2.0
〃	13 : 45	L—5 : 09			47	30.2	31	11
10/21/68	10 : 05	L+1 : 47	1.5	0.1	56	30.2	2.0	<1.8
〃	13 : 20	L+5 : 02			32	29.8	7.8	2.0
10/22/68	09 : 55	L+0 : 37	1.8	—0.1	32	31.0	<1.8	<1.8
〃	13 : 10	L+3 : 52			84	30.6	<1.8	<1.8
10/23/68	10 : 00	L—0 : 24	—	—0.3	61	29.8	790	790
〃	13 : 37	L+3 : 13			44	29.8	4.5	2.0

Table 4A. Bacteriological examination of oyster samples from the West Fowl River area, Mobile, Alabama

Station 2.

Date	Time	Plate count per g.	MPN per 100 g.	
		35℃	Coliform	E. C. positive
10/15/68	11 : 00	4,600	7,900	950
〃	14 : 20	4,300	4,900	460
10/16/68	12 : 30	<3,000	2,400	790
〃	14 : 50	3,700	11,000	1,700
10/21/68	10 : 50	3,800	2,200	490
〃	14 : 00	3,300	1,700	490
10/22/68	10 : 35	3,400	2,400	1,300
	13 : 45	<3,000	1,700	700
10/23/68	11 : 05	3,000	4,600	3,100
10/23/68	14 : 15	4,300	7,000	2,400

Table 4B, Bacteriological examination of oyster samples from the West Fowl River area, Mobile, Alabama

Station 3.

Date	Time	Plate count per g'	MPN per 100 g'	
		35℃	Coliform	EC positive
10/15/68	10 : 40	4, 200	2, 400	790
〃	13 : 50	3, 800	2, 400	790
10/16/68	10 : 20	<3, 000	490	23
〃	14 : 10	<3, 000	1, 100	330
10/21/68	10 : 30	<3, 000	490	170
〃	14 : 40	<3, 000	170	45
10/22/68	10 : 20	<3, 000	1, 100	700
〃	13 : 40	<3, 000	330	130
10/23/68	10 : 45	3, 000	13, 000	3, 300
〃	14 : 05	3, 200	4, 900	4, 900