DISTRIBUTION AND ECOLOGY OF THE LITTORAL FORAMINIFERA OF TIMBALIER BAY, LOUISIANA

by John Robert Inabinet and A. Geoffrey Fish

ABSTRACT

The living littoral Foraminifera of Timbalier Bay, Louisiana, were studied from September 1972 to May 1973, to determine species composition, the distribution and abundance with respect to environmental factors, and effects of activities of the oil industry of the bay upon Foraminifera. Four study areas were selected. A Mud Experimental Station (MES-1) was located close to producing wells in the northern bay, and a Mud Control Station (MCS-3) was isolated from oil production. A Sand Experimental Station (SES-2) was located close to oil production activities in the southern bay, and a Sand Control Station (SCS-4) was chosen remote from such activities. Data were collected from the high, mid, and low-tide level of each station and included temperature, salinity, pH, orthophosphate, nitrate, nitrite, sulfate, heavy metals, organic carbon, hydrocarbon, sediment size, and foraminiferal fauna. Species diversity analyses were performed on the foraminiferal data.

Thirty-nine species from 12 families were identified. The largest populations were measured in September with declines in January and May. The Mud Experimental Station supported larger numbers than MCS-3. In contrast, more Foraminifera were collected from SCS-4 than from SES-2. Foraminifera populations were divisible into a sand group, located at SES-2 and SCS-4, a mud group from MES-1 and MCS-3, and a group

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common to both environments. Foraminiferal distribution and abundance seemed related to seasonal temperature changes, salinity, sediment size, and the unusual precipitation of May 1973. Species diversity was reduced at MES-1 and SES-2 with respect to their control stations, indicating that Foraminifera may be experiencing some environmental stress; however, the effects were believed minimal.

INTRODUCTION

The objectives of the present study were to determine the species of living Foraminifera inhabiting selected littoral sites in Timbalier Bay, Louisiana; to relate the distribution and abundance of species to environmental factors; and to determine what effects, if any, the offshore oil industry had on the distribution and abundance of the species.

The early foraminiferal research was dominated by morphologic and taxonomic studies. In the early twentieth century, Foraminifera were recognized as economically important in exploration for petroleum, and numerous paleontological studies resulted in which Foraminifera were used for identification of geologic age and ancient environments. In the past 30 years, increasing interest in Foraminifera as living organisms has arisen. Numerous papers have been published concerning the distribution, abundance, and ecology of modern benthic Foraminifera (Boltovskoy 1966; Bradshaw 1968; Buzas 1969; Kornfeld 1931; Lankford 1959; Lehmann 1957; Parker et al. 1953; Phleger 1954; Waldron 1963; Warren 1956). Few of these studies have dealt with the intertidal zone, where environmental parameters are subject to sharp diurnal and seasonal variations (Moore 1958).

Little is known concerning the effects man has upon the distribution and abundance of benthic Foraminifera. Few papers deal with this problem (Bandy et al. 1964; Seiglie 1968; Watkins 1961), and literature concerning the effects of the oil industry on the foraminiferal ecology of Timbalier Bay is nonexistent; therefore, this bay, which has been historically associated with activities of the oil industry, is well suited for such a study. While Waldron carried out a seasonal ecological study of the Foraminifera of Timbalier Bay, he did not address the possible effects of the oil production activities on this group of organisms.

MATERIALS AND METHODS

Description of study area

Timbalier Bay extends from longitude 90°13′ to 90°29′ N and latitude 29°03′ to 29°19′ W (figure 1). The maximum width is approximately 23 km and the length is 27 km from north to south. The bay averages approximately 1.85 m in depth. There is little natural fresh water influx other than local rainfall. Saline waters enter the bay through Grand Pass Timbalier, which connects the bay with the Gulf of Mexico. There is one tide each 24 hours with an average tidal range of about 0.3

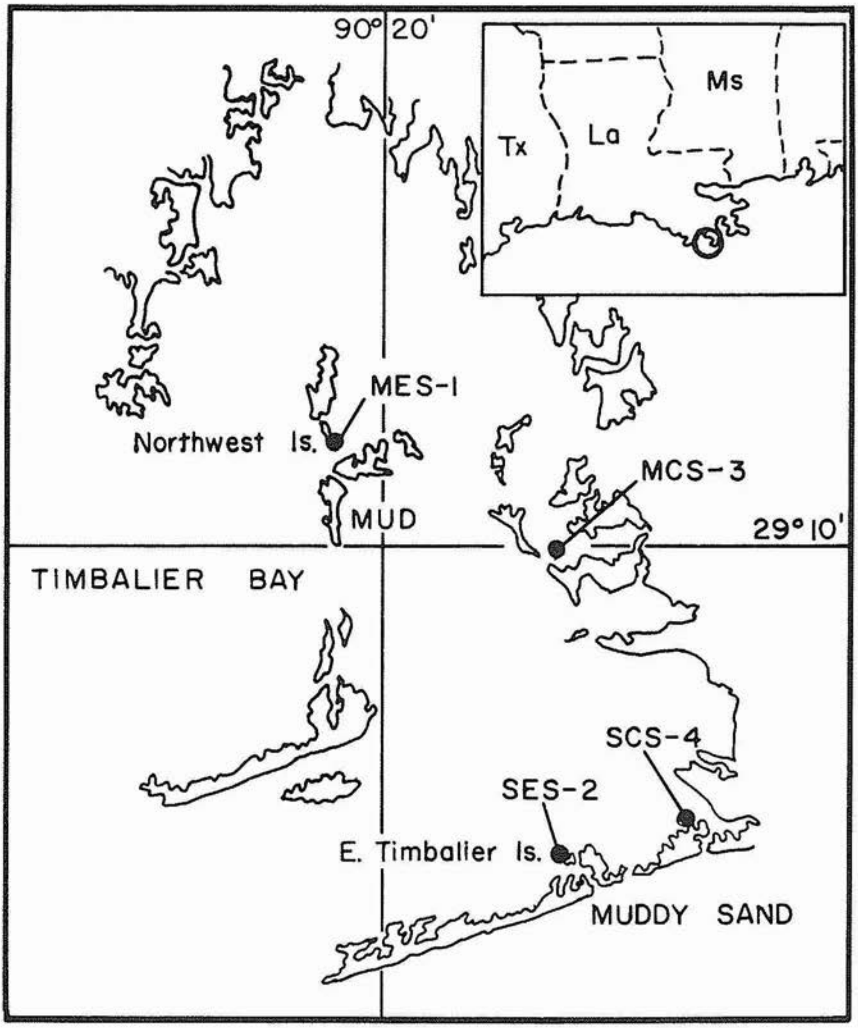

FIG. 1. THE LOCATION OF SAMPLING STATIONS WITHIN TIMBALIER BAY, LOUISIANA.

m. Many of the islands within the bay are remnants of natural levees. Most are low-lying land areas and marshes composed of muddy-sand sediments. The southern boundary of the bay is composed of natural sand barrier islands (Waldron 1963).

Four sites were chosen for study within the bay. Station 1 was established on the southeastern tip of Northwest Island (figure 1) at latitude 29°11.73′ N, and longitude 90°20.93′ W. The study area was a narrow beach of fine silt and mud, sporadically covered with crushed shell material. The site was located within sight of several active oil producing platforms. This station was designated the Mud Experimental Station (MES-1).

Station 2 was located on East Timbalier Island, approximately 68 m northeast of a Gulf Oil Company installation at latitude 29°04.8′ N and longitude 90°17.20′ W. The sampling area was an isolated sand beach bordered by *Spartina* and within sight of a productive oil platform and natural gas wells. This station will be referred to as the Sand Experimental Station (SES-2).

Station 3 was situated on the southwestern tip of a small low-lying island located at latitude 29°09.80′ N and longitude 90°17.18′ W. The sample site was an isolated mud beach, bounded by *Spartina*. This station was located as far from active oil production areas as possible and served as the control site for MES-1. It was designated as the Mud Control Station (MCS-3).

Station 4 was established on a narrow sand island located at latitude 29°05.65′ N and longitude 90°14.59′ W. This station was as isolated as possible from active oil production sites. It has been designated as the control site for SES-2 and was referred to as SCS-4.

Sampling techniques

Twenty-two equal-size faunal samples were collected during the period from September 19, 1972, to May 19, 1973. The dates of the collection trips were as follows: September 19-20, 1972; January 31-February 2, 1973; and May 18-19, 1973. Samples were collected from the high-, mid-, and low-water marks at each study site. Samples were taken using a plastic hand-operated coring tube, with inside diameter of 4 cm and length of 45 cm. Each core was 30 cm long and had a volume of 376.8 ml. The cores were divided into upper and lower halves and preserved in 70% isopropyl alcohol.

The sediment temperature at 5 and 25 cm was recorded from the low-, mid-, and high-water marks at each station and from the adjacent sea water. Water samples for the determination of salinity and pH were collected from the surface and from the 5 and 25 cm depths at the mid-water mark using a 50 ml glass syringe fitted with a long stainless steel needle whose end was plugged. Eight small holes were drilled in the shaft approximately 2 mm from the top of the plug. Salinity determinations were made with a Goldberg Refractometer.

Samples for the determination of orthophosphates, nitrates, nitrites, and sulfates were taken from the mid-water mark by digging a hole for water to flow into and filling the respective containers from the hole. The containers were then placed on ice. Samples for carbon analysis were taken from the sediment at the 5 cm and 25 cm depths from the low-, mid-, and high-water marks. Hydrocarbon samples were taken from the sediment at 5 cm and 25 cm depths at the mid-water mark. These samples were obtained by digging a hole approximately 45 cm in depth at the appropriate tide level and taking a small horizontal core at the desired depth. Core samples for sediment size analysis were collected during the January trip from the low-, mid-, and high-water marks at each station.

In the laboratory, an aliquot of 100 ml was taken from each faunal sample and washed through a U.S. standard sieve number 200. This aliquot was treated with rose Bengal stain for recognition of living Foraminifera (Walton 1952). After staining, samples were washed through U.S. screen sieves numbers 80, 100, and 200 to divide the sample into subsamples to facilitate identification. The finer fraction contained the smaller specimens, probably juveniles, which were unidentified. Therefore, only the organisms from the coarser fraction were identified (Parker et al. 1953).

Samples from mud and sand stations were treated differently. Little sediment was left on the sieves after washing mud samples, but large amounts of organic debris remained. This debris was removed by slowly decanting from a beaker onto a standard screen sieve No. 200. The decanted portion was examined under a binocular dissecting scope for loss of Foraminifera (Warren 1956). Sand samples contained less organic debris, but large amounts of sediment remained in the sieves. The washed residue was placed in a Boisseau extraction apparatus (Hulings and Gray 1971) and filtered at a constant flow rate for 20 minutes to remove most of the Foraminifera. Organic debris was removed by the decanting.

The washed residue of each sample was placed in a Petri dish whose bottom had been divided into 63 1-cm squares. Samples were examined under a binocular dissecting scope and all living Foraminifera were counted and identified. The proportion of dead Foraminifera was also estimated for each sample.

Sediment size analysis was performed using a modification of the method outlined by Hulings and Gray. Analysis of orthophosphate, sulfate, nitrate, nitrite, and carbon samples was conducted by Dr. C. R.

Brent of the University of Southern Mississippi, and the analysis of hydrocarbon samples was performed by Dr. J. L. Laseter of the University of New Orleans.

Species diversity indices were calculated from the data collected at each sampling site by using the formula proposed by Margalef (1956):

$\bar{d} = \Sigma\, ({}^{ni}/_{n}) \log_2 ({}^{ni}/_{n})$

Where d = diversity index

ni = the number of individuals in the I^{th} species

n = the total number of individuals in a community

This diversity index was chosen because it takes into account the relative abundance of the different species, and it is relatively independent of sample size (Warren 1971).

RESULTS

Physical and chemical data

The temperature range of the interstitial water, 12° C to 35° C, differed slightly from that of the adjacent sea water, 12° C to 36° C (table 1). The maximum temperature of interstitial waters occurred from the high-water mark of SES-2 on September 20, 1972. The sea water maximum was also recorded on this date. The minimum temperature of interstitial water was from low-water, MES-1, on January 31, 1973. The minimum sea water temperature was also recorded on this date. The temperature range was greatest at the high-water mark and least at the low-water mark for all locations. Temperature data for the mid-water beach level are included in table 1.

The salinity of the interstitial water generally exceeded that of the adjacent sea water (table 1). Maximum salinities were recorded from the high-water mark of stations; minimal salinities were usually at the low-water mark. The salinity of the two southern stations always exceeded that of the two northern stations.

Orthophosphate levels were highest in January and lowest in September. Sulfate levels were generally highest in September and lowest in May. In general, the two southern stations contained higher levels of sulfates than the two northern stations (table 1).

Because of instrument failure, pH data were recorded only for September. Values of pH were lower for the interstitial water than for the adjacent sea water (table 1).

Nitrate and nitrite levels were so low as to be barely detectable. Because of their low values, only the September and January samples were anlayzed (table 1).

Organic and inorganic carbon levels demonstrated a general trend to

TABLE 1

Temperature, salinity, pH, phosphate, sulfate, nitrate, and nitrite at 5 and 25 cms from the mid-water mark of each station, 1972-1973.

Station	Date	Depth cm	Beach Level	Temp °C	Sal. ‰	pH	PO_4 mg/l	SO_3 mg/l	NO_3 mg/l	NO_2 mg/l
MES-1	9-19-72	5	high	31.0	24.98	7.6	0.025	1580	0.0748	0.0732
		5	mid	30.0	24.98	8.3				
		25	mid	29.5						
			sea-water	29.0	25.52	8.3				
SES-2	9-20-72	5	high	35.0	41.63	7.6	0.000	3425	0.0088	0.0264
		5	mid	32.0						
		25	mid	31.5						
			sea-water	31.5	26.50					
MCS-3	9-19-72	5	high	34.5			0.200	1480	0.0264	0.0033
		5	mid	32.0	30.53					
		25	mid	29.5	27.76	7.3				
			sea-water	32.2	26.50					
SCS-4	9-20-72	5	high	31.0			2.075	1350	0.000	0.000
		5	mid	34.0	33.31	7.3				
		25	mid	32.0	33.31	7.4				
			sea-water	33.5	26.50	8.5				
MES-1	1-31-73	5	mid	12.0	21.11					
		25	mid	12.5	27.76		8.64	800	0.044	0.001
			sea-water	11.8	21.67					
SES-2	2-2-73	5	mid	14.0	27.22					
		25	mid	13.8	28.32		4.16	1300	0.020	0.003
			sea-water	14.0	25.54					
MCS-3	1/31/73	5	mid	13.8						
		25	mid	13.5			6.48	850	0.030	0.0001
			sea-water	12.5	19.43					
SCS-4	2/1/73	5	mid	20.0	39.98					
		25	mid	16.8	31.65		3.94	956	0.017	0.002
			sea-water	20.5	27.76					
MES-1	5-18-73	5	high	22.6	17.22		1.40	625		
		5	mid	22.9						
		25	mid	22.5						
			sea-water	24.0	15.00					
SES-2	5-19-73	5	high	22.5	12.71		1.68	1400		
		5	mid	23.4						
		25	mid	23.2						
			sea-water	24.7	17.22					
MCS-3	5-18-73	5	high	22.5	17.22		0.14	550		
		5	mid	22.3						
		25	mid	22.5						
			sea-water	24.6	15.00					
SCS-4	5-19-73	5	high	22.8			0.33	11800		
		5	mid	22.4						
		25	mid	22.0						
			sea-water	23.3	19.99					

decrease from September to January, followed by a slight increase in May. Both levels were found to be higher at the two northern stations than at the two southern stations (table 2).

Hydrocarbon data were available only for September (table 3). More complete data are reported elsewhere (Oetking et al. 1974).

The sediment analysis indicated that the two northern stations have an average composition of 92.1% mud, while the average composition of the two southern stations was 78.8% sand (table 4). The mean grain size of the two southern sand stations was 0.114 mm, which is listed as very fine sand in the Wentworth (1922) size scale.

Biological data

A total of 3,458 living specimens of Foraminifera was collected. Largest populations were found in September and smallest populations in May (figure 2).

Station MES-1, located near active oil production sites, supported larger numbers of living Foraminifera than the control beach, MCS-3, except in September. More living Foraminifera were taken from the control sand beach, SCS-4, than from the sand beach located near active oil production sites, SES-2.

Thirty-nine species from 12 families and 20 genera inhabited the four beaches. Of these, 37 species from 12 families and 18 genera were living at the time of collection. The remaining two species, representing two families and two genera, were found only as dead specimens (tables 5-7).

Living Foraminifera were recorded from both the upper and lower 15 cm of each faunal core, for both sand and mud beaches. In most cases, larger numbers were observed in the upper 15 cm. In mud beaches, much greater numbers of organisms were collected from the upper 15 cm than from the lower 15 cm, whereas the number of organisms living at both depth ranges was much more equal for sand beaches.

Diversity index data

The calculated diversity indices for the four study sites were similar and remained relatively constant throughout the study (table 8). Species diversity indices ranged from 2.19 to 2.43 (average 2.28) at stations located near active oil production sites and 2.51 to 2.70 (average 2.62) at control stations.

DISCUSSION

Thirty-nine species of Foraminifera were identified from the littoral

(text continues p. 505)

TABLE 2

Monthly sediment carbon analysis at 5 and 25 cms from the mid-water mark of each station.

Station	Date	Depth cm	Total ppt	Organic ppt	Inorganic ppt
MES-1	9-19-72	5	25.40	24.16	1.24
		25	19.78	19.34	0.44
SES-2	9-20-72	5	1.57	1.47	0.10
		25	33.84	30.16	3.68
MCS-3	9-19-72	5	33.20	31.60	1.60
		25	31.80	30.56	1.24
SCS-4	9-20-72	5	1.70	1.51	0.19
		25	1.97	1.65	0.32
MES-1	1-31-73	5	18.94	18.14	0.80
		25	16.92	16.52	0.40
SES-2	2-2-73	5	0.98	0.87	0.16
		25	1.98	1.81	0.17
MCS-3	1-31-73	5	31.28	30.88	0.40
		25	38.70	37.90	0.80
SCS-4	2-1-73	5	4.77	4.20	0.57
		25	4.43	4.05	0.38
MES-1	5-18-73	5	16.44	16.04	0.40
		25	23.96	23.96	0.80
SES-2	5-19-73	5	2.51	2.35	0.16
		25	1.42	1.32	0.10
MCS-3	5-18-73	5	31.60	31.00	0.60
		25	41.80	41.22	0.58
SCS-4	5-19-73	5	2.13	1.97	0.16
		25	2.52	2.42	0.10

TABLE 3

Hydrocarbon analysis of 0-15 and 15-30 cm depths from the four sampling stations for September.

Station Number	Depth cm	Total Lipids mg	Hexane Eluate mg	Benzene Eluate mg	MeOH Eluate mg
MES-1	0-15	9.0	0.1	3.1	1.1
	15-30	1.2	0.0	0.8	1.1
SES-2	0-15	1.9	0.5	0.8	0.6
	15-30	-	-	-	-
MCS-3	0-15	3.9	0.5	0.9	2.8
	15-30	0.9	0.0	0.7	0.8
SCS-4	0-15	2.0	0.1	0.7	1.5
	15-30	-	-	-	-
Outboard Motor Fuel	-	0.6	0.0	2.1	1.7

TABLE 4

The percent mud and sand and the mean grain size from 0-15 and 15-30 cm depths at the mid-water mark of the sampling stations.

Station Number	Depth cm	% Mud	% Sand	Mean Grain Size
MES-1	0-15	88.88	11.12	
	15-30	83.78	16.22	
SES-2	0-15	13.82	86.18	0.106
	15-30	10.70	89.30	0.102
MCS-3	0-15	98.35	1.65	
	15-30	97.48	2.52	
SCS-4	0-15	14.31	85.69	0.148
	15-30	45.97	54.03	0.101

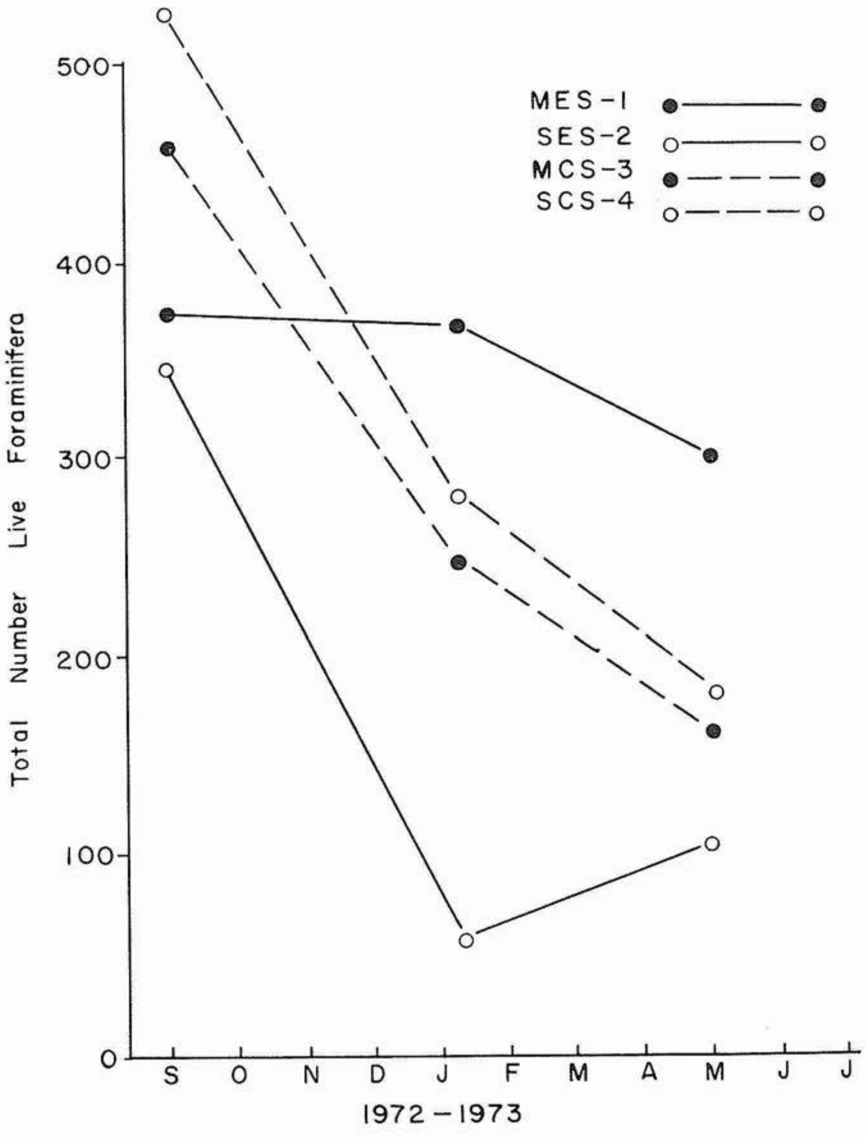

FIG. 2. NUMBER OF LIVE FORAMINIFERA RECORDED from Stations One, Two, Three, and Four for September 1972 and January and May 1973.

TABLE 5

DISTRIBUTION OF FORAMINIFERA IN LITTORAL SEDIMENT SAMPLES
FROM TIMBALIER BAY, SEPTEMBER 1972

Station	MES-1						MCS-3						SES-2						SCS-4					
Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Total Population 0.149 mm	52	198	56	36	19	53	63	32	131	153	76	46	82	17	48	45	68	129	41	105	90	54	136	122
Ammoastuta inepta							2	11	3	3	25	5												
Ammotium dilatatum		.6											1		2	3		.9	2	1	3	2		.8
Ammotium salsum	2	1	4				23	9	5	1	6		1		2			2		2	9	2	2	
Ammobaculites pseudospiralis																3					1			
Arenoparella mexicana	2	22	8	39	26	39		14	4	21	18	33							2				2	
Bolivina lowmani		.6																						
Cornuspira sp.	4						5		3															
Elphidium delicatulum		.6																						
E. discoidale									.9									2			1			.8
E. gunteri	17	20	35	3			3	6	14	27	7	5	31	40	26	35	21	32	34	35	24	27	18	22
E. mexicanum	2									1		2									1			
E. matagordanum	2								.9	1			3		9	5	13	6	5	4	7	7	22	18
E. poeyanum		2					3		3	.7			5				5	4	7	3	5	6	26	24
Epistominella vitrea									2									.9						
Hanzawaia strattoni																								.3
Haplophragmoides wilberti	4					4	2			.7		5						.9						
H. manilaensis	2				5																			
Miliammina fusca		.6						3	2	.7											3			3
Nonionella atlantica																		4		10	1		2	.8
N. opima																		3		1				.8
Quinqueloculina compta		1							.9		3		3			3	5	3		4	3	4	4	5
Q. funafutiensis																						2		3
Q. lamarckiana															6			2	2				2	
Q. rhodiensis															2			2			1	2		
Q. wiesneri																	2	.9			1			.8
Ammonia beccarii var. A	11	25	29		5		17	3	19	14			28	20	15	25	20	30	20	19	22	20	9	10
Ammonia beccarii var. B	17	4	4		11		8	3	27	9	2	10	28	40	34	28	30	9	27	21	17	29	15	12
Trochammina comprimata	4	2	6	6	5	45	10	6	4	.7	2	12			2		2						2	
T. inflata	30	20	14	53	47	12	27	46	15	20	37	29								1				
T. macrescens		1								.7	2													

TABLE 6

DISTRIBUTION OF FORAMINIFERA IN LITTORAL SEDIMENT SAMPLES
FROM TIMBALIER BAY, JANUARY 1973

Station	MES-1						MCS-3						SES-2						SCS-4					
Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Total Population 0.149 mm	147	20	95	25	80	6	110	27	28	13	61	15	12	7	11	5	26	2	15	14	47	34	162	11
Ammoastuta inepta				4			14																	
Ammotium dilatatum	8		1				3				3													
Ammotium salsum	2		2		3				4		8						4							
Arenoparella mexicana	5	35	3	13			26	4	27		5	13								7				
Bucella hannai	5						.9																	
Cornuspira sp.							.9																	
Elphidium advenum																					2			
E. discoidale					3																			
E. gunteri	42	20	39		23	33	12	33	8	54	31	20	50	14	36	20	39		33	7	19	27	18	9
E. mexicanum			1		1		2											50			2		4	
E. matagordanum					3		4			15	7	7	33		27				27	7	26	18	26	18
E. poeyanum			1			17					16		17				8		13	29	15	15	29	46
Haplophragmoides wilberti					1		2		4															
Miliammina fusca		15									3	13											.6	
Nonionella atlantica																				21	2			27
N. opima																						9		
Proteonina lagenaria			1																					
Quinqueloculina compta	.7																4			14		18	1	
Q. funafutiensis																						9		
Q. lamarckiana									4												6		8	
Q. poeyana														14										
Q. rhodiensis																	8			14	2		1	
Q. seminulum																					2		1	
Q. wiesneri																							4	
Recurvoides sp.			1																					
Ammonia beccarii var. A	30	10	41	4	43		14	19	12	23	16	13		29			15		20		9		.6	
Ammonia beccarii var. B			5		7		6	4	4		7	7		43	36	80	19	50	7		13	6	8	
Trochammina comprimata	1		1	4	4												4							
T. inflata	.7	20	4	74	13	50	16	41	39	8	3	27									2			
T. laevigata	5																							
T. macrescens							.9																	

TABLE 7

DISTRIBUTION OF FORAMINIFERA IN LITTORAL SEDIMENT SAMPLES
FROM TIMBALIER BAY, MAY 1973

Station	MES-1						MCS-3						SES-2						SCS-4					
Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Total Population 0.149 mm	60	15	72	21	127	7	75	26	60	8	18	6	18	11	16	10	30	12	11	9	32	29	84	21
Ammoastuta inepta	15						8		7															
Ammotium dilatatum			1		.8		7				11										3			
Ammotium salsum	8				6		11		12		17					10						3	2	
Arenoparella mexicana	23	20	7	24	6	14	11	27	33	25														
Elphidium delicatulum																							1	
E. discoidale	3																							
E. gunteri	17	13	43	10	54	29	1	19	7		28	17	33	27	24	30	27	17	36	22	28	21	14	14
E. mexicanum								4																
E. matagordanum	2		3		.8		1	15			6	17		18	14		7		18	33	13	17	23	5
E. poeyanum			6		6		4						11				10	8	9	22	19	31	28	38
Haplophragmoides wilberti		7					3																	
H. manilaensis							1																	
Miliammina fusca					.8						6						3							
Nonionella atlantica													6					8				7		
N. opima																20					9		8	5
Quinqueloculina compta															5		10		9			7		14
Q. funafutiensis																							4	
Q. lamarckiana																							4	
Q. rhodiensis														9						11				
Q. wiesneri															5						6			
Ammonia beccarii var. A	12	7	24		13	14	16		3	13	28	33	17	9	19	20	40	33	27		9	3	11	10
Ammonia beccarii var. B			1		4		3		3		6		33	36	33	20	3	33	9	11	13	11	5	14
Trochammina comprimata	2	7	3	19	4	14	5		2														1	
T. inflata	18	33	11	29	6	29	29	35	32	38		33												
T. laevigata		13		19																				
T. macrescens			1						2															

TABLE 8

Monthly analyses of the number of species, number of individuals, and calculated species diversity index of each sampling site.

Station Number	Date	Number of Species	Number of Individuals	Species Diversity Index
MES-1	9-19-72	19	382	2.43
SES-2	9-20-72	18	347	2.22
MCS-3	9-19-72	18	465	2.67
SCS-4	9-20-72	21	529	2.54
MES-1	1-31-73	21	371	2.19
SES-2	2-1-73	11	63	2.21
MCS-3	1-31-73	17	246	2.66
SCS-4	2-2-73	18	283	2.51
MES-1	5-18-73	15	300	2.35
SES-2	5-19-73	12	102	2.28
MCS-3	5-18-73	16	173	2.70
SCS-4	5-19-73	16	187	2.52

sediment samples from Timbalier Bay (tables 5-7). Waldron listed 17 of these species in his study of this bay.

Heaviest populations were recorded in September, with decreasing numbers in January and May (figure 2). This seasonal cycle differs from the one Waldron found, where minimum populations were counted in January and increasing numbers in May and September. The large number of living Foraminifera found in September may be attributed to the increased food supply during the summer months, with the decreased number in January correlated with a drop in the food supply. The minimal populations of May may be accounted for by such factors as the spring reproductive period and its subsequent reduction in adult

Foraminifera. The excessive precipitation of the spring of 1973, causing record Mississippi River runoff, which decreased the salinity in the bay, was perhaps the most important reason for the population decrease in May.

The distribution of Foraminifera also appeared correlated with the seasonal cycle of temperature. Highest temperatures were recorded in September and lowest temperatures in January. The density of Foraminifera exhibited a similar seasonal cycle. Temperature changes affect food supplies and the rate of reproduction. Foraminifera reproduce predominantly during the warmer spring and summer months (Myers 1943).

The seasonal distribution of Foraminifera and that of salinity exhibited similar cycles. Salinity also appears related to the geographic variation throughout Timbalier Bay. Species predominantly found at the northern mud stations (MES-1 and MCS-3) were collected from a salinity range of 16 ppt to 30 ppt; those collected primarily from the southern sand stations (SES-2 and SCS-4) were associated with a salinity range of 28 ppt to 39 ppt.

It is imposible with the data available to determine whether or not dissolved nutrient substances such as orthophosphate, nitrate-nitrite, and sulfate levels had any direct effect upon the populations of Foraminifera. These nutrients, however, influence the production of photosynthetic organisms, which constitute the principal food for the benthic Foraminifera, and periods of growth and reproduction in Foraminifera generally coincide with periods when nutrients are most abundant. It is, therefore, believed that by directly limiting the food supply of the Foraminifera, nutrients indirectly determine the density of foraminiferal populations.

The inorganic and organic carbon levels decreased from September to January and increased slightly in May (see table 2). The seasonal cycle for the Foraminifera was similar except for the continued decrease in numbers in May (figure 2). It is felt that inorganic or organic carbon levels had little direct effect on the seasonal distribution of Foraminifera, because these organisms are holozoic and low pH levels of mud habitats cause breakdown of calcareous test (Eltringham 1971).

The vertical distribution of Foraminifera seems attributable to scarcity of food and the presence of toxic substances in the deeper sediment (Myers 1943). Foraminifera have symbiotic algae to supply oxygen (Boltovskoy 1966). More Foraminifera were collected at the 15-30 cm depth range in sand beaches than in mud beaches. Foraminifera penetrate sandy sediments more readily because spaces between particles allow better aeration, greater flushing action, greater penetration of food supplies, and easier movement.

The Foraminifera throughout Timbalier Bay form two distinct biofacies: those primarily found in the northern mud stations (MES-1 and MCS-3) and those predominantly found at the southern sand stations (SES-2 and SCS-4). A third group of organisms is common to both mud and sand beaches.

The mud biofacies comprises the following species: *Ammoastuta salsa*, *Ammotium salsum*, *A. dilatatum*, *Arenoparella mexicana*, *Haplophragmoides manilaensis*, *H. wilberti*, *Trochammina comprimata*, *T. inflata*, and *T. macrescens*.

Ammotium salsum and *Ammotium dilatatum* were also found in high numbers at the two sand stations (SES-2 and SCS-4) in September; however, in January and May they were recorded primarily from the mud stations. All of those species that characterize the mud biofacies have arenaceous, or agglutinated, tests.

The sand biofaces comprises *Elphidium matagordanum*, *E. poeyanum*, *Nonionella atlantica*, *N. opima*, *Quinqueloculina compta*, *Q. lamarckiana*, *Q. rhodiensis*, and *Q. wiesneri*.

All of these species have calcareous tests. Foraminifera having calcareous tests are rarely found in mud habitats (Lankford 1959). The following calcareous species occurred at all stations, however, and were generally major species in every population: *Elphidium gunteri*, *Streblus beccarii* var. *parkinsoniana*, and *S. beccarii* var. *tepida*. Phleger (1954) found *Elphidium* spp. and *Streblus beccarii* vars. confined to high-salinity open-Gulf water in the Mississippi Sound area; whereas Parker et al. (1953) found these species not only in the open Gulf but also in San Antonio Bay, Texas, whose waters originate in the open Gulf. The distribution of these organisms in the relatively saline waters of Timbalier Bay verifies the conclusions of Phleger and Parker.

Foraminiferal distribution along the beach face varied between mud beaches and sand beaches. Higher numbers of living Foraminifera were collected from the high-water mark of the mud beaches, whereas the most dense populations from sand beaches were always recorded from the low-water mark. The larger size of the sand grains in sand beaches results in rapid drying of the upper reaches of these beaches during low tide and subsequent sharper variations of ecological parameters, whereas the capillary attraction of closely packed particles in mud beaches prevents rapid drying out (Eltringham 1971).

The two stations located near active oil production sites consistently yielded lower calculated species diversity indices than control sites (see table 8). Warren (1956) stated that a marked environmental change, without the passage of sufficient time for the evolution of a new community, tends to lead to a reduction of species diversity at the affected location.

It appears that Foraminifera in closer proximity to oil industry activities are experiencing some environmental stress; because the indices are relatively high at both experimental and control stations, however, it is believed the stress is only minimal and the presence of the oil industry in Timbalier Bay has shown little long-term effect on the distribution and abundance of littoral Foraminifera inhabiting the area.

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