Effects of Oilfield Brine on Marine Organisms
An Ecological Evaluation of the Aransas Bay Area, Job No. 1

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Abstract

Toxicity studies were made of oilfield brine from two separator locations in conjunction with the Sinton oilfields: Haas' Ditch, emptying into Chiltipin Creek, and Southwestern Oil and Refinery emptying into Copano Bay. Salinity of this brine ranged from 82.4 to 91.6 parts per thousand. Mortalities were noted in all tests using brown shrimp (Penaeus aztecus), white shrimp Penaeus setiferus), and juvenile blue crabs (Callinectes sapidus). Brine concentrations of above 40 per cent produced 100 per cent mortalities on all species tested.

Introduction

A public hearing was held in March 1970 by the Railroad Commission of Texas concerning brine-water disposal into Chiltipin Creek by oil producers in Refugio and San Patricio counties. At this hearing the Texas Parks and Wildlife Department introduced limited data which indicated that oilfield brine, per se, was toxic to postlarval marine life. Since these data were limited, further tests were conducted during the summer of 1970 and continued through 1971 to evaluate the effects of brine on marine organisms. These included preliminary toxicity tests on juvenile brown and white shrimp and blue crab megalops, and acute toxicity tests, establishing the concentration in which 50 per cent of the tested organisms died. Results indicate that oilfield brine is extremely toxic to these forms normally inhabiting the local marine environments.

Procedure

Oilfield brine samples were obtained from oil-brine separators. Sample 1 was taken from a discharge line at Haas' Ditch (Texaco et al) and Sample 2 was taken from the Southwestern Refinery separator which discharges into a slough leading to the junction of the Aransas River and Copano Bay in Copano Bay State Tract 119.

Brine samples were collected in clean five-gallon plastic bottles. Temperature of the sample was recorded at the collection site. The sample remained stored in these bottles, stoppered, and at a fairly uniform temperature. Duration of storage prior to testing was kept at a minimum. Analytical chemical tests were performed at the laboratory to determine the amounts of Ca, $CaCO_3$, Mg, and also the salinity and pH of each sample.

Animals used in the tests were collected in the Rockport Ski Basin near the Marine Laboratory (brown shrimp), Holiday Beach (brown shrimp and white shrimp), St. Charles Bay (brown and white shrimp), and Cedar Bayou Pass (blue crab megalops).

All test animals used were of local economic significance. The organisms used were relatively uniform in size, healthy, purposely selected for good physical condition and activity, and acclimated to laboratory conditions.

None were fed prior to or during the testing period. Feeding tends to increase the rate of respiratory metabolism and increases excretory products which may influence the toxicity of test solutions.

These test animals were transferred from the acclimatizing aquarium to the test containers as soon as temperature equalization was within 0.5 degrees C. All tests were performed at room temperature. The D.O. was maintained at levels greater than 3-4 ppm, averaging 5 ppm.

Fundamental bioassay procedures were followed to determine toxicity of tested substances to test animals. The percentage of test animals surviving at various concentrations was established. The 50 per cent $TL^{t}m$, or median tolerance limit, was then estimated graphically by plotting the experimental data on semilogarithmic graph paper, with the test concentration presented on the log scale and the per cent survival on the arithmetic scale.

In addition to establishing the $TL^{t}m$, the concentration which corresponds to 50 per cent survival on the graph, a critical concentration range was established. This is the interval between the highest concentration at which all test animals survive and the lowest concentration at which they all die.

Each series of evaluations of oilfield brine (samples 1 and 2) involved six chemically clean glass tanks in the preliminary test and seven in the secondary test. These tanks contained 10,000 ml, 4,000 ml, or 1,000 ml of liquid. The volume of liquid used and the size of the containers depended on the required volume of test medium, which in turn depended on the number and size of organisms used in each test.

The preliminary tests consisted of bay water containing, 20, 25, 30, 35, 40 per cent brine; secondary tests usually consisted of 20, 22, 24, 26, 28, 30 per cent brine in bay water. All dilutions required for a single bioassay were prepared with the same sample of toxicant and the same sample of bay water. For every series a control was prepared using bay water without brine.

The bay water used in all tests and controls came from a large storage tank at the Marine Laboratory (originally came from Aransas Bay at Rockport), directly from Aransas Bay, Rockport Ski Basin, Holiday Beach, and Cedar Bayou Pass, the areas where test animals were obtained. Bay water having unusually high salinity of 35 ppt or greater was diluted with distilled water to salinity of approximately 26-27 ppt.

Each test tank was provided with constant aeration during each study.

Hydrographic data consisting of temperature, pH, D.O., salinity, Calcium ion, $CaCO_3$, Hardness, and Magnesium ion were analyzed at the commencement of each testing period. These data are presented in Tables 1-5.

Dead organisms were removed, measured, and recorded as soon as observed. Test periods of 48 hours were used for shrimp and crabs.

Chemical analysis of brine water, bay water, and test tank was conducted at the laboratory using standard analytical methods.

Findings

Oilfield brine from both sources had a definite toxic effect on shrimp, both brown and white, and on crab megalops (Tables 1-5, Figures 1-9).

Sample 1 (Haas' Ditch)

A 40% concentration of brine in bay water produced 100% mortality in the test utilizing brown shrimp. Concentrations of 35% and 30% produced mortalities of 80% and 76%, respectively. Deaths of 30% were observed in concentrations of 20% brine. The $TL^t m$ was estimated to fall between 20-30%. By interpolation, this point was found to be between 24.5-26.5% concentration.

At a 40% concentration, all white shrimp died. Concentrations of 35%, 30% and 26% produced mortalities of 83%, 55%, and 40%, respectively. By interpolation, the $TL^t m$ was found to be a concentration of 28% brine, falling between the expected range of 26%-30%. No mortalities were experienced in the control tanks.

Sample 2 (Southwestern Oil and Refinery)

A concentration of 40% oil brine killed 100% of the crab megalops; a concentration of 35% killed 83%. Concentrations below 35% produced no mortalities. By interpolation, 50% of the specimens could survive in 21% concentrations of oil brine.

Utilizing brown shrimp with sample 2, mortalities of 100% were produced in concentrations between 24-40%. The $TL^t m$ was estimated to fall between the 20-22% brine concentrations (which produced mortalities of 67% and 17%). By interpolation, the $TL^t m$ was found to range between 18-21.5%.

Concentrations from 20-40% produced 100% mortalities in the tests using white shrimp and brine sample 2. Concentrations of 18%, 14-16%, and 12% produced mortalities of 80%, 70% and 40%, respectively. Therefore, the $TL^t m$ was estimated to fall between concentrations of 12-16%. By interpolation, this value was found to be 13.5%.

Discussion

Among the more frequently cited substances demonstrated to have caused damage to marine populations are oilfield brine associated with petroleum wastes (Heffernan 1971; Spears 1960). The influence of oilfield brine on juvenile populations of shrimp and crabs is equally critical. The disposal of this brine into prime nursery areas has adverse effects including: (1) direct mortality; (2) reduced survival rates of larval and juvenile forms: (3) disturbance of food chain organisms. These effects cannot be attributed to natural changes in water temperature or salinity but are caused by the direct discharge of foreign material (brine) not normally present into the waters. Field studies (Heffernan 1970; Simmons 1970) have shown that brine also degrades the marine environment, disrupts the balance of the ecosystem, and may provide barriers to migration through such factors as salinity and temperature.

Any discussion of waste disposal into marine environments must also take into consideration the ultimate biological and physiological effects upon aquatic life. Toxic wastes have a direct physiological effect on marine organisms. Two types of responses can readily be recognized: (1) acute toxicity resulting in death in a relatively short time; (2) low level or cumulative toxicity exerting a slight detrimental effect over an extended period. This may never actually kill the organism, but may result in decreased productivity. There is probably a threshold of sensitivity, somewhat below the lethal concentration for any pollutant although test organisms may show no immediate ill-effects.

References

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Table 1

Hydrographic Factors for Haas' Ditch-Brown Shrimp Tests

Preliminary Test

	Temperature	D.O.	pH	Sal.ppt	Calcium ppm	$CaCO_3$ppm	Mg ppm
Control		7	8.00	35.4	421	7000	1446
20%		6	7.75	46.8	762	6600	1142
25%		5	7.60	48.6	882	7000	1166
30%		6	7.60	50.8	992	7100	1166
35%		7	7.55	51.2	1042	7100	1093
40%		5	7.35	52.8	1082	6900	1008
BRINE (5-18-71)				82.4	2305	7600	449

Secondary Test

	Temperature	D.O.	pH	Sal.ppt	Calcium ppm	$CaCO_3$ppm	Mg ppm
Control	22.0	6	8.05	37.2	461	6900	1397
20%	21.5	6	7.65	48.0	782	7200	1275
22%	21.7	6	7.65	48.8	842	7300	1263
24%	21.9	6	7.60	49.4	902	7200	1203
26%	21.8	5	7.55	50.8	962	7300	1190
28%	21.8	6	7.48	53.2	1022	7300	1154
30%	21.7	5	7.40	54.4	1022	7200	1130
BRINE (7-22-71)			6.90	85.8	2325	7500	412

Table 2

Hydrographic Factors for Haas' Ditch-White Shrimp Tests

Preliminary Test

	Temperature	D.O.	pH	Sal.ppt	Calcium ppm	$CaCO_3$ ppm	Mg ppm
Control	18.3	7	7.75	28.2	361	5200	1045
20%	18.4	7	7.65	40.4	762	5900	972
25%	18.5	7	7.65	41.8	882	6300	996
30%	18.5	7	7.65	45.0	1042	6400	923
35%	18.6	7	7.60	47.2	1122	6500	899
40%	18.6	7	7.60	51.2	1242	6500	823
BRINE (8-2-71)	35.0			84.6	2645	8800	534
				Secondary Test			
Control	26.0	6	7.81	26.6	321	5000	1020
20%	25.4	6	7.30	39.0	761	5600	899
22%	25.6	5	7.29	40.2	802	5800	923
24%	25.6	5	7.24	43.0	862	5800	887
26%	25.6	5	7.20	43.0	942	5800	874
28%	25.6	6	7.21	43.0	942	5800	838
30%	25.6	5	7.20	44.4	1002	6000	850
BRINE (8-9-71)				84.0	2545	8300	473

Table 3

Hydrographic Factors for Southwestern Oil & Refinery-Brown Shrimp Tests

Preliminary Test

	Temperature	D.O.	pH	Sal.ppt	Calcium ppm	$CaCO_3$ ppm	Mg ppm
Control	25.4	5	8.20	37.4	387	7200	1515
20%	25.4	5	7.40	47.0	1202	8000	1215
25%	25.4	6	7.50	49.0	1403	8400	1190
30%	25.4	6	7.33	51.6	1617	8700	1133
35%	25.4	5	7.25	53.6	1844	9100	1093
40%	25.3	5	7.17	56.0	2017	9400	1061
BRINE (6-7-71)				83.3			

Secondary Test

	Temperature	D.O.	pH	Sal.ppt	Calcium ppm	$CaCO_3$ ppm	Mg ppm
Control	22.0	6	8.05	37.2	461	6900	1397
20%	21.9	6	7.65	47.8	1503	8900	1251
22%	21.8	6	7.60	50.0	1603	9000	1215
24%	21.8	5	7.55	51.2	1703	9200	1203
26%	21.8	5	7.50	53.0	1804	9400	1190
28%	21.9	5	7.48	53.4	1904	9600	1178
30%	22.4	5	7.48	54.4	2064	9800	1130
BRINE (7-7-71)				91.6	5832	16600	497

Table 4

Hydrographic Factors for Southwestern Oil & Refinery-White Shrimp Tests

Preliminary Test

	Temperature	D.O.	pH	Sal. ppt	Calcium ppm	$CaCO_3$ ppm	Mg ppm
Control	26.1	6	8.25				
20%	25.8	6	7.84				
25%	25.4	6	7.75				
30%	25.2	6	7.70				
35%	24.9	6	7.71				
40%	24.5	6	7.80				
BRINE (7-7-71)				91.6	5832	16600	497

Secondary Test

	Temperature	D.O.	pH	Sal. ppt	Calcium ppm	$CaCO_3$ ppm	Mg ppm
Control	24.8	7	8.43		421	6400	1300
10%	25.0	6	8.23		922	7300	1215
12%	24.8	6	8.21		1062	7600	1203
14%	24.4	7	8.28		1142	7800	1203
16%	24.6	6	8.13		1263	7900	1154
18%	24.6	6	8.08		1383	8400	1202
20%	23.6	3	8.05		1483	8400	1142
BRINE (7-7-71)					5832	16600	497

Table 5

Hydrographic Factors for Southwestern Oil & Refinery-Crab Megalops Tests

Preliminary Test

	Temperature	D.O.	pH	Sal.ppt	Calcium ppm	$CaCO_3$ ppm	Mg ppm
Control	21.2	4	8.15	41.2	461	7700	1592
20%	21.2	3	8.00	50.8	1463	9300	1373
25%	21.2	3	7.90	53.6	1804	10000	1336
30%	21.4	4	7.80	56.4	2004	10400	1312
35%	21.4	3	7.75	58.6	2305	10600	1178
40%	21.5	4	7.65	60.6	2585	11000	1105
BRINE (7-7-71)				91.6	5832	16600	497

FIGURE 1

PRELIMINARY TEST

BROWN SHRIMP HAAS DITCH

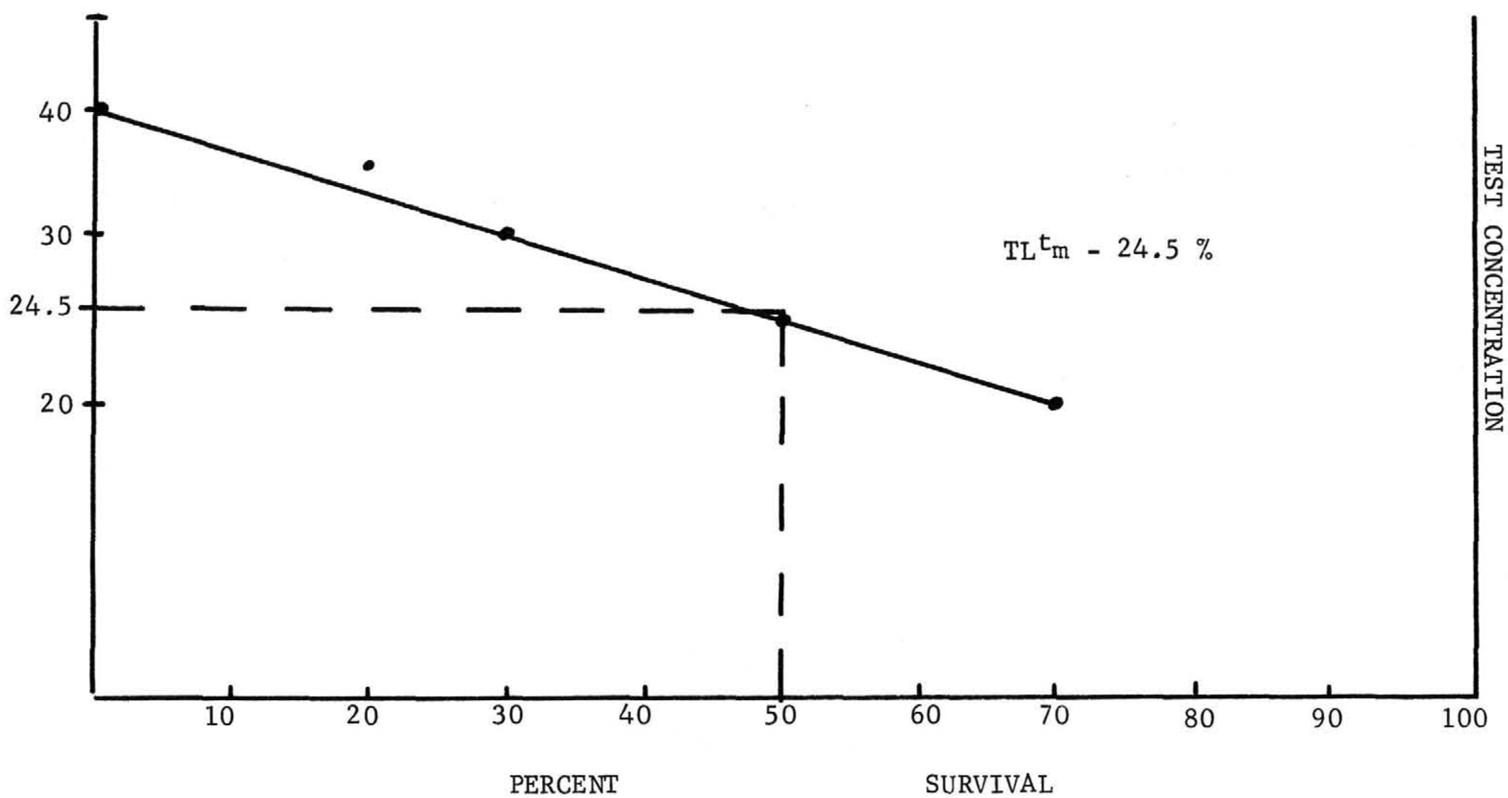


FIGURE 2

SECONDARY TEST

BROWN SHRIMP HAAS DITCH

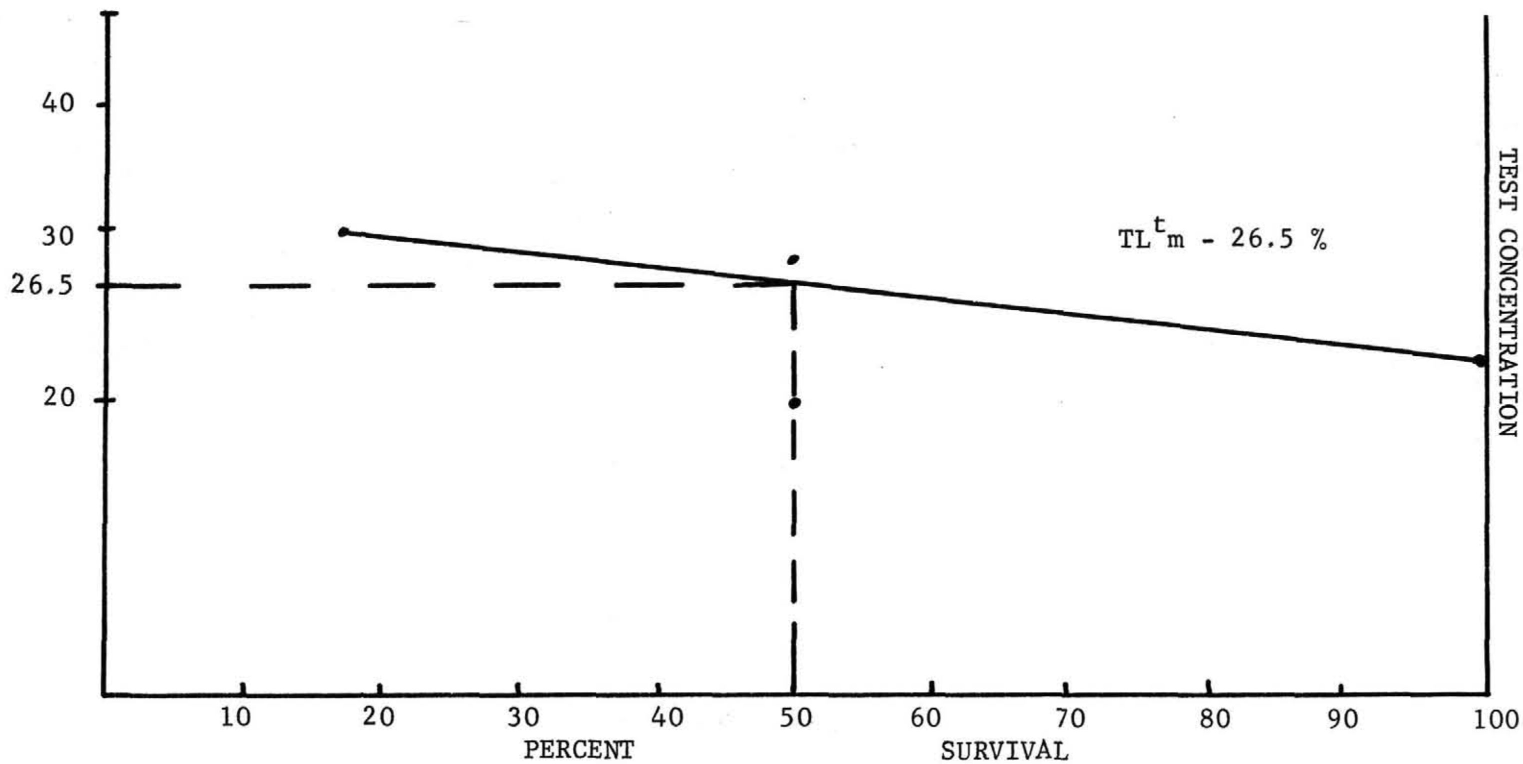


FIGURE 3

PRELIMINARY TEST

WHITE SHRIMP HAAS DITCH

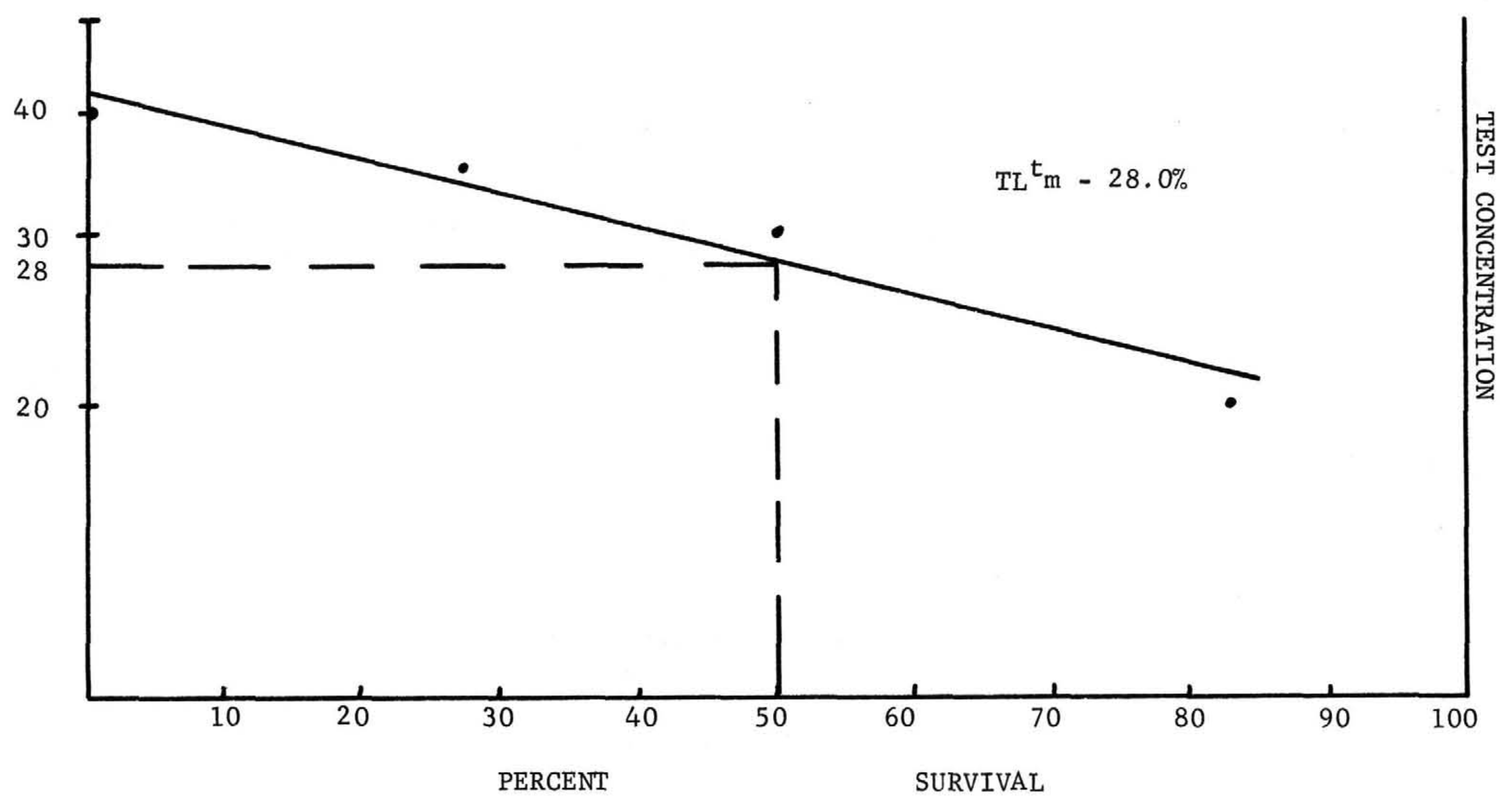
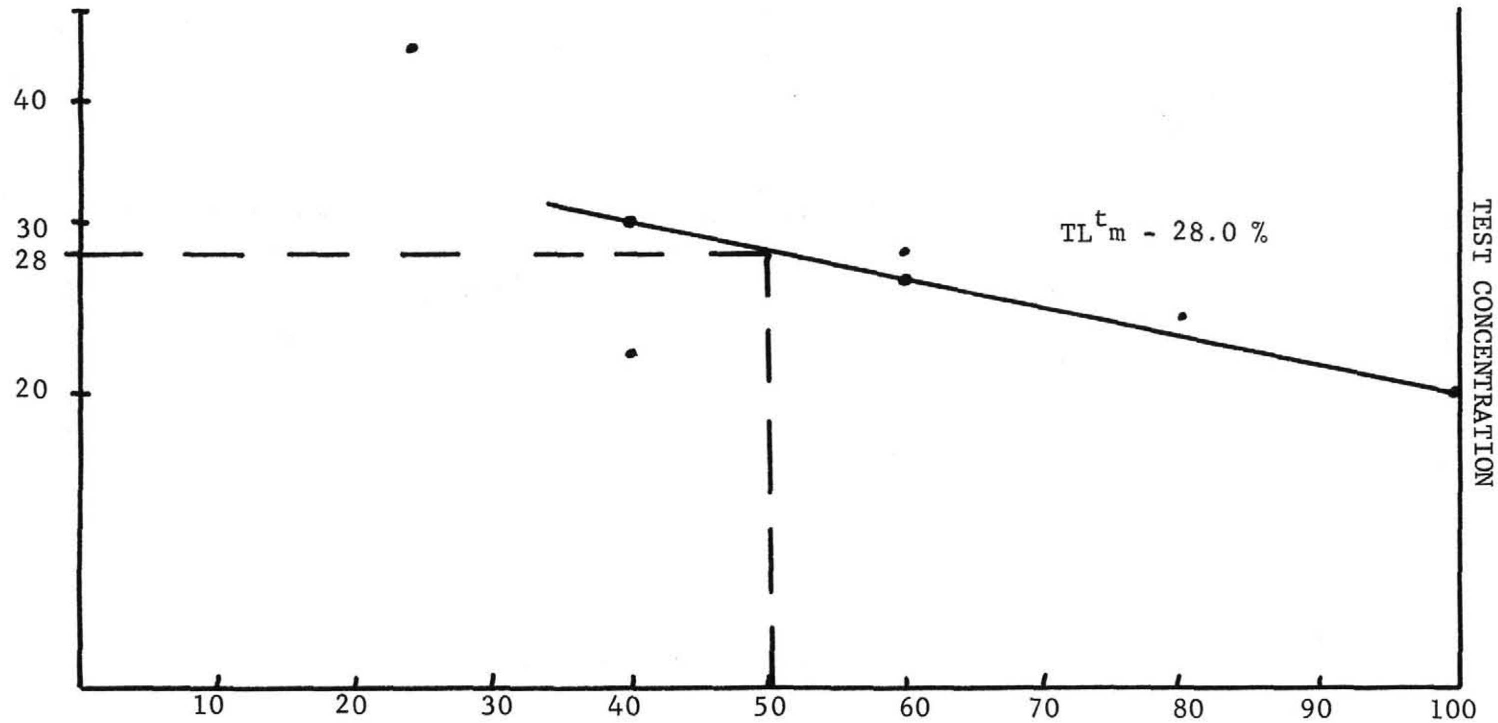


FIGURE 4

SECONDARY TEST

WHITE SHRIMP HAAS DITCH



PERCENT SURVIVAL

FIGURE 5

PRELIMINARY TEST

BROWN SHRIMP SOUTHWESTERN OIL

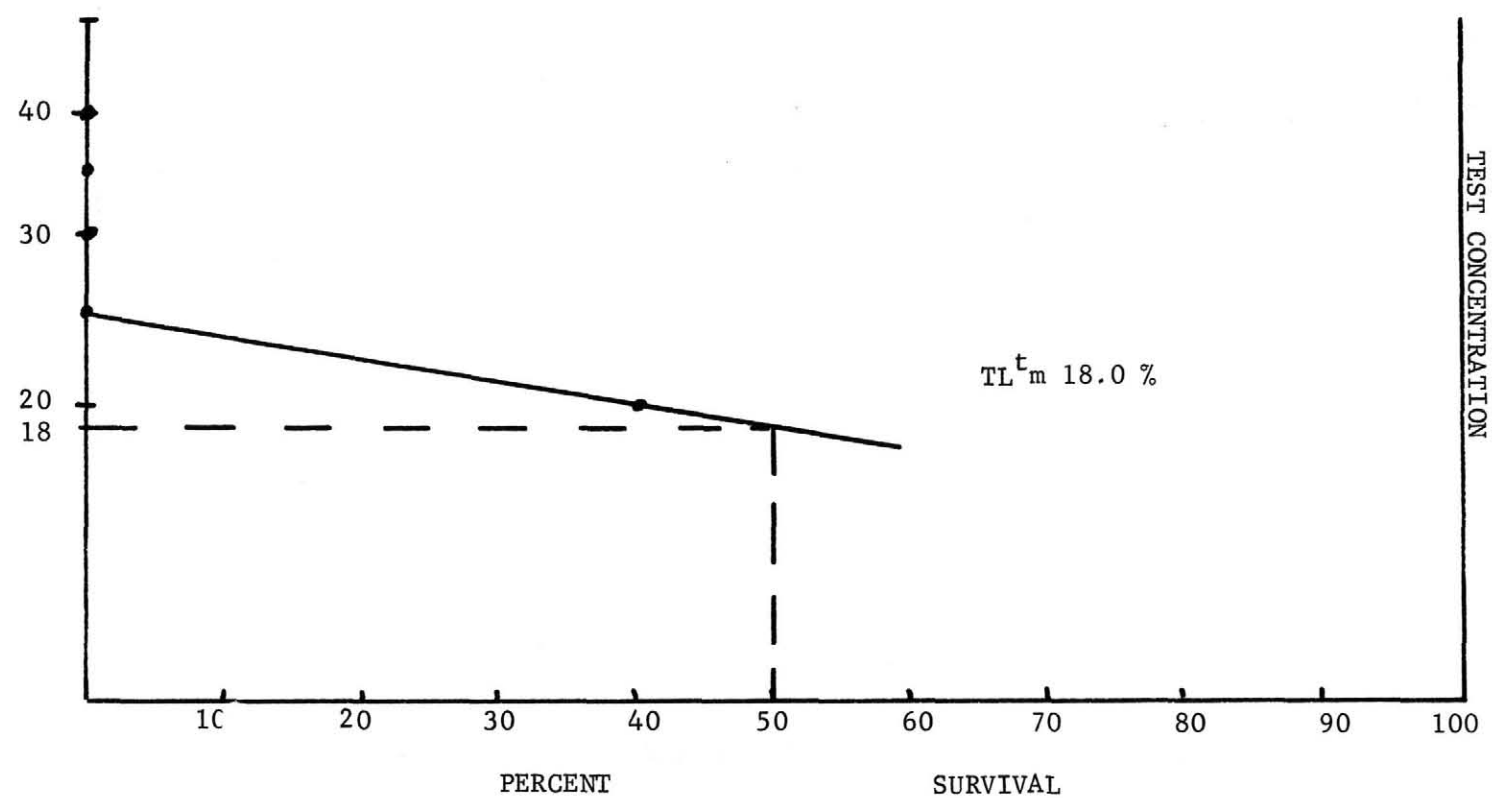


FIGURE 6

SECONDARY TEST

BROWN SHRIMP SOUTHWESTERN OIL

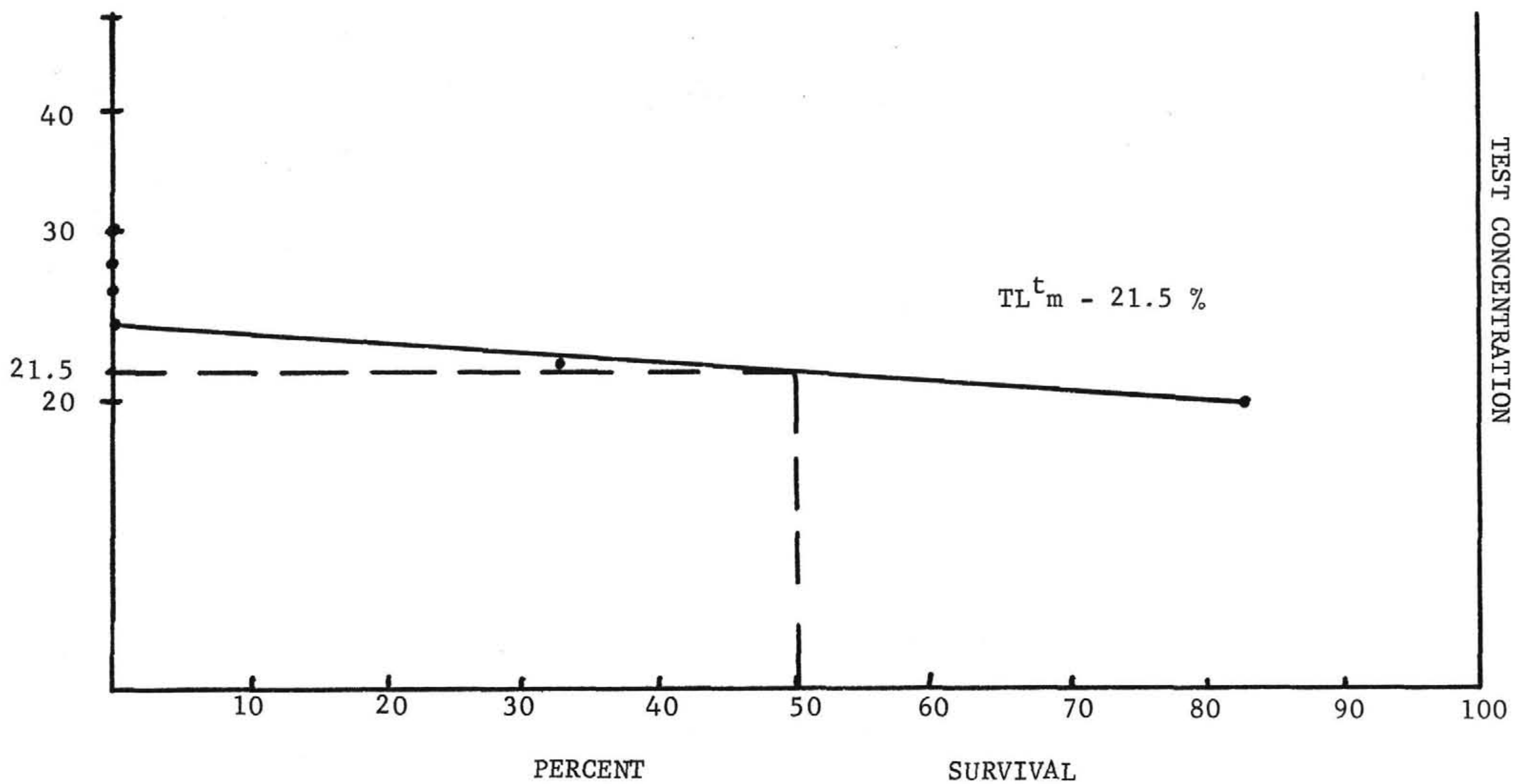


FIGURE 7

PRELIMINARY TEST

WHITE SHRIMP SOUTHWESTERN OIL

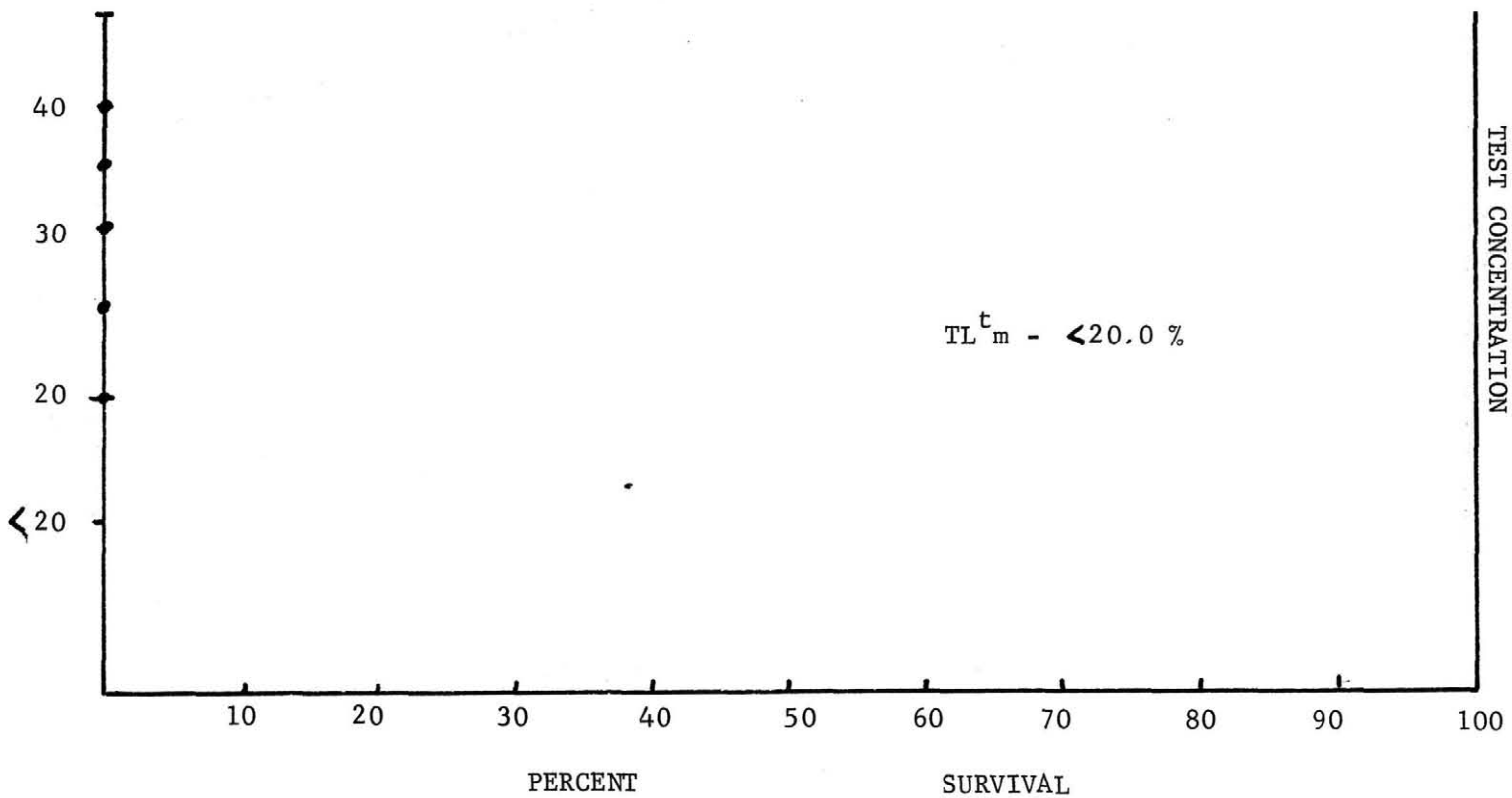


FIGURE 8

SECONDARY TEST

WHITE SHRIMP SOUTHWESTERN OIL

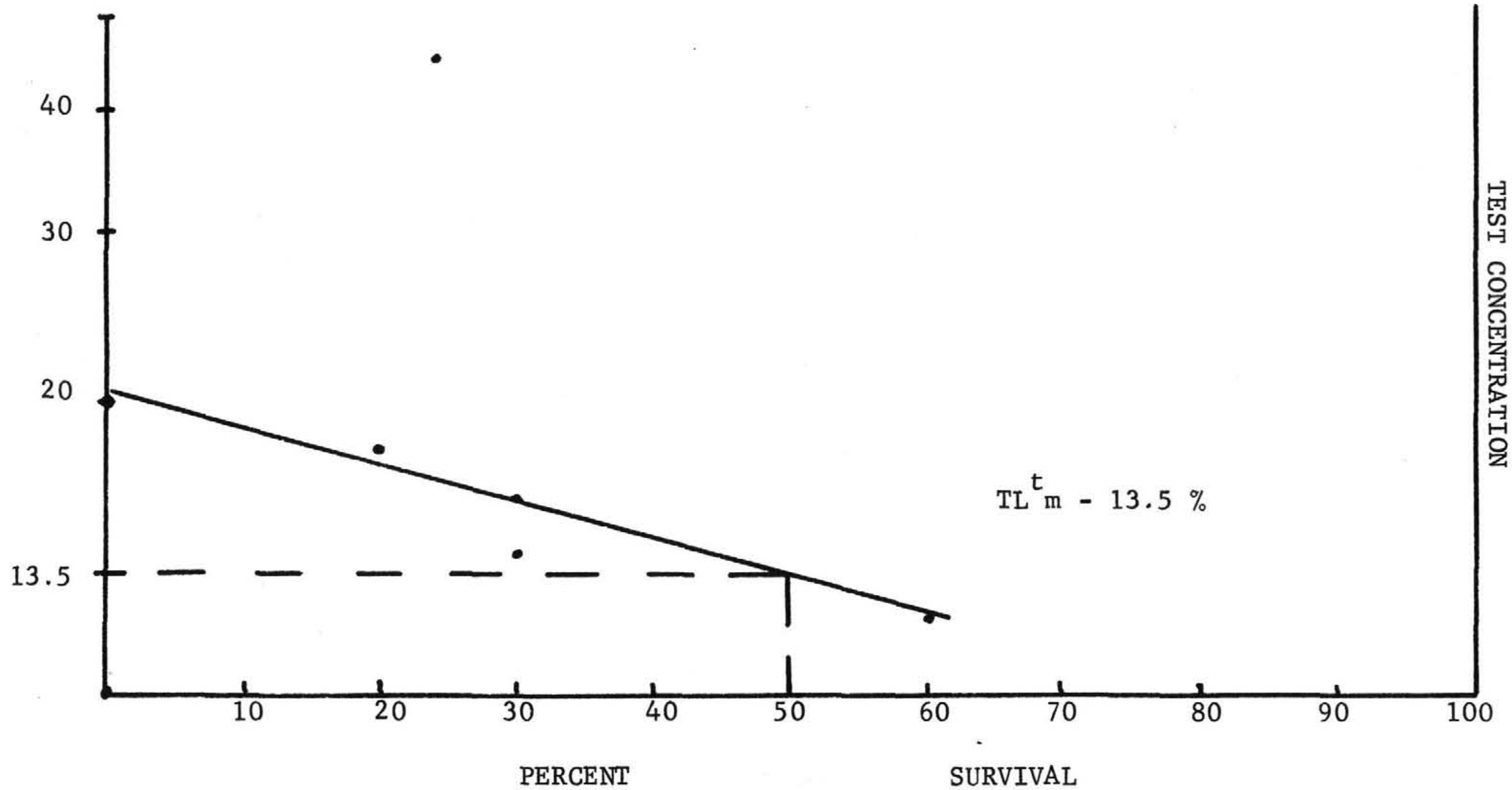


FIGURE 9

PRELIMINARY TEST

BLUE CRAB MEGALOPS SOUTHWESTERN OIL