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Utilization of Diversity Indices in Evaluating the Effect of a Paper Mill Effluent on Bottom Fauna*

by

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Abstract

Bottom fauna surveys of the Lower Sabine River in the vicinity of Orange, Texas were performed from 1967 to 1969. During this time samples were taken before and after effluent from a black-liquor paper mill was discharged into the Sabine River. Species diversity indices were determined for each station (one station above the discharge canal and four below it). The results obtained indicated that the paper mill effluent was not disturbing the river to a degree that it would cause damage. However, the proximity of Sabine Lake (an estuary) and the very low flow often encountered on the Sabine River makes it imperative that high standards be imposed in treatment of the waste water and that qualified personnel make periodic studies on the river.

Introduction

The establishment of a black-liquor paper mill and subsequent discharge of effluent into the Lower Sabine River has required consideration of a number of environmental problems unique to that portion of the river. These problems are: 1) Low or non-existent flow during part of the year; 2) A naturally high organic load with concomitant below saturation level oxygen concentrations; 3) A salt wedge intrusion which moves above the mill's effluent outfall

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during a part of the year; 4) The proximity of a shallow, wide estuary which could become a "settling basin" for complex organic compounds which are difficult to decompose. The only method for disposal of the mill's treated waste was quite obviously by way of the river. Since the states of Louisiana and Texas have established guidelines which set limits for the quality of the river water below the plant's outfall, it was necessary that both biological and chemical analyses be made periodically, on the river water before and after the beginning of production.

It is the purpose of this report to illustrate and discuss the effects of the mill effluent upon the bottom fauna of that portion of the river studied. This report will also point out some of the particular effects of the environment upon the organisms.

Material and Methods

An extensive description of the materials and methods used in collecting the bottom fauna has been described earlier (Henrdicks et al., 1969), however, a brief summary will be given.

The bottom fauna were collected with a Petersen dredge and bottom fauna net. Approximately 15 samples were taken from each station. Samples were taken along the bank, in six feet (1.83 m) of water and at mid-channel. The samples were returned to a field lab for screening with #40 sieves. The organisms were preserved in formalin for later identification and enumeration.

Location and Description of Study Area

Figure 1 is a map of the Lower Sabine River. The map indicates the location of the various sampling sites plus distances between the stations. That portion of the river studied was subject to tidal actions (Rawson, et al., 1966). The water had a light brown apperance and a pH of approximately 7 (Rawson, et al., 1966, U.S.G.S.; 1967). The river was from 70—100 feet (21.35—30.5 m) wide at Stations A, E. AB, and B with forest and marsh grass types of vegetation along the shorelines. At Station C the width of the river was approximately 300 feet (91.5 m) and marsh grass and cyprus trees were present. A more complete description of the area has been presented earlier (Hendricks, et al., 1969).

Figure 1.

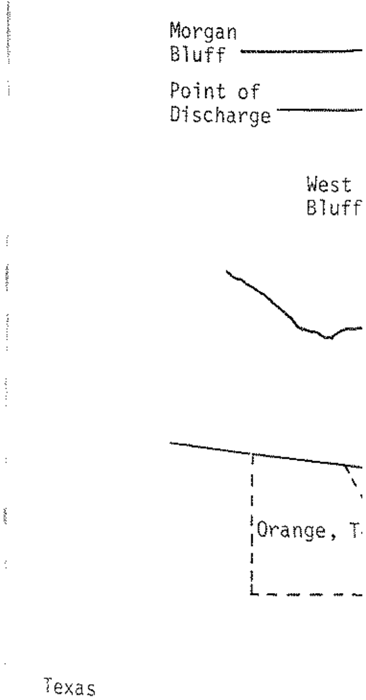

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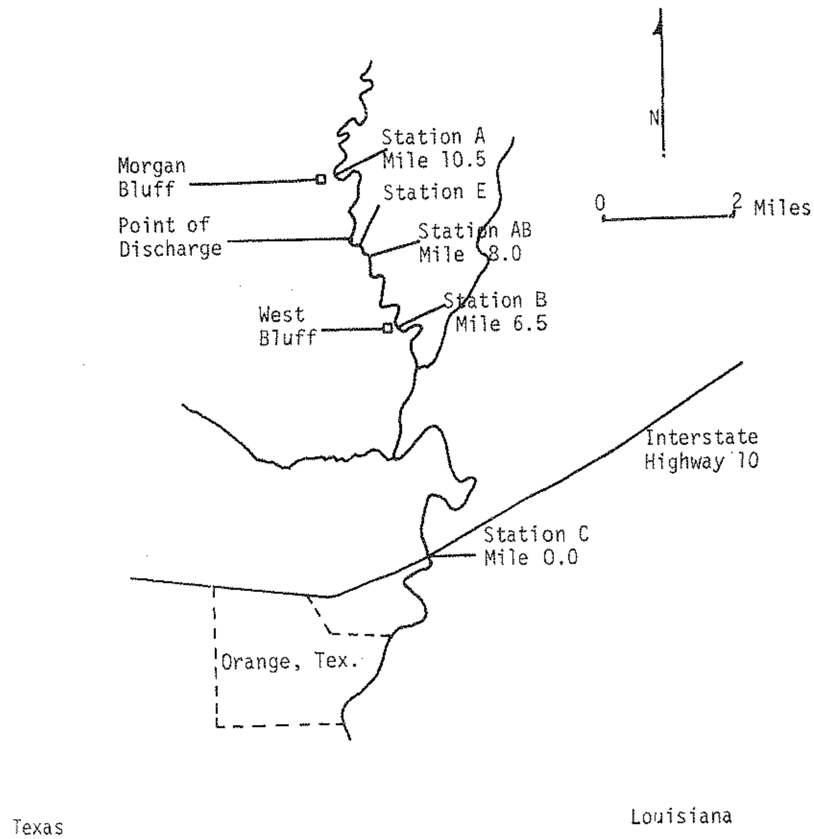
Figure 1. Map of Lower Sabine River showing locations of stations sampled.



Results and Discussion

Bottom Fauna

The bottom fauna collected during the sampling periods of 1967—68 and 1969 together with the number of organisms are given in Tables I—V. The organisms collected in 1967 were taken before the paper mill began discharging effluent into the river. Station E was not established until the fall of 1968.

A small number of species and a large number of individuals were always found at each station. This is usually indicative of polluted or semipolluted conditions (Wilhm & Dorris, 1968). However, if one compares the data from 1967 (prior to effluent discharge) with those of the remaining years, and also the data collected at Station A above the outfall with that collected below the outfall, it becomes obvious that the paper mill's effluent alone did not bring about the situation of a low number of species and a high number of individuals.

The bottom fauna community structure found in the area under study was developed under natural conditions and through natural selection. The harsh environment of the river, ie, high and low periodic flows, heavy organic loads, intermittent inundation by salt water, coarse sandy bottoms, and periodic drops of oxygen levels, has perhaps eliminated a large number of probable inhabitants.

Also, a lack of diverse habitats within the river would decrease the number of species found. No pools or riffles occurred in the area of the river under study. Therefore, many of the organisms generally found in riffles and quiet pools would not have occurred. When compared to other areas that have been recorded (GAUFIN & TARZWELL, 1956; MATHIS & DORRIS, 1968; WURTZ, 1955), one can deduce from the data that the natural environment of the river contributed to the reduced diversity of the bottom fauna.

Species Diversity Indices

Table VI presents the species diversity indices derived from the data presented in Tables I—V. These indices were calculated from equations presented by WILHM & DORRIS (1968). The Table presents the diversity and redundancy for each station. Diversity ($\bar{d}$) refers to the diversity of the bottom fauna community. A high species diversity is usually encountered under natural conditions. Redundancy (r) is an expression of the dominance of one or more species in a community. Therefore, it is evident that a high d value would yield a correspondingly low r value.

Indices of this type are very useful in pollution studies since they provide a non-biased numerical value for community diversity. Also the technique does not depend upon the size of the sample (WILHM & DORRIS, 1968). It should be pointed out, however, that indices such as these are only comparable when organisms are collected from similar habitats. WILHM & DORRIS (1968) suggested the following guidelines for determining the degree of pollution of a stream: (1) $\bar{d}$ values less than 1 would be indicative of polluted conditions; (2) $\bar{d}$ values of 1—3 would indicate semi-polluted conditions; (3) $\bar{d}$ values greater than 3 would correspond with clean waters.

Applying these guidelines to the $\bar{d}$ values in Table VI, it would be assumed that semi-polluted conditions existed at all sampling stations. However, the $\bar{d}$ values are quite consistent (about 2) through-

Insects
Hexagenia sp.
Caenis sp.
Didymops sp.
Dromogomphus sp.
Somatochlora sp.
Aphylla sp.
Telebasis sp.
Hetaerina sp.
Macromia sp.
Enallogma sp.
Gomphidus sp.
Sialis sp.
Tendipes sp.
Chaoborus sp.
Pentaneura sp.
Elmidae (Family)
Probezzia sp.
Phylocentropus sp.
Psychomyia sp.
Hesperocorixa sp.
Dubiraphia sp.
Curculionidae (Family)
Crustaeceans
Mysis sp.
Gammarus sp.
Unidentified sp. (Decapoda)
Sphaeroma sp.
Annelids
Lumbriculus sp.
Branchiuris sp.
Lumbricidae (Family)
Lycastoides sp.
Naidium sp.
Helobdella sp.
Molluscs
Polymesoda sp.
Uniomerus sp.
Unidentified sp. (Gastropoda)
Total

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TABLE I

Organisms Found at Station A

	1967 9—12	1968 4—29	1968 9—10	1969 8—27
Insects				
Hexagenia sp.		140	142	31
Caenis sp.		5		1
Didymops sp.				3
Dromogomphus sp.	1	6		
Somatochlora sp.		3		
Aphylla sp.	2	1	1	
Telebasis sp.	1			
Hetaerina sp.	3			
Macromia sp.	2			3
Enallogma sp.	1			
Gomphidus sp.				6
Sialis sp.		1	1	
Tendipes sp.	8	26	1	
Chaoborus sp.		2		1
Pentaneura sp.	23	83	26	36
Elmidae (Family)	2			
Probezzia sp.		1		
Phylocentropus sp.		1		1
Psychomyia sp.	2			2
Hesperocorixa sp.	1	2		
Dubiraphia sp.				
Curculionidae (Family)		1		
Crustaeceans				
Mysis sp.	28	10		4
Gammarus sp.	1	21	3	134
Unidentified sp. (Decapoda)	2	3		
Sphaeroma sp.	72			57
Annelids				
Lumbriculus sp.		15	7	36
Branchiuris sp.	3	3	52	19
Lumbricidae (Family)			1	
Lycastoides sp.	4		1	
Naidium sp.				
Helobdella sp.	1	2		2
Molluscs				
Polymesoda sp.		25	4	2
Uniomerus sp.	2			
Unidentified sp. (Gastropoda)				1
Total	159	351	239	339

Table II

Organisms Found at Station E

	1968 9–13	1969 8–27
Insects		
Hexagenia sp.	11	71
Caenis sp.		1
Gomphus sp.		12
Hydrophilus sp.		1
Pentaneura sp.	112	40
Chaoborus sp.	4	
Crustaceans		
Gammarus sp.		1
Sphaeroma sp.		1
Mysis sp.		7
Annelids		
Branchiura sp.	26	78
Lumbriculus sp.	150	
Lumbricidae (Family)	12	
Helobdella sp.	1	
Molluscs		
Polymesoda sp.		1
Totals	316	213

out the data, suggesting semi-polluted conditions before discharging of waste and at a station above the discharge ditch. Rather than assuming that some man-made pollutant was depressing the $\bar{d}$ value, it is suggested again that the natural condition of the river was such that a large number of species could not develop. The only data that suggests the classical situation of a clean zone, polluted zone, and recovery zone (Wurtz, 1965) comes from the 1969 sampling period. The comparatively high $\bar{d}$ value at Station A (above the outfall), a decrease in $\bar{d}$ value at E (immedidately below the outfall), and an increase in $\bar{d}$ farther down the river indicated an effect on the biota from the mill waste. And indeed this may be true, however, it can hardly be shown to be unequivocal for a number of reasons: (1) the $\bar{d}$ value for the 1969 sampling period are all greater than those of the fall 1968 sampling period. If waste were polluting the stream, the argument could be made that since more waste had been discharged into the river (total amount) at the time of the 1969 sampling period than had been discharged in the fall 1968, then the $\bar{d}$ value should be higher for the fall 1968 period than the fall 1969 period; (2) The $\bar{d}$ values for the 1969 period exhibited practically

Table III

Organisms Found at Station AB

	1967 9—14	1968 4—30	1968 9—11	1969 8—28
Insects				
Hexagenia sp.	2	24	21	172
Aphylla sp.			1	
Macromia sp.				
Ophiogomphus sp.				1
Tendipes	3	3		
Pentaneura sp.	31	71	173	129
Probezzia so.		2	2	
Pyralididae (Family)			1	
Chaoborus sp.	1		1	
Dubirathia sp.		1		
Notonecta sp.		3		
Neocorixa sp.				1
Hesperocorixa sp.	11			
Crustaceans				
Gammarus sp.	6			3
Mysis sp.	11		9	43
Annelids				
Lycastoids sp.		22		
Pristina sp.		3		
Branchiura sp.			48	2
Lumbriculus sp.		28	305	37
Helobdella sp.		1	2	2
Molluscs				
Polymesoda sp.		34	4	30
Mytilopsis sp.		1		
Unioidae (Family)		3		
Margaritifera sp.			1	
Totals	65	196	568	420

the same patterns as the $\bar{d}$ values for the 1967 period; (3) All of the $\bar{d}$ values for the 1969 period were above 2 (except at Station C); (4) The r values for the 1969 period are quite similar (except at Station C) and even appear to contradict the $\bar{d}$ values (the higher the $\bar{d}$ value, the lower the r value). $\bar{d}$ values from Station C have not been included in the above discussion. The environmental conditions at Station C are completely different from those at the other stations, therefore, it is rather hazardous attempt any comparisons. It should be pointed out that it would be very difficult to show any effect of mill waste at Station C due to the remoteness of the station from the

Table IV

Organisms Found at Station B

	1967 9—13	1968 5—1	1968 9—12	1969 8—26
Insects				
Hexagenia sp.	2	48	330	178
Caenis sp.	1		1	1
Aphylla sp.	5	4		
Gomphus so.				1
Macromia sp.	4	3		
Dubirathia sp.			2	
Sialis sp.	3	1		
Probezzia sp.		1	1	1
Pentaneura sp .	50	83	283	[illegible]
Tendipes sp.	5	45		
Chaoborus sp.				
Tabanidae (Family)				
Phylocentropus sp.		3		1
Rhantus sp.		1		
Crustaceans				
Gammarus sp.	10	5		
Mysis sp.	1	24		[illegible]
Asellus sp.		1		
Sphaeroma sp.	17	3		
Annelids				
Lycastoides sp.	135	29	9	
Laeonereis sp.		5	8	
Helobdella sp.		1		
Brunchiura sp.			20	[illegible]
Lumbriculus sp.		6	91	[illegible]
Naidium sp.	5			
Lumbricidae (Family)			6	
Molluscs				
Polymesoda sp.		49	51	
Mitylopsis sp.		8		
Totals	240	320	802	[illegible]

outfall and the influence of other factors; that is, salt water, waste from other sources, etc. (Hendricks, et al., 1969).

It is difficult to explain the high $\overline{d}$ vaues of the spring 1968 period and since samples could not be taken in the spring of 1969 one cannot say if the pattern would have reoccurred. One can speculate, however, that the larger number of species could have been an attribute of the life cycle of bottom organisms or could have resulted from increased flows which may have transported the organisms in from areas farther up the river (Anderson & Lehmkuhl, 1968).

T

Organisms

Insects
Hexagenia sp.
Caenia sp.
Aphylla sp.
Tendipes sp.
Pentaneura sp.
Siphlonurus sp.
Psychomyia sp
Anthripsodes sp.
Chaoborus sp.
Crustaceans
Gammarus sp.
Sphaeroma sp.
Mysis sp.
Unidentified sp. *(Decapoda)*
Annelids
Lumbriculus sp.
Lycostoides sp.
Laeonereis sp.
Lumbricidae (Family)
Aeolosoma sp.
Molluscs
Polymesoda sp.
Totals

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Bottom fauna have been nisms in pollution studies. T themselves very well for stu 1955). They form rather sta identify and exhibit differe is also quite easy to formu organisms (Wilhm, 1967). group will reflect not only by man, but natural condi that in a habitat such as t natural phenomena, such intrusions, may have much

TABLE V

Organisms Found at Station C

	1967 9—15	1968 5—2	1968 9—14	1969 8—28
Insects				
Hexagenia sp.		38		
Caenia sp.			2	3
Aphylla sp.		1	4	
Tendipes sp.		13	2	
Pentaneura sp.	8	96	233	245
Siphlonurus sp.			5	
Psychomyia sp		1		
Anthripsodes sp.				1
Chaoborus sp.				
Crustaceans				
Gammarus sp.	36	5	67	4
Sphaeroma sp.		2		
Mysis sp.		1	13	26
Unidentified sp. *(Decapoda)*	18		2	
Annelids				
Lumbriculus sp.			4	1
Lycostoides sp.	5	7		2
Laeonereis sp.	5	2	3	14
Lumbricidae (Family)		2	2	
Aeolosoma sp.			6	
Molluscs				
Polymesoda sp.		1	4	1
Totals	72	169	347	297

CONCLUSIONS

Bottom fauna have been used for many years as indicator organisms in pollution studies. This very diverse group of organisms lend themselves very well for studies of this type (WILHM, 1967; WURTZ, 1955). They form rather stable communities, are easy to collect and identify and exhibit different tolerance levels to polluting agents. It is also quite easy to formulate species diversity indices from these organisms (WILHM, 1967). However, species diversity within this group will reflect not only conditions of environmental alteration by man, but natural conditions also (WILHM, 1967). This is to say, that in a habitat such as the Lower Sabine River, the infrequent natural phenomena, such as periodic high flow and salt wedge intrusions, may have much the same effect as polluting agents. Salt

TABLE VI

Species Diversity of Bottom Fauna Collected from Sabine River for Fall 1967, Spring 1968, Fall 1968 and Fall 1969

Date	Station	d̄	r#
9–12–67	A	2.68	0.43
9–14–67	AB	2.15	0.24
9–13–67	B	2.11	0.47
9–15–67	C	1.89	0.20
4–29–68	A	2.77	0.40
4–30–68	AB	2.65	0.29
5– 1–68	B	3.24	0.27
5– 2–68	C	2.04	0.49
9–10–68	A	1.77	0.54
9–13–68	E	1.70	0.42
9–11–68	AB	1.75	0.53
9–12–68	B	2.06	0.46
9–14–68	C	1.68	0.59
8–27–69	A	2.73	0.38
8–27–69	E	2.09	0.40
8–28–69	AB	2.13	0.36
8–26–69	B	2.25	0.37
8–28–69	C	1.03	0.71

d̄ = Species Diversity
r# = Redundancy

wedge intrusions occur during periods of low stream flow .With the corresponding high osmotic gradients and low oxygen levels survival becomes extremely difficult for fresh water organisms. If one were sampling in an area where a salt wedge was present, he would find few organisms (PATRICK, 1962; HENDRICKS, et al., 1969). Finding few organisms under these conditions could hardly be attributed to man-made pollutants.

One also must consider the location of the sampling site in the river where samples are to be taken when studying a river such as the Sabine. Samples taken along the banks and areas outside the main channel will invariably yield more organisms than those taken at mid-channel (PERCIVAL & WHITEHEAD, 1929; HENDRICKS et al., 1969). This is due primarily to the types of bottom sediments. In the Lower Sabine River, sediments of debris and mud are found along the banks and shallow areas. At mid-channel a coarse sand is found. The shallow areas provide ideal habitats for the bottom organisms. Therefore, samples taken from this area would yield many organisms

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organisms and species.

Data taken during the past th
indicate that the natural stresses p
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able to withstand exposure to
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priority.

Other aspects of effluent disch
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waste compounds reach the estu
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2. Species diversity indices v
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3. The data suggest that th
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diversity of the bottom fauna
4. Due to the natural quality
extremely important that grea
mill waste into the river. The
the river must be the primary

Collected from
1968, Fall 1968

	r²
68	0.43
15	0.24
11	0.47
39	0.20
77	0.40
55	0.29
24	0.27
04	0.49
77	0.54
70	0.42
75	0.53
06	0.46
58	0.59
73	0.38
09	0.40
13	0.36
25	0.37
03	0.71

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...n the future effects on the bottom fauna from continued dump-
...of paper mill wastes. If the harsh conditions of the river have
...duced a very hearty group of organisms, perhaps they will be
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...ts. If, on the other hand, the bottom organisms are in the
...carious position of being able to barely tolerate the natural con-
...ions, then the extra stress imposed by the mill's pollutants could
...the proverbial straw. Certainly it would be to the benefit of the
...r if the first supposition is true and the data does tend to sub-
...ntiate this; however, the last supposition must be given the highest
...rity.

Other aspects of effluent discharging that have not been consider-
...nt which should be are the possible effects the waste will have on
Sabine River Estuary. The proximity of the mill's outfall to the
...ary is such that much of the material from the plant could
...ve at the estuary virtually unchanged. Due to the reduced move-
...nt of the water and change in chemical environment when these
...te compounds reach the estuary, it would be possible and proba-
...for the compounds to settle to the bottom of the estuary. A
...ld-up of such compounds would certainly have a detrimental ef-
... upon the estuary. (For the purpose of clarification it should be
...nted out that the paper mill is meeting its discharge permit for
...leable solids.) This problem can only be resolved by allowing
...uent with the lowest possible loads to be discharged into the river.

SUMMARY

1. Bottom fauna were collected during sampling periods in 1967, ...68, and 1969 from the Lower Sabine River.
2. Species diversity indices were determined for the various sta-...ns sampled.
3. The data suggest that the natural environmental and semi-...lluted conditions have acted in such a manner as to depress the ...ersity of the bottom fauna populations.
4. Due to the natural quality of the Sabine River water, it will be ...tremely important that great care be exercized when discharging ...ill waste into the river. The physical and chemical conditions of ...e river must be the primary factor which determines when wastes

will be discharged. That is, during high flows on the river, discha...
times would be optimum.

5. Due to the proximity of the mill's outfall to the Sabine R...
estuary and the natural tendancy of such bodies of water to ac...
natural catch basins, it becomes imperative that the best poss...
treatment facilities be employed by the paper mill.

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