APPRAISAL OF OTTER TRAWL TOW LENGTHS AND REPLICATE SAMPLING

VINCENT GUILLORY, Louisiana Department of Wildlife and Fisheries, Marine Research Laboratory, Grand Isle, LA 70358
JOHN E. ROUSSEL, Louisiana Department of Wildlife and Fisheries, Marine Research Laboratory, Grand Isle, LA 70358
CAROLYN MILLER, Louisiana Department of Wildlife and Fisheries, Marine Research Laboratory, Grand Isle, LA 70358

Abstract: This study was conducted to determine the effects of otter trawl tow length on variability and catch rates, and to assess replicate sampling. Longer tows caught more individuals/minute, individuals/tow, and species/tow than the shorter tows. The total number of species caught per hour of sampling, however, were essentially equal for all tow lengths. No difference in precision between tow lengths were detected. The number of replicates needed to detect changes within desirable statistical limits were logistically impractical. We recommend that otter trawls be used strictly for qualitative purposes and conclude that a small number of replicated 10-minute tows would adequately describe basic community structure.

Proc. Ann. Conf. S.E. Assoc. Fish & Wildl. Agencies 34:158-166

Most marine biologists recognize the importance of utilizing various gear types to sample estuarine fish communities. However, most researchers use otter trawls to sample fish in the Gulf of Mexico coastal waters. The popularity of the trawl is due to the economic, versatile nature of the gear, minimal manpower and vessel requirements, and its ability to sample commercially important species such as shrimp and blue crabs (Livingston 1976, Kjelson 1977). Member states participating in the Gulf of Mexico Estuarine Inventory recommended standardized gear and sampling procedures for otter trawls, which most marine biologists adopted individually. In regards to gear specifications, a 4.9 m long flat type with 19.1 mm bar mesh wings and 6.4 mm bar mesh tail was adopted; operationally, this trawl was to be towed for 10 minutes at approximately 3 knots.

Further improvements and refinements are still needed, however, to surmount certain problems inherent in otter trawl usage. In particular, trawling data usually exhibits such variability that estimates of low precision are obtained unless sample effort is large. Variance associated with mean trawl catch per tow is high because of the heteregeneous distribution of fish (Taylor 1953). Taylor (1953) suggested that the variability could be reduced by a reduction in the length of the tow. Lambou (1963), in his analysis of sampling variability, also concluded that the variance could be reduced by taking a larger number of smaller-unit samples. Since then several marine investigators have utilized pooled data from a series of replicated 2-minute tows (Roessler 1965, Livingston 1976). However, no one has analyzed trawl sampling variability from a series of repetitive samples of different tow lengths to determine the most efficient and precise tow length. The primary objectives of this report are to determine the effects of otter trawl tow length on variability and on catch rates and to assess the replicate sampling scheme.

METHODS

All samples were taken in Barataria Bay just north of the Marine Research Laboratory on Grand Terre Island, Louisiana along a transect immediately eastward of a protruding pipeline marker. General biological, geological and physical descriptions of the Barataria Bay system have been presented in Adams et al. (1976), Bahr and Hebrard (1976), and Wax et al. (1978).

A 4.9 m flat otter trawl with 19.1 mm bar mesh wings and 6.4 mm bar mesh tail was used. This trawl was towed in a straight line at 1200 rpm. Sampling duration was defined as the length of time the trawl was actually towed by the boat at the designated trawling speed. In other words, time commenced after the tow line became taut and the standard rpm was reached, and time terminated when the engine was placed in neutral and forward movement of the trawl ceased. Fish collected in the samples were identified, counted, and weighed in the aggregate by species in the laboratory.

Sampling for the first and second segments of the study was undertaken in June and July, 1979. The first segment involved "equal effort" sampling (i.e., 1 hour of total trawling time) for all tow lengths. Two 15-minute, three 10-minute, six 5-minute, and fifteen 2-minute samples were made on each of 2 sampling days. The second segment consisted of a series of 25 repetitive 2-, 5-, 10-, and 15-minute tows each on separate days.

The precision and variability of each tow length was evaluated by applying various statistical computations and tests to the data. Cumulative means and 95 percent confidence intervals, coefficient of variation, empirical estimation of sample size (Burns 1966), and species accumulation curves were calculated on the repetitive trawl data. The first 3 calculations were based on both number of individuals and number of species, whereas the last 1 was based only on number of species. An analysis of variance (ANOVA) was performed on the equal effort data for the following: total number of species; species per tow; individuals per tow, and individuals per minute. The level of significance for all statistical tests was set at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Data from the fifteen 2-minute, six 5-minute, three 10-minute, and two 15-minute tows taken on each of two days are presented in Table 1. This equal effort data was used primarily to assess the effects of tow length on catch rates. The total number of species collected ranged from 15 in 10-minute tows to 19 in 5-minute tows. The total number of species collected in each tow length was not statiscally different (Table 1); however, the species per tow increased from 4.5 in the 2-minute tows to 9.8 in the 15 minute tows. The total number of individuals captured steadily increased for each tow length from 654 in the 2-minute tows to 1367 in the 15-minute tows. The number of individuals per tow increased from 21.7 in the 2-minute tows to 341.5 in the 15-minute tows. Differences in both catch per minute and catch per tow of individuals were found to be highly significant ($P \leq 0.01$). Tow length appeared to influence number of individuals more than total number of species. Other studies yielded varying results on catch rates of different tow lengths. Tow lengths of 5-, 10-, and 15-minutes yielded no significant differences in blue crab catch per tow (Chittenden and Van Engel 1972). Chittenden (1978) also found tow duration to be a minor factor in the total variation of catches of penaeid shrimp; tow duration only accounted for 9-15 percent of the variation. In other words, increasing towing time would not necessarily increase shrimp catch. Livingston (1976) found that short repetitive samples improved the effective catch potential of the otter trawl for both number of species and number of individuals. He could not explain the increase in trawling efficiency but indicated that the weight of a heavy load of detritus and animals could alter the action of the trawl.

Replicate data were obtained to measure variability and to assess replicate sampling. Catch rates from these samples were not compared because replicates for each tow length were taken on different days. Coefficients of variation (c.v.) for the replicate data were calculated for the 16 most abundant species and on number of species per sample and number of individuals per sample for each tow length (Table 2).

The 10-minute tows had the lowest c.v. for both species and individuals. The ranges in c.v. were obviously narrow and no attempt was made to determine whether any of the differences in c.v. were statistically significant. Smaller sample units supposedly generate data of greater precision than larger units because variation theoretically increases in longer tows due to the heterogeneous nature of the population (Roessler 1965, Taylor 1953). The data presented in this study indicates that no one tow length was any more precise than the others. The c.v. from our otter trawl study were lower than those reported in the literature: 0.40-0.80 by Barnes and Bagenal (1951); 0.0-2.0 by Taylor (1953); and 0.55-1.00 by Kjelson (1977).

The number of samples required for each tow length to describe the population mean within prescribed statistical limits is presented in Table 3 for both mean number of species and mean number of individuals. The number of replicates needed to detect changes with an acceptable error of 5-10 percent of the mean and a level of significance of 0.05-0.10 desirable for field research, or a level of significance of 0.20, used sometimes for management decisions, would be logistically impractical; the possible exeption would be the number of samples required to detect a 10 percent change in number of species at the 0.10 or 0.20 level of significance. In most cases, considerable effort would be involved in decreasing the confidence limits about the mean or increasing the level of significance. For instance, decreasing the acceptable confidence limits by half from 10 percent to 5 percent of the mean would quadruple, not double, the sampling effort. In reality, it may be uneconomical to expend such high levels of sample effort to achieve such small improvements in precision. Several other important points are apparent from data presented in Table 3. First, the number of samples required to detect changes in number of species is much smaller than those required to detect changes in number of individuals for the same statistical limits. Second, because of small differences in precision of each tow length, the variation in number of samples between tow length is unimportant, especially considering the large number of samples needed to achieve desirable statistical limits. Grosslin (1971) and Kjelson (1976) calculated the number of otter trawl hauls necessary for certain levels of precision in the estimates of indices of abundance for several species and also found the required sampling effort to be very high.

The effects of increasing sample number on mean number of species per tow and 95 percent confidence intervals are presented for each tow length in Fig. 1. Generally, the

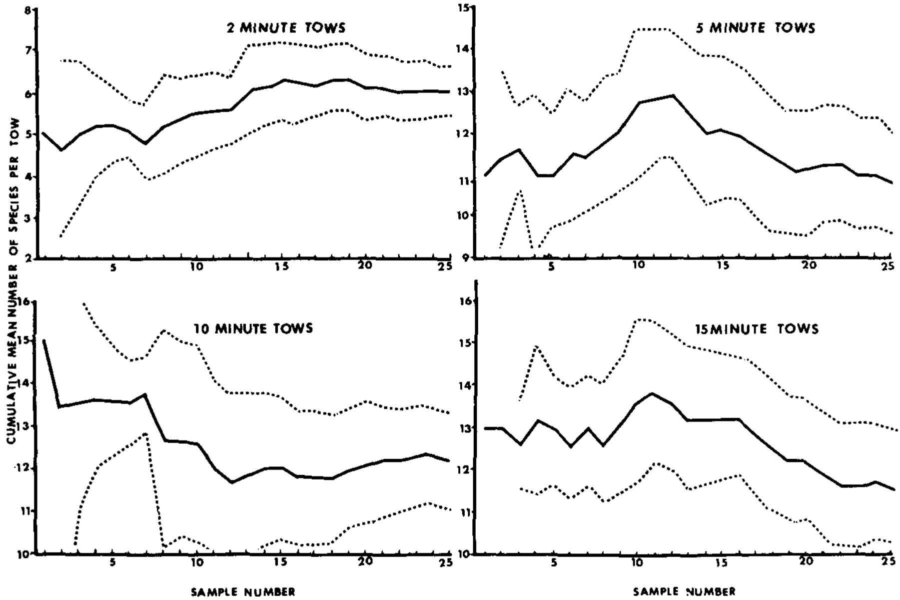

Fig. 1. Cumulative mean number of species per sample and 95 percent confidence intervals for 25 replicates of each tow length (solid line = mean, dashed line = confidence intervals).

greatest reduction in 95 percent confidence intervals occurs between samples 2 and 5. After 5 samples, meaningful improvement in 95 percent confidence intervals would require a considerable increase in sample number. The effects of sample number on the cumulative mean of successive samples follow a pattern similar to that of the 95 percent confidence intervals, with fluctuations in the cumulative mean corresponding to wide confidence intervals. However, fluctuations in the cumulative mean appear to be affected less by sample number than does the width of the confidence interval. Although fluctuations in the cumulative mean are occurring through all 25 samples, most of the sizeable fluctuations occur before 15 samples have been summed.

Fig. 3 illustrates the effects of increasing sample number on mean number of individuals per tow and 95 percent confidence intervals. Again the greatest reduction in 95 percent confidence intervals occurs between samples 2 and 5. However, appreciable reduction occurs through the first 10 samples for tows of 5 minutes or longer. Fluctuations in the cumulative mean are wide during the first few samples and decrease as sample number increases.

A species accumulation curve (Fig. 4) illustrates the rate of increase of previously unencountered species with increased number of samples. The accumulation curve of species for the 2-minute tows maintains a nearly constant slope, whereas the curve for tows greater than 2 minutes start to level somewhere between 4 and 10 samples. Consequently, the optimum sample number based only on species accumulation would be in the 4-10 tow range for tows longer than 2 minutes and, possibly, some value greater than 25 for the 2-minute tows. In Appalachicola Bay an asymptote was reached on species accumulation curves by the seventh 2-minute sample (Livingston 1976).

Final recommendations on the most precise tow length and assessment of replicate sampling are based both on our equal effort and replicate samples for each tow length. There are advantages in taking repetitive samples as opposed to a single sample. The

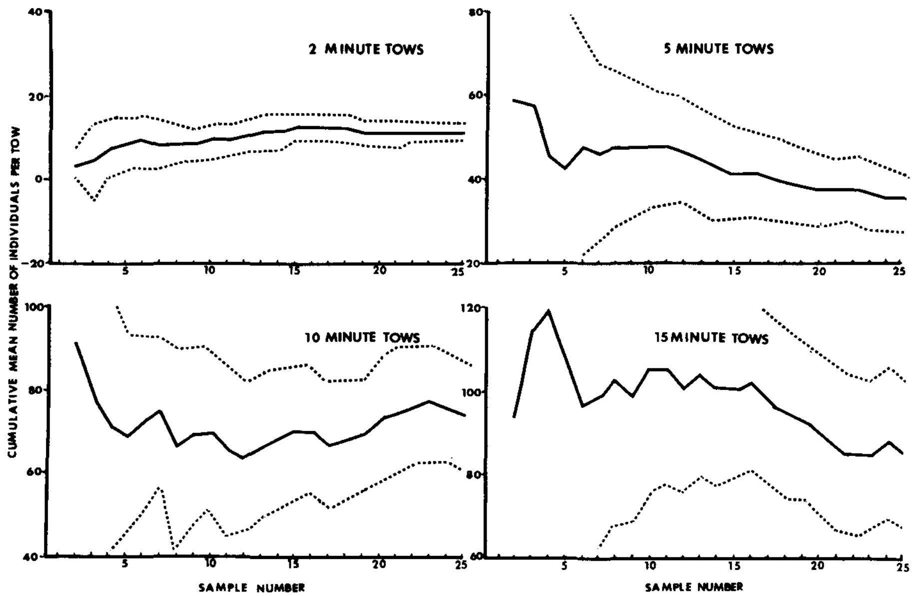

Fig. 2. Cumulative mean number of individuals per sample and 95 percent confidence intervals for 25 replicates of each tow length (solid line = mean, dashed line = confidence intervals).

repetitive method of collection allows for statistical analysis of sampling efficiency and more individuals and species are captured than in a single tow. The number of replicates that must be taken to yield meaningful results is of paramount importance in the practical problems of designing and financing a biological study. Our empirically estimated sample sizes needed to describe the population within desirable statistical limits are logistically impractical. Our cumulative mean and 95 percent confidence intervals graphs also suggest a large number of samples. Because of this, we follow the recommendation of Mearns and Allen (1978) who stated that the primary focus of otter trawl surveys should not be quantitative but rather on documenting presence or absence of species, relative abundance, and size distributions. We also add basic community structure. Considering the primary emphasis of otter trawl surveys, we suggest that simple species and number of individuals accumulation or, possibly, cumulative species diversity data be used to determine sampling effort. Mearns and Allen (1978) concluded that otter trawl catches on the order of 200-1000 individuals, representing 20-30 species, were more than adequate the assess the dominant biological characteristics of a given station. Livingston (1976) used cumulative species diversity graphs to determine his sampling effort. He found that the graph becomes asymptotic during early stages of collection because of the relatively high level of dominance and low number of species usually encountered in estuaries.

Insofar as tow length is concerned, the use of 10-minute tows is recommended because it can be compared with historic data obtained in most trawl surveys, it captures more individuals and species than shorter tows, and there are no differences in precision between any tow lengths. Moreover, there is little difference in total sampling time between the 10-minute and shorter tow lengths. The handling time (i.e., raising and lowering trawl, removing fish, etc.) comprises a large portion of the time spent in sampling and is approximately equal for all tow lengths. Thus, five 10-minute samples do not take 5 times longer than five 2-minute samples. Chittenden (1978) also recommended 10-minute otter trawl tows for monitoring brine discharge. Using the 10-minute tow lengths and the guidelines suggested earlier, it would appear that 4-5 replicates would adequately describe the fish community at the station we sampled. At this point, approximately 83 percent of the total species captured in the 25 replicates had been collected. However, a pilot survey should be made before each study to obtain replicate data for determination of optimum sample number.

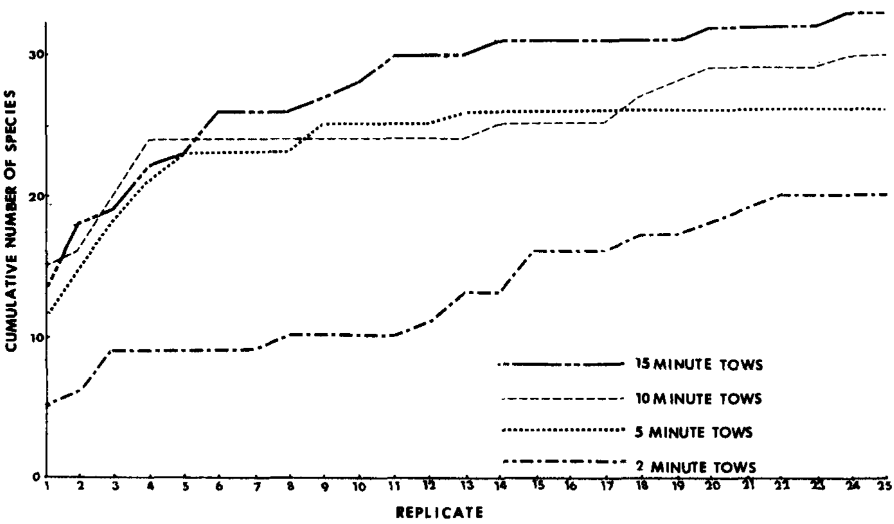

Fig. 3. Species accumulation curves for 25 replicates of each tow length.

Table 1. The number of individuals and species collected for each tow length and each day (1 or 2) in the equal effort sampling (effort = 30 min./day; T = total)

	2'			5'			10'			15'		
	1	2	T	1	2	T	1	2	T	1	2	T
Total individuals	283	371	654	433	379	812	472	679	1151	347	1020	1367
Total species	13	15	17	14	14	19	12	13	15	13	13	17
Mean individuals/tow	18.9	24.7	21.8	71.2	63.2	67.2	157.3	226.3	191.8	173.5	510.0	341.8
Mean individuals/minute	9.4	12.4	10.9	14.4	12.6	13.4	15.7	22.6	19.1	11.6	34.0	22.8
Mean species/tow	4.1	4.9	4.5	7.7	5.5	6.6	8.0	10.0	9.0	10.0	9.5	9.8

Table 2. Mean catch per tow (c/c) and coefficients of variation (c.v.) for 16 individual species, for number of species and total number of individuals in 25 replicate samples of each tow length.

	2'		5'		10'		15'	
Species	c/e	c.v.	c/e	c.v.	c/e	c.v.	c/e	c.v.
Anchoa hepsetus	0.20	3.23	0.60	1.36	0.28	2.63	0.36	2.39
Anchoa mitchilli	5.80	0.53	17.92	0.51	37.08	0.44	44.92	0.49
Synodus foetens	0.56	1.27	2.76	0.88	0.12	2.76	0.24	2.18
Caranx hippos	0.04	5.00	0.56	2.00	0.56	1.46	0.08	5.00
Leiostomus xanthurus	0.20	5.00	0.96	1.36	1.44	1.57	0.56	3.26
Menticirrhus americanus	0.04	5.00	0.08	3.45	0.16	2.34	0.16	2.34
Micropogon undulatus	0.08	3.45	1.60	1.37	1.20	0.90	1.08	1.10
Chaetodipterus faber	0.04	5.00	0.32	2.34	0.60	1.07	1.72	2.60
Peprilus burti	1.20	1.30	1.64	1.77	0.24	2.76	0.68	3.25
Prionotus rubio	0.20	2.50	0.64	1.27	1.60	1.17	1.04	1.46
Citharichthys spilopterus	0.32	1.49	0.84	1.32	5.32	0.76	8.16	0.67
Etropus crossotus	0.20	2.04	0.36	1.58	6.88	0.73	5.44	0.87
Lagocephalus laevigata	0.04	5.00	0.20	2.04	0.08	3.45	0.04	5.00
Sphoeroides parvus	2.48	0.82	1.72	1.14	9.08	0.96	1.16	1.99
Chilomycterus schoepfi	0.04	5.00	0.12	2.76	0.08	3.45	0.04	5.00
Penaeus aztecus	3.24	0.59	8.44	1.01	16.84	0.57	36.44	0.98
Callinectes sapidus	3.56	0.81	10.00	0.73	11.76	0.57	9.84	0.60
Number of species/tow	6.00	0.26	11.16	0.27	12.20	0.22	11.68	0.29
Number of individuals/tow	11.64	0.54	37.36	0.49	74.12	0.43	86.68	0.50

Table 3. Empirically estimated sample size needed for 5, 10, 15 percent confidence limits (C.L.) for given levels of significance for each tow length.

Level of	5 Percent C.L.				10 Percent C.L.				20 Percent C.L.			
Significance	2'	5'	10'	15'	2'	5'	10'	15'	2'	5'	10'	15'
					Number of individuals							
99	709.3	597.5	471.8	632.5	177.3	149.4	118.0	158.1	44.3	37.3	29.5	39.5
95	334.3	281.6	224.4	298.2	83.6	70.4	55.6	74.5	20.9	17.6	13.9	18.6
90	198.4	167.1	132.0	176.9	49.6	41.8	33.0	44.2	12.4	10.4	8.2	11.1
80	83.9	70.7	55.8	74.8	21.0	17.7	13.9	18.7	5.2	4.4	3.5	4.7
70	32.2	27.1	21.4	28.7	8.0	6.8	5.4	7.2	2.0	1.7	1.3	1.8
60	7.5	6.3	5.0	6.7	1.9	1.6	1.2	1.7	0.5	0.4	0.3	0.4
					Number of species							
99	166.7	177.3	116.8	213.5	41.6	44.3	29.2	53.4	10.4	11.1	7.3	13.3
95	78.6	83.6	55.1	100.6	19.6	20.9	13.7	25.2	4.9	5.2	3.4	6.3
90	46.6	49.6	32.7	59.7	11.6	12.4	8.2	14.9	2.9	3.1	2.0	3.7
80	19.7	21.0	13.8	25.2	4.9	5.2	3.5	6.3	1.2	1.3	0.9	1.6
70	7.6	8.0	5.3	9.7	1.9	2.0	1.3	2.4	0.5	0.5	0.3	0.6
60	17.5	1.9	1.2	2.3	0.4	0.5	0.3	0.6	0.1	0.1	0.1	0.1

LITERATURE CITED

ADAMS, R. D., B. B. BARRETT, J. H. BLACKMON, B. W. GORE, and W. G. McINTIRE. 1976. Barataria Basin: geologic processes and framework. La. St. Univ. Cent Wetland Resourc., Sea Grant Publ. No. LSU-T-76-006. 117pp.

BAHR, L. M. and J. J. HEBRARD. 1976. Barataria Basin: biological characterization. La. St. Univ. Center Wetland Resourc., Sea Grant Publ. No. LSU-T76-005. 143pp.

BARNES, H. and T. B. BAGENAL. 1951. A statistical study of variability in catch obtained by short repeated trawls taken over an inshore ground. Mar. Biol. Assoc. U.K. 29:649-660.

BURNS, J. W. 1966. How big a sample? Pages 161-162 *in* A. Calhoun, ed. Inland fisheries management. California Department of Fish and Game. Sacramento.

CHITTENDEN, M. E., JR. 1978. An evaluation of the relationships between catch and tow duration for the brown shrimp *(Penaeus aztecus)* white shrimp *(P. setiferus)*, and pink shrimp *(P. duorarum)*. Texas A & M Univ., Envir. Eng. Div. Final Rept. Predisposal Stud. 122pp.

______ and W. A. VAN ENGEL. 1972. Effect of a tickler chain and tow duration on trawl catches of the blue crab, *Callinectes sapidus*. Trans. Am. Fish. Soc. 102:732-734.

CLARK, S. H. 1974. A study of variation in trawl data collected in Everglades National Park, Florida. Trans. Am. Fish. Soc. 103:777-785.

GROSSLEIN, M. D. 1971. Some observations on accuracy of abundance estimates derived from research vessel surveys. Res. Doc. ICNAF 71/59. 27pp.

KJELSON, M. A. 1977. Estimating the size of juvenile populations in southeastern coastal plain estuaries. Pages 71-90 *in* W. Van Winkle, ed. Proceedings of the conference on assessing the effects of power-plant-induced mortality on fish populations, Permagon Press, New York.

LAMBOU, V. 1963. Application of distribution patterns of fishes in Lake Bistineau to design of sampling programs. Prog. Fish-Cult. 25:79-85.

LIVINGSTON, R. J. 1976. Duirnal and seasonal fluctuations of organisms in a north Florida estuary. Est. Coastal Mar. Sci. 4:373-400.

MEARNS, A. J. and M. J. ALLEN. 1978. Use of small otter trawls in coastal biological surveys. U.S.E.P.A., Rept. No. EPA-600/3-78-083. 35pp.

ROESSLER, M. A. 1965. An analysis of the variability of fish populations taken by otter trawl in Biscayne Bay, Florida. Trans. Am. Fish. Soc. 94:311-318.

TAYLOR, C. C. 153. Nature of variability in trawl catches. Fish. Bull. 54:145-166.

WAX, C. L., M. J. BORENGOSSER, and R. A. MULLER. 1978. Barataria Basin: synoptic weather types and environmental responses. La. St. Univ. Center Wetland Resour., Sea Grant Publ. No. LSU-T-78-001. 60pp.