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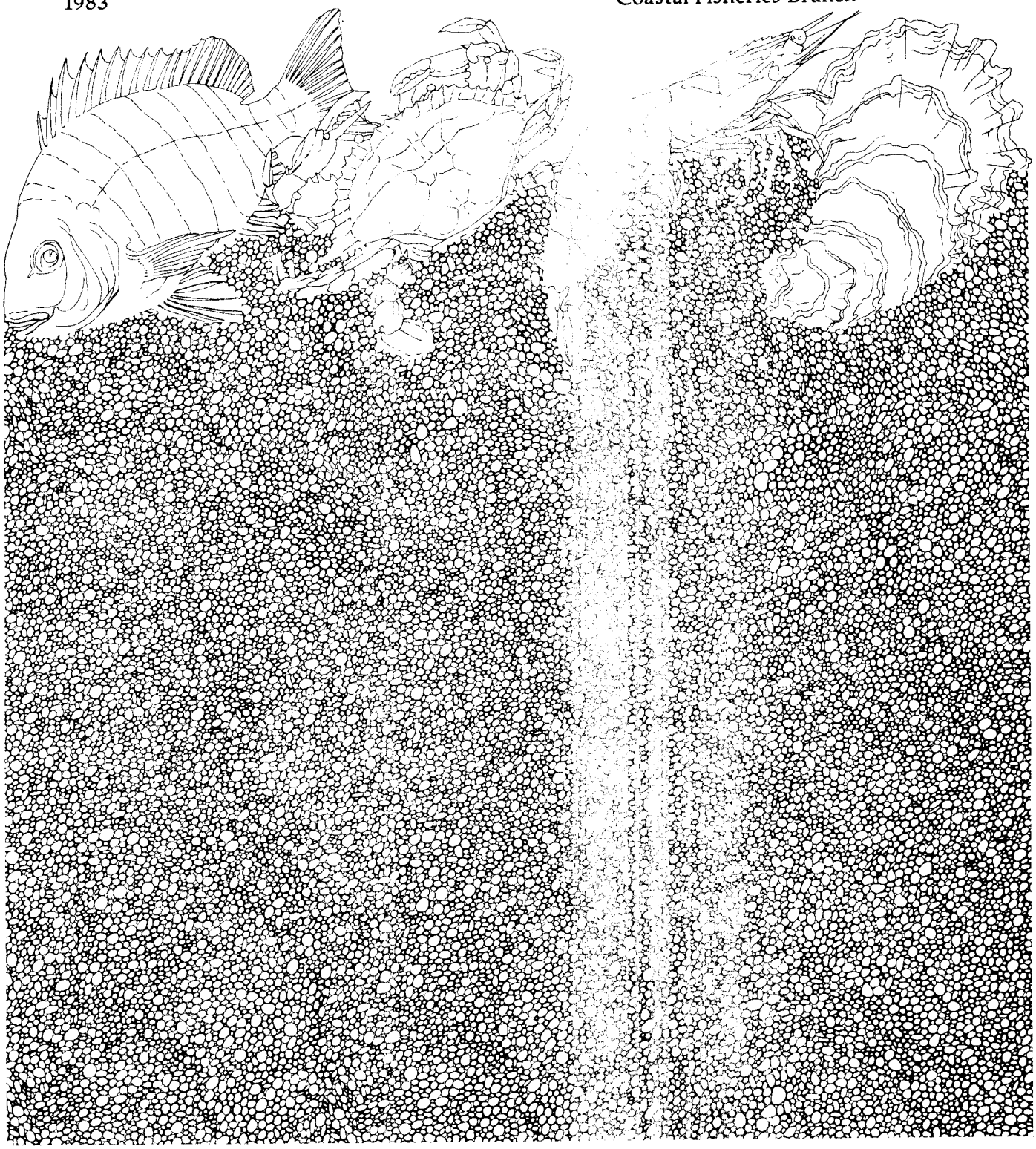

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ABSTRACT

To determine the closing and opening dates of the shrimping season in the Texas territorial sea in 1982 and relative abundance of brown shrimp (Penaeus aztecus) in 1981 and 1982, samples were taken with 18.3 m (60.0 ft) bag seines along shorelines of seven bay systems; with 6.1 m (20.0 ft) trawls in the deeper ($\geq$ 0.9 m or 3 ft) portions of three bay systems and in five passes leading from the bays to the Gulf; and with 12.2 m (40.0 ft) trawls in Gulf of Mexico waters off the central coast. The purpose of the closed season was to protect small shrimp from fishing until they reached a larger, more valuable size and to minimize waste caused by discarding smaller sizes during the harvest. Based on biological sampling in April the closed season dates were set for 25 May-14 July 1982. Additional sampling through July verified that these dates were appropriate to accomplish the purpose of the closure.

There was no significant ($P > 0.05$) differences between mean catch rates of brown shrimp in 1981 and 1982 along shorelines during April-June or the deeper bays sampled during 15 May-31 July. The major differences between the 2-years was a more prolonged movement of shrimp from the bays to the Gulf in 1982 as indicated by mean catch rates in trawls through time in 2 of the 3 bay systems sampled. The causes or effects, if any, of this different pattern are not understood at this time. Coastwide sampling in Gulf waters off Texas by the National Marine Fisheries Service and Texas Parks and Wildlife Department during June-July indicated there were about 30% fewer shrimp in 1982 than in 1981. Continued fishery independent sampling in a similar fashion as in 1982 should aid in clarifying cause and effect relationships.

INTRODUCTION

Shrimp are the most valuable commercial seafood product landed in the United States each year. In 1981 160.8 million kg, heads on, valued at $463 million to the fishermen were reported (U. S. Department of Commerce 1982). Texas contributed greatly to national shrimp production in 1981 with reported landings of 43.4 million kg valued at $165 million (Hamilton 1982). If an economic multiplier of 3 (Grubb 1973) is applied to reflect the impact of the landings at the wholesale level their minimum value to the Texas economy approached $500 million in 1981. Shrimp are the most important commercial Texas fishery accounting for about 95% of the value and over 80% of the weight of seafood products landed each year; and brown shrimp (Penaeus aztecus) is the most important species, comprising about 80% of weight and value of the annual reported landings (Hamilton 1982).

Brown shrimp spawn in the Gulf of Mexico, go through several larval stages and enter the bays during February-April as post-larvae (Baxter and Renfro 1967, King 1971). They seek the shallow peripheral areas (nursery areas) in the bays where they grow rapidly, migrate to the deeper portions of bays and then in late May or early June return to the Gulf at a mean size of about 90 mm total length (Trent 1967, Parker 1970, King 1971, Benefield 1983). Movement back to the Gulf through passes is mainly at night during long tidal durations (King 1971).

Shrimp are managed by the Texas Legislature through the Shrimp Conservation Act of 1959 (Parks and Wildlife Laws 1981). This Act established a closed season in the state's territorial waters (9 nautical miles) during 1 June-15 July each year but authorized the Texas Parks and Wildlife Commission (TPWC) to adjust both the closing and opening dates as long as the total closure was $\leq$ 60 days.

The purpose of this annual closure is to protect small shrimp from fishing until they reach a larger, more valuable size and to minimize waste caused by discarding smaller sizes during the harvest. Texas has closed its territorial waters for over 20 years, and the statutory 1 June-15 July season date was changed in 1967, 1972, 1976 and 1981. The rationale for adjusting the closure dates was detailed by Moffett (1967, 1972), Johnson (1982) and Benefield (1983). While small shrimp were protected in the state waters by the closure, large numbers of small shrimp were still captured and discarded from waters beyond the state's jurisdiction (Berry and Benton 1969, Baxter 1973, Bryan et al. 1983).

In 1981 the Gulf of Mexico Fishery Management Council's management plan for shrimp was implemented (Center for Wetland Resources 1980). Among other options, this plan called for the closure of U. S. waters (>9 to 200 nautical miles) off Texas to complement the traditional Texas closed season. Total closure of Gulf waters off Texas during 22 May-15 July 1981 was believed to have been beneficial by increasing the overall yield and value of the northern Gulf brown shrimp fishery (Jones et al. 1982).

The objectives of this report are to:

1. document the rationale behind the recommendation for the 1982 dates of closing and opening the Texas territorial sea to shrimping; and

2. determine the relative abundance of juvenile brown shrimp in Texas bays during 1981-82 as indicated by biological sampling.

MATERIALS AND METHODS

The biological sampling program was based on the life cycle of the shrimp. Samples were collected along shorelines with 18.3-m wide bag seines to capture post-larval and juvenile shrimp as they were first recruited to the gear; 6.1-m wide otter trawls were used to capture shrimp as they moved to the deeper ($\geq$ 0.9 m) portions of bays, then through the passes leading to the Gulf of Mexico; and finally 12.2-13.7-m wide otter trawls were used in Gulf waters where the shrimp complete their life cycle.

The 18.3-m wide bag seines had 19.0-mm stretched mesh in the wings and 12.7-mm stretched mesh in the 1.8-m wide bag. They were pulled parallel to shore at randomly selected stations for a minimum distance of 15.2 m and a maximum distance of 30.5 m and the catch was expressed as No./ha. Six samples per month were collected during October 1977-September 1981 and 10 samples per month October 1981 through June 1982 in each of the following bay systems: Galveston, Matagorda, San Antonio, Aransas, Corpus Christi and the upper and lower Laguna Madre (Figures 1-9). One half of the samples were collected during the first 2 full weeks of each month and one half during the last 2 full weeks each month. Additonal sampling details are given in Hegen (1982).

The 6.1-m trawls had mesh sizes of 39.1-mm stretched mesh throughout and were spread by 0.5 x 1.2 m otter doors. No tickler chain was used. In 1981 stations were at fixed locations in Galveston, San Antonio and Aransas Bays (Figures 10, 11, 12, 14 and 15) and sampled during mid-May and twice monthly (first half and second half of month) during June-July. The number of monthly samples per bay system varied from 9 to 18. Beginning January 1982 bays were partitioned into sampling grids based on longitude-latitude coordinates one minute apart and stations from these grids were selected randomly. Comparisons between 1981 and 1982 trawl samples in this report are based on 1982 random samples that fell with 1.6 km of 1981 historical sites during each sampling period in Galveston, San Antonio and Aransas Bays. Monitoring with 6.1-m trawls was increased during May 1982 to include Matagorda and Corpus Christi Bays and the Laguna Madre to correspond with areas that were being sampled with bag seines (Figures 10-19). Galveston, Matagorda, San Antonio, Aransas and Corpus Christi Bays were stratified into upper (Zone 1) and lower (Zone 2) bay areas (Figures 10-16). Ten samples per month were taken in each zone (5 per each 2-week sampling period). The upper and lower Laguna Madre were considered lower zones only and 10 samples per month were taken in those areas--five every 2 weeks. Trawls were towed for 15 minutes in a circular pattern near the center of randomly selected sample grids.

Samples in passes (Zone 3) were collected with 6.0-m trawls weekly in Bolivar Roads (Galveston Bay), Pass Cavallo (Matagorda Bay), Lydia Ann Channel (Aransas Bay), Corpus Christi Ship Channel (Corpus Christi Bay) and Brazos Santiago Pass in the lower Laguna Madre (Figures 12, 13, 15, 16 and 19). Two samples per week were taken in each pass parallel with the orientation of the pass. Direction of tow (bayward or Gulfward) was alternated with each sample.

Samples in the Gulf of Mexico were collected along the central coast (Figure 20) between 15-30 June in 1978-82. Samples were collected in transect at depths approximately 9.1 m apart out to 36.6 m off Port Aransas during 1978-81 and randomly from Pass Cavallo to Baffin Bay in 1982. Trawls were 12.2-13.7-m wide with 44.5-mm stretched mesh spread by 0.9 x 2.1 m otter doors. A tickler chain was used. Tows were generally for 30 minutes duration at a speed of 4-5 km.

All brown shrimp captured in each sample were counted. A minimum of 19 shrimp (if available) in bag seine samples and 50 shrimp in trawl samples were measured. Total lengths were measured in mm from tip of rostrum to tip of telson.

Catches were expressed in No./ha (bag seines), No./15 minute tow (6.1 m trawls) and No./h (12.2-13.7 m trawls). The coastwide mean catch (number and size) in bag seines was weighted by shoreline distance in each bay system and mean trawl catch rates were weighted by the area of open water in each bay system (Matlock and Ferguson 1982). Projected growth rates for combined bays were based on the Von Bertalanffy model from Parrack (1979). Sexes were assumed to be 50% male and 50% female since shrimp were not sexed.

Bag seine data were analyzed for significant differences of mean catch rates among bay systems, and time periods for 2 years using a three-way analysis of variance (ANOVA) (Sokal and Rohlf 1981). Trawl data were analyzed for significant difference of mean catch rates among bay systems and time periods for 2 years using a three-way ANOVA which allows for unequal and disproportionate sample size (Overall and Spiegel 1969). Catch rates were transformed to common logarithms after adding 1 to reduce variance heterogeneity.

The following criteria, procedures and assumptions were used to recommend the closing date of the 1982 shrimping season in the Texas territorial sea:

1. The number of shrimp captured in bag seines during April 1982 was compared to the mean number caught during normal 1 June closure years (1978, 1979, 1980). Relatively large numbers of shrimp (> April mean for 1978-1979 and 1980 plus 2 S. E.) captured in April were interpreted as indicating good survival and/or early recruitment of post-larval shrimp and therefore a probable earlier than 1 June emigration from bays to the Gulf.

2. The percentage of samples in which brown shrimp occurred. A relatively high percentage of samples containing shrimp was interpreted to mean that shrimp were well distributed coastwide.

3. The mean length of shrimp during April. If the number of shrimp in samples indicated an early migration, the Von Bertalanffy growth model from Parrack (1979) was used to estimate the date that shrimp captured in April would reach a mean length of 90 mm.

4. The period of longest outgoing tides immediately following the date that the shrimp caught in April were projected to reach 90 mm was determined and recommended as the closure date.

The following criteria, procedures and assumptions were used to recommend the opening date of the 1982 shrimping season:

1. Catch rates in the Gulf of Mexico in depths of 7.3-36.6 m during 15-30 June were compared to previous years to determine relative abundance. Similar catch rates between years were interpreted to indicate that recruitment into the Gulf shrimping grounds had occurred. If shrimp are relatively abundant in Gulf waters by the latter half of June the shrimping fleet has an opportunity to disperse when the season opens. This should reduce fishing pressure on those smaller shrimp which may be continuing to emigrate from the bays.

2. Mean sizes in the Gulf of Mexico during 15-30 June were obtained and growth rates projected to determine recommendation for an earlier or later opening date. The criteria was that the majority of brown shrimp on the fishing grounds in depths of 7.3-36.6 m would be 39 whole shrimp (112 m) to the pound when the season was opened.

3. Number and mean size of shrimp caught in bag seines during June were compared to those caught in previous years. If substantial numbers of small shrimp (a mean of 2 S. E. greater than average) were still found along shorelines the season could be extended to the full 60 days authorized.

RESULTS

Recommendation for Season Dates

The Closure Period. Data indicated that an early emigration of shrimp to the Gulf of Mexico in 1982 was probable. In April the mean number of shrimp captured in bag seines was similar (1.77/ha) to 1981 (2.03/ha), but 2 S.E. > the mean catch rate (0.53/ha) for 1978, 1979 and 1980 (Table 1). The percentage of samples containing shrimp in 1982 was 64.29% compared to a mean of 28.00% for 1978-80, indicating more shrimp with a wider distribution than normal.

Mean length of shrimp was 47.50 ± 2.20 mm in April 1982 (Table 2) and growth calculated from 15 April indicated that the mean length would be 90 mm on about 20 May. The periods of longest outgoing (ebb) tides as predicted for Galveston Bay were 11-15 May, 25-28 May and 6-13 June (Figure 21). The period of outgoing tides which immediately followed the date that shrimp were projected to reach a mean length of 90 mm began on 25 May. Therefore, the recommended Gulf closure period was from 30 minutes after sunset on 25 May to 30 minutes after sunset on 14 July 1982.

Samples in passes indicated the major movement to the Gulf began during the latter half of May (4.5/tow) and that the 25 May recommended closure date was appropriate (Table 3). Greatest numbers of shrimp were found along shorelines from 16 April through 15 June (about 1000-2000/ha); in deeper portions of bays from May through July (about 10 to 40/tow); and in passes from the latter half of May through the first half of July (about 1 to 5/tow).

Samples collected in the Gulf of Mexico along the central Texas coast in 1982 indicated catch rates (21.1 ± 5.1 kg/h) similar to the 16.8 ± 9.9 kg/h average for 1978-81 (Table 4). The mean length of 103.7 ± 0.3 mm in 1982 was similar to the mean length of 106.4 ± 10.4 mm for 1978-81, indicating that most shrimp would be at least 112 mm (39 whole shrimp to the pound) by the reopening date of 14 July.

June bag seine data also indicated there was no need to extend the closed season. Catch rates during June 1982 (2.26 ± 0.38/ha) were similar to the average (2.12 ± 0.26 ha.) of previous years (Table 5) as were mean sizes of 65.24 ± 2.48 mm in 1982 compared to a mean of 64.06 ± 1.02 mm for 1979-81 (Table 6).

Relative Abundance 1981-1982

Bag seine data indicated that the number of shrimp recruited to bay shorelines was similar for both years. The coastwide mean catch rate of 1644.42/ha during April-June 1982 was not significantly different from the 1668.19/ha caught in 1981 (Tables 7 and 8). Catch rates were significantly different among bay systems and months (Table 8). Interaction terms were not significant.

Mean catch rates in trawl samples collected in Galveston, San Antonio and Aransas Bays combined and weighted by area for May-July 1981-82 were 75.72 ± 24.19/tow in 1981 and 33.02 ± 13.95/tow in 1982, indicating no difference between years at the 95% confidence interval (Table 9). A three-way ANOVA performed on transformed catch rates indicated significant interactions among the main effects of bays, time periods and years (Table 10). The significant interactions and the expected mean squares prevented the testing of the main effects and, the data were regrouped based on similarity of means. Data from Galveston and San Antonio Bays were analyzed in another three-way ANOVA which indicated a two-way interaction between years and time periods (Table 11). In 1981 catch rates for Galveston and San Antonio Bays combined were high (1.66-1.58/tow) during the first two sampling periods, but much lower (0.30/tow) during the last two sampling periods, while in 1982 the catch rates remained relatively constant (0.90-1.26/tow) throughout the entire period (Figure 22). A two-way ANOVA of catch rates in Aransas Bay indicated a significant difference in catch rates between years and among time periods (Table 12). Aransas Bay catch rates were higher (2.15/tow in 1981 and 1.90/tow in 1982) at the beginning and lower (1.30/tow in 1981 and 0.84/tow in 1982) at the end of the sampling period for both years (Figure 22).

DISCUSSION

Management of brown shrimp in Texas is designed to accommodate all users (bait, small food shrimp, and large food shrimp) while protecting the resource and minimizing waste. The supply of large shrimp is insured by regulating harvest in bays and simultaneously prohibiting harvest in the Gulf after initial migration until they reach a larger more valuable size. Waste is minimized and harvest is maximized. Prior to 1981 there was a minimum size restriction of 39 whole shrimp to the pound. In 1981 the Texas Legislature repealed the minimum size restriction contingent upon the closure of the Fishery Conservation Zone (FCZ) to shrimping at the same time that the state closed its territorial sea.

If the FCZ had not been closed and the size restriction been in place some shrimp would have been discarded because they would not have met the legal size (Bryan et al. 1983). If there had been no closure and no minimum

size restriction, waste would have probably still occurred because of the preference of fishermen for larger sizes (higher market value) and the difficulty and extra labor involved in sorting and de-heading large quantities of small shrimp which are sometimes mixed with large quantities of other organisms. Even with restrictions there is a trend toward declining sizes of brown shrimp landed in Texas (Caillouet et al. 1980). If the trend continues the minimum effect will be a reduction in the ex-vessel value of a limited resource. Klima et al. (1983), based on observations from National Marine Fisheries Service (NMFS) statistical port agents, indicated that no major discarding of shrimp occurred after the season opened. Therefore, the selected closed season dates apparently assured that the management objectives were met.

TPWD samples indicated similar abundance of brown shrimp in 1981 and 1982. In 1981 the season was closed on 22 May and samples in passes indicated that the first major movement of shrimp from the bays to the Gulf began on 20 May (Benefield 1983) or at about the same time as in 1982. If emigration from bays occurred at the same time and rate for both years abundance and distribution in the Gulf should have been similar for both years.

Coastwide fishery independent sampling in Gulf waters off Texas during the Southeast Area Monitoring and Assessment Program (SEAMAP) (Figure 20) demonstrated a catch-per-unit-effort (CPUE) of 4.14 kg in 1982 compared to 5.64 kg in 1981 (Matthews 1983). The 25% reduction from 1981 to 1982 was not statistically significant; however, the CPUE in 1982 within the 11.0-45.7 m depth zone was significantly less (30%) than in 1981. These data were collected approximately 1 month later in 1982 than in 1981 so shrimp sampled in 1982 should have been 1 month older, larger and more widely distributed in the Gulf than those sampled in 1981.

The reported commercial catches in Gulf waters off Texas during July-August 1982 (5.91 million kg) were 48% less than in 1981 (11.36 million kg) but slightly higher than the 1972-79 historical average of 5.70 million kg (Klima et al. 1983). Klima et al. (1983) attributed the lower Gulf catches off Texas in July-August 1982 to lower recruitment from Texas bays. This was based on an index of relative abundance of bait shrimp in Galveston Bay during 25 April-12 June 1982 (Caillouet and Baxter 1972). Had TPWD trawl data collected from Galveston Bay during 15 May-15 June been used as an index of coastwide abundance, lower commercial catches would have also been expected for 1982 (Figure 22). Reported commercial catches in Texas bays indicated little difference in pounds landed between years. During 1982 1.85 million kg were landed or only slightly less than the 1.90 million kg reported in 1981 (Klima et al. 1983).

Commercial landings and SEAMAP data were reported by weight instead of by number. If the size of shrimp was not the same for the time periods being compared then weight may not have adequately reflected numbers caught. Reporting by number would facilitate comparison of abundance, but the present broad categories of size reported in commercial landings, especially for the smallest categories, make it difficult to assess possible differences in size of shrimp landed. The smallest count size category reported is 68 tails to the pound or over. This is a total length of 111 mm. A 90 mm shrimp, the size commonly present in bays, would produce 123 tails to the pound (Fontaine 1971). If the overall size was shifted by as little as 5 mm (85 mm

total length or 146 tails to the pound) it would mean that 19% more shrimp would have been landed in bays even though weight landed was similar.

Of four indices of abundance in Texas bays three indicated no difference in catch rates between 1981 and 1982. The index that indicated lower abundance in 1982, the NMFS Galveston Bay bait index, was similar to TPWD trawl samples when compared to the same bay and time period. The major difference between 1981 and 1982 appeared to be in the delayed pattern of movement in 1982 as indicated by trawl catch rates through time in two of three bay systems sampled. The causes or effects, if any, of this different pattern are not understood at this time. It is also unknown if different patterns or catch rates occurred in the bay systems not sampled with trawls in 1981.

If there was no difference in size of shrimp between the 2 years and abundance in Texas offshore waters was dependent solely upon recruitment from Texas bays, then the reasons for the apparent decline in reported offshore commercial landings in 1982 are unclear. Continued fishery independent sampling in a similar fashion in future years should aid in clarifying cause and effect relationships.

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Table 1. Mean catch rates[a] of brown shrimp (P. aztecus) collected with 18.3 m bag seines in Galveston, Matagorda, San Antonio, Aransas, Corpus Christi Bays and the upper and lower Laguna Madre during April 1978-82.

	1978	1979	1980	Mean 1978-80	1981	1982
Mean	0.64	0.58	0.37	0.53	2.03	1.77
Standard Error	0.40	0.38	0.25	0.34	0.50	0.35
No. Samples or (years) for S. E.	42	42	42	(3)	42	70
Percent of samples containing shrimp	30.95	30.95	21.43	28.00	76.19	64.29

[a](No./hectare + 1) transformed to Log_{10}.

Table 2. Mean length (mm) ± 1 S.E. of brown shrimp (P. aztecus) collected with 18.3 m bag seines in Galveston, Matagorda, San Antonio, Aransas and Corpus Christi Bays and the upper and lower Laguna Madre during April 1978-1982.

	1978	1979	1980	1981	1982
Mean Length	43.93	41.42	47.48	51.83	47.50
Standard Error	2.06	3.87	9.58	3.51	2.20
No. for S.E.	13	13	9	32	45

Table 3. Mean catch rates of brown shrimp collected with 18.3 m bag seines (No./ha) and 6.1 m trawls (No./15 min tow) in Galveston, Matagorda, San Antonio, Aransas, Corpus Christi Bays and the upper and lower Laguna Madre during April-July 1982.

Date	Bag seines	Trawls[a]		
	Shoreline	Upper bay	Lower bay	Pass
April 1-15	865.9	0.2	6.7	0.1
April 16-30	1006.1	0.3	3.3	0.0
May 1-15	2209.1	11.2	7.9	0.5
May 16-31	1535.0	44.8	38.3	4.5
June 1-15	2609.5	33.4	40.9	4.9
June 16-30	706.9	15.6	10.9	0.5
July 1-15	350.9	30.3	7.6	1.1
July 16-31	274.7	16.8	10.4	0.1

[a]Samples prior to May did not include samples from Matagorda, Corpus Christi Bays or upper and lower Laguna Madre.

Table 4. Mean catch rates (No./h and kg/h ± 1 S.E.) and mean total length (mm) of brown shrimp (*P. aztecus*) heads-on collected with 12.2-13.7-m wide otter trawls in Gulf of Mexico waters off the central Texas coast during June 15-30, 1978-81 compared to same period (June 23-30) in 1982.

	1978	1979	1980	1981	Mean 1978-81	1982
No. samples or (years) for S. E.	5	3	3	4	15	15
No./h	2564 ± 577	152 ± 106	2359 ± 1389	2006 ± 822	1770 ± 1103	2145 ± 538
kg/h	20.2 ± 4.3	2.1 ± 1.4	23.2 ± 18.0	21.6 ± 9.4	16.8 ± 9.9	21.1 ± 5.1
Mean length(mm)	95.4 ± 3.3	120.5 ± 0.7	104.7 ± 0.8	104.8 ± 3.2	106.4 ± 10.4	103.7 ± 0.3

Table 5. Mean catch rates[a] of brown shrimp (P. aztecus) collected with 18.3-m wide bag seines along shorelines of Galveston, Matagorda, San Antonio, Aransas, Corpus Christi Bays and the Laguna Madre (upper and lower) during June 1979-82.[b]

	1979	1980	1981	Mean 1979-81	1981
Mean No./ha	2.01	2.43	1.93	2.12	2.26
Standard Error	0.53	0.26	0.52	0.26	0.38
No. Samples or (years) for S. E.	42	42	42	(3)	70

[a] (No./hectare + 1) transformed to Log_{10}

[b] No bag seine samples collected during June 1978.

Table 6. Mean length (mm) ± 1 S. E. of brown shrimp (P. aztecus) collected with 18.3-m wide bag seines along shorelines of Galveston, Matagorda, San Antonio, Aransas, Corpus Christi Bays and the Laguna Madre (upper and lower) during June 1979-82.[a]

	1979	1980	1981	Mean 1979-81	1982
Mean length (mm)	63.29	65.05	63.84	64.05	65.24
Standard Error	3.73	3.28	2.61	1.02	2.48
No. samples of (years) for S. E.	31	35	29	(3)	53

[a] No bag seine samples collected during June 1978.

Table 7. Mean catch rates (No./ha ± 1 S.E.) of brown shrimp (Penaeus aztecus) collected with 18.3 m wide bag seine along shorelines of Galveston, Matagorda San Antonio, Corpus Christi Bays and the Laguna Madre (upper and lower) during April-June 1981-82.

Bay system	April		May		June		April-June	
	1981	1982	1981	1982	1981	1982	1981	1982
Galveston	2883.33 ± 1065.41	1246.67 ± 435.95	4888.89 ± 2692.14	3899.97 ± 1494.30	1172.22 ± 230.53	4486.67 ± 1979.59	2981.48 ± 981.20	3211.10 ± 851.21
Matagorda	52.78 ± 28.36	240.00 ± 141.12	1152.78 ± 536.24	691.67 ± 280.57	655.56 ± 193.92	1146.67 ± 710.68	620.37 ± 235.27	692.78 ± 264.24
San Antonio	377.78 ± 170.33	510.00 ± 229.33	2883.33 ± 1479.26	3143.33 ± 935.50	827.78 ± 378.64	1390.00 ± 592.03	1362.96 ± 596.81	1681.11 ± 416.59
Aransas	160.00 ± 87.94	630.61 ± 420.41	2796.55 ± 825.17	2203.50 ± 1159.43	203.57 ± 179.61	2155.00 ± 741.86	1053.37 ± 400.33	1663.04 ± 482.12
Corpus Christi	1100.00 ± 736.10	1728.00 ± 1725.78	3686.67 ± 2937.58	1864.00 ± 1072.67	1473.33 ± 1031.31	1001.33 ± 431.36	2086.67 ± 1069.21	1531.11 ± 670.81
Upper Laguna Madre	62.50 ± 34.61	20.00 ± 17.40	770.83 ± 701.41	520.00 ± 331.03	108.33 ± 88.90	45.00 ± 29.53	313.72 ± 235.13	195.00 ± 115.25
Lower Laguna Madre	3508.34 ± 1673.70	2216.47 ± 1013.51	3402.94 ± 2362.40	801.67 ± 295.19	694.12 ± 624.65	1382.67 ± 515.68	2535.13 ± 979.72	1466.94 ± 392.95
Coastwide[a]	1319.20 ± 803.29	935.67 ± 755.30	2942.31 ± 1898.26	2035.71 ± 869.37	743.13 ± 496.85	1957.20 ± 878.46	1668.19 ± 726.33	1644.42 ± 509.63

[a] Catch rates weighted by amount of shoreline in each bay system.

Table 8. Results of three-way analysis of variance on mean catch rates [a] of brown shrimp (Penaeus aztecus) collected with 18.3-m wide bag seines along shorelines of Galveston, Matagorda, San Antonio, Aransas, Corpus Christi Bays and the Laguna Madre (upper and lower) during April-June 1981-1982.

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F
Bay systems	6	86.73	14.46	10.04*
Months	2	43.72	21.86	15.18*
Years	1	0.42	0.42	0.29
Bay systems x months	12	35.40	2.95	2.05
Bay systems x years	6	6.55	1.09	0.76
Months x years	2	3.88	1.94	1.35
Interaction	12	17.32	1.44	0.96
Error	294	440.22	1.50	
Total	335	634.24		

[a] (No./hectare + 1) transformed to Log_{10}

* Significant at P = < 0.05

Table 9. Mean catch rate (No./15 minute tow ± 1 S.E.) of brown shrimp (P. aztecus) collected with 6.1 m trawls in Galveston, San Antonio and Aransas Bays during 15 May-31 July 1981 and 1982.

Sampling Period	Galveston Bay		San Antonio Bay		Aransas Bay		Bays Combined[a]	
	1981	1982	1981	1982	1981	1982	1981	1982
May 15-31	143.50 ± 82.53	37.33 ± 12.07	112.00 ± 60.06	20.00 ± 9.06	181.86 ± 52.94	129.42 ± 51.73	149.67 ± 36.55	71.18 ± 24.16
June 1-15	119.67 ± 60.40	19.67 ± 15.39	50.33 ± 25.23	21.67 ± 10.87	157.24 ± 43.32	133.03 ± 54.31	113.90 ± 27.48	98.00 ± 35.07
June 16-30	29.50 ± 23.57	11.75 ± 1.65	2.67 ± 1.33	7.50 ± 3.86	288.00 ± 195.00	41.50 ± 39.50	79.78 ± 52.06	16.00 ± 7.45
July 1-15	14.00 ± 14.00	16.67 ± 12.44	0.60 ± 0.40	22.40 ± 10.98	94.60 ± 14.64	19.00 ± 6.01	39.69 ± 13.94	20.43 ± 4.90
July 16-31	7.25 ± 5.71	17.00 ± 8.83	0.17 ± 0.17	24.33 ± 6.75	52.25 ± 25.89	8.83 ± 8.93	17.07 ± 9.22	16.71 ± 3.86
Total	70.45 ± 28.38	22.62 ± 4.93	33.50 ± 16.24	19.68 ± 3.73	143.64 ± 26.59	81.78 ± 21.77	75.72 ± 24.19	33.02 ± 13.95

[a]Catch rates weighted by amount of area in each bay system.

Table 10. Results of three-way analysis of variance of mean catch rates[a] (No./15 minute tow, Log_{10} + 1) of brown shrimp (P. aztecus) collected with 6.1 m trawls in Galveston, San Antonio and Aransas Bays during 15 May-31 July 1981 and 1982.

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F
Bay systems	2	13.955	6.9776	
Time periods	4	15.590	3.8975	
Years	1	0.083	0.0826	
Bay systems x time periods	8	1.490	0.1862	0.237
Bay systems x years	2	3.664	1.8320	2.338
Time periods x years	4	3.734	0.9334	1.190
Interaction	8	6.274	0.7843	2.2662*
Error	104	35.992	0.3461	
Total	134	84.525		

[a] (No./hectare + 1) transformed to Log_{10}

[b] Significant at P = < 0.05

Table 11. Results of three-way analysis of variance on mean catch rates[a] of brown shrimp (P. aztecus) collected with 6.1 m trawls in Galveston and San Antonio Bay systems during five time periods in 1981 and 1982.

Source of Variation	SS	DF	MS	FS
Bay Systems	1.023	1	1.0235	2.4841
Time Periods	9.179	4	2.2947	
Years	0.664	1	0.6644	
Bay Systems x Time Periods	0.234	4	0.0585	0.1419
Bay Systems x Years	0.885	1	0.8848	2.1476
Time Periods x Years	6.772	4	1.6930	4.1091*
Interaction	0.869	4	0.2173	0.5274
Error	26.781	65	0.4120	
Total	48.154	85		

[a](No./15 minute tow + 1) transformed to Log_{10}

*Significant at P = 0.05

Table 12. Results of two-way analysis of variance on mean catch rates[a] of brown shrimp (P. aztecus) collected with 6.1 m trawls in Aransas Bay during five time periods in 1981 and 1982.

Source of Variation	SS	DF	MS	FS
Time Periods	7.773	4	1.9433	8.2277*
Years	2.397	1	2.3967	10.1471*
Interaction	1.335	4	0.3339	1.4135
Error	9.211	39	0.2362	
Total	21.026	49		

[a](No./15 minute tow + 1) transformed to Log_{10}

*Significant at P = 0.05

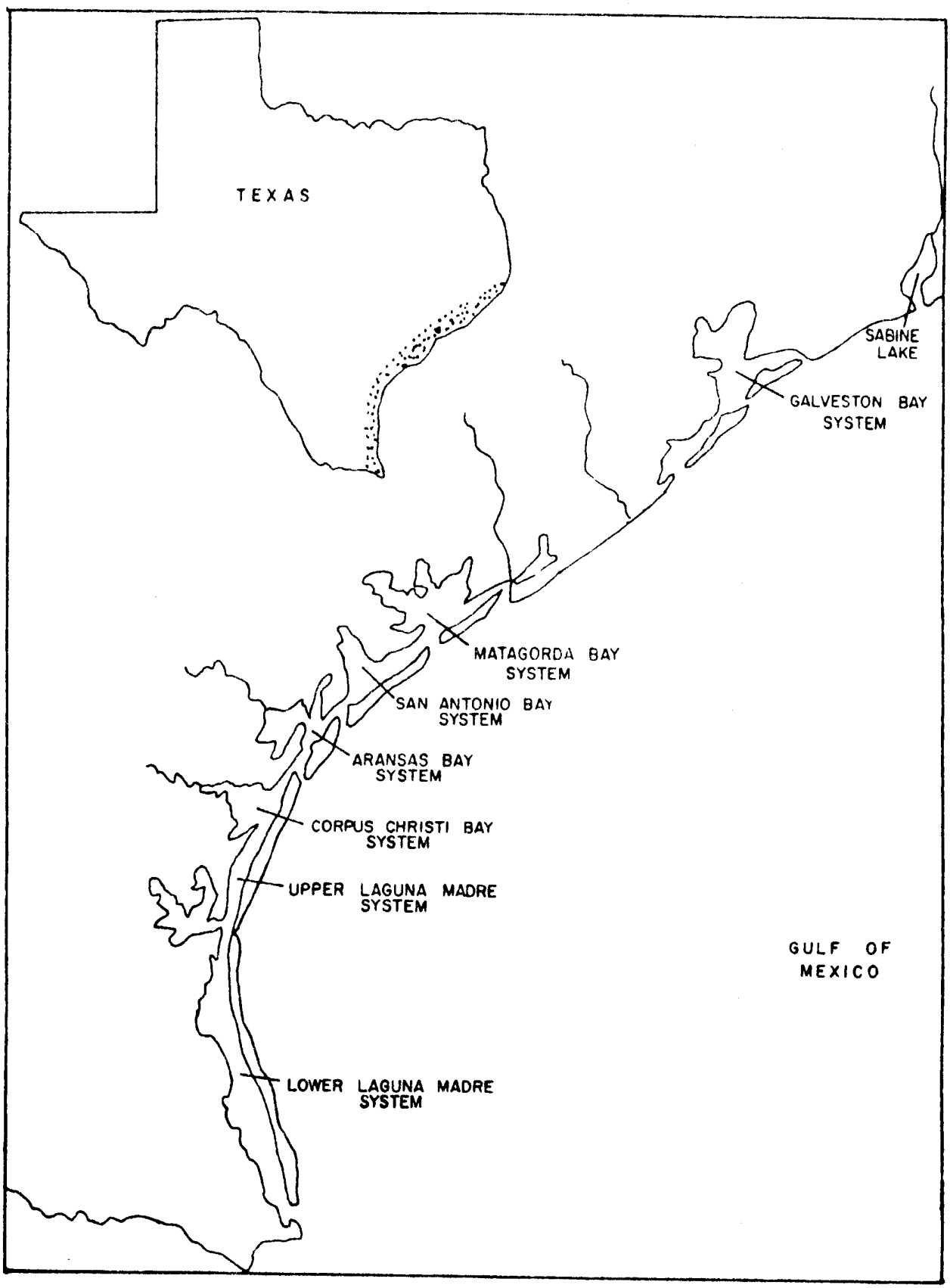

Figure 1. Texas coast illustrating major bay systems and Gulf of Mexico

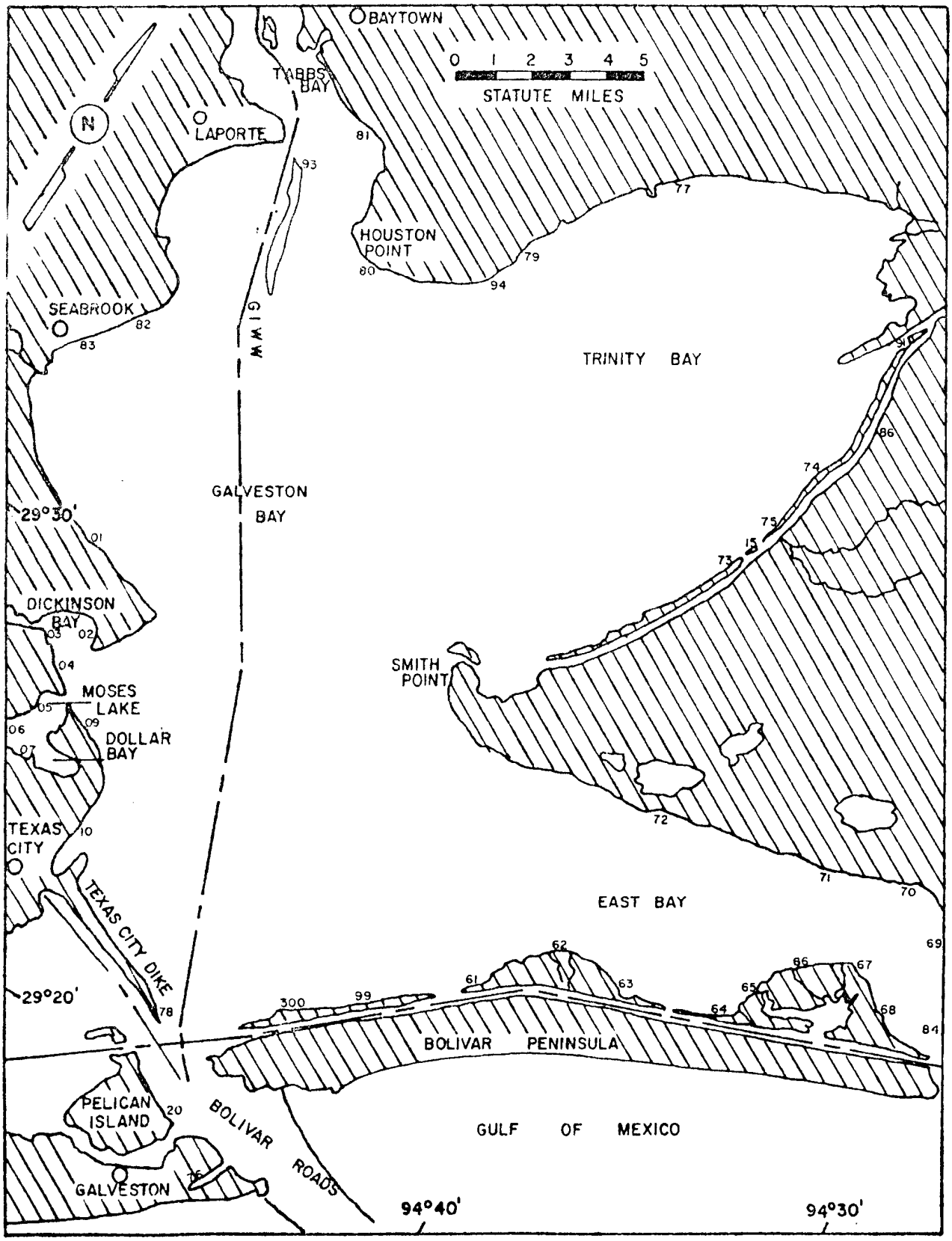

Figure 2. Bag seine sample sites (indicated by numbers) in the Galveston Bay System. October 1980-September 1981. From: Hegen (1982).

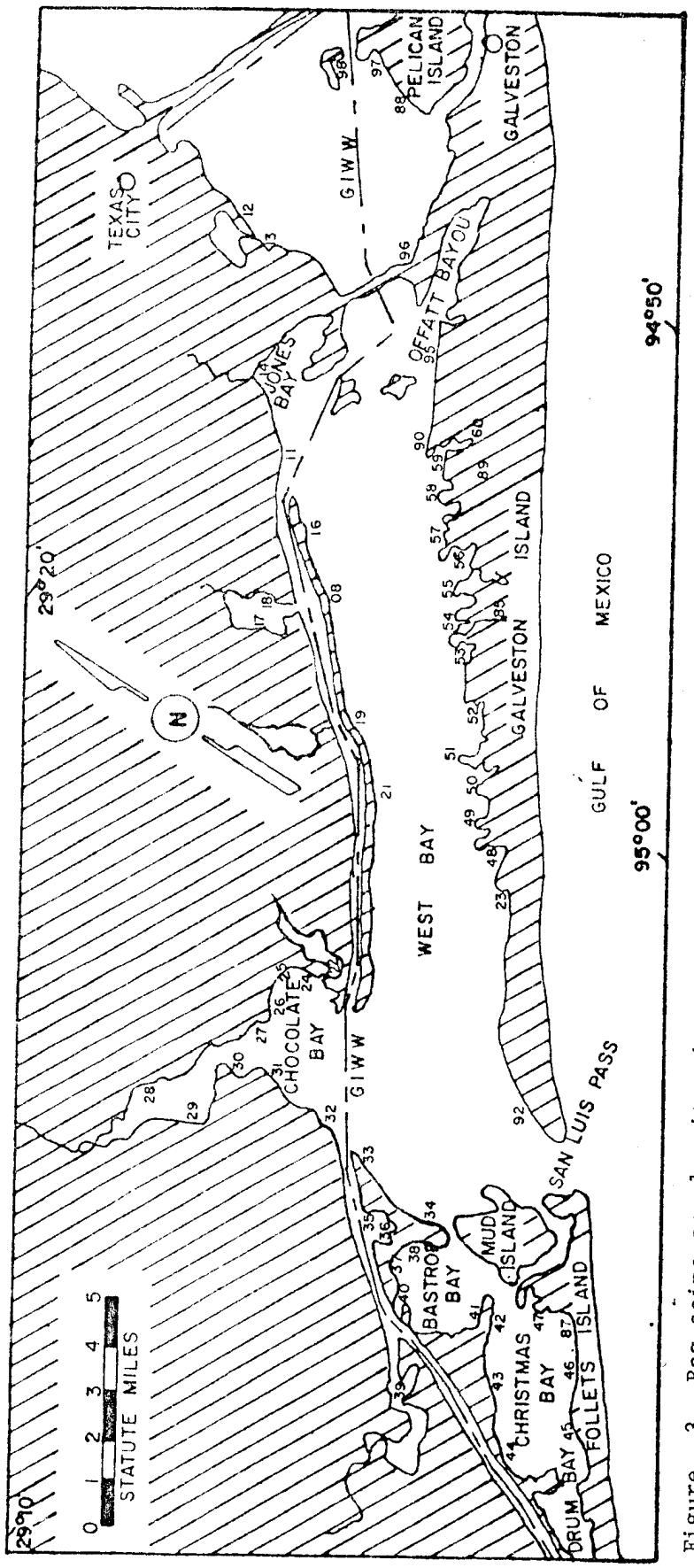

Figure 3. Bag seine sample sites (indicated by numbers) in the Galveston Bay System, October 1980-September 1981. From: Hegen (1982)

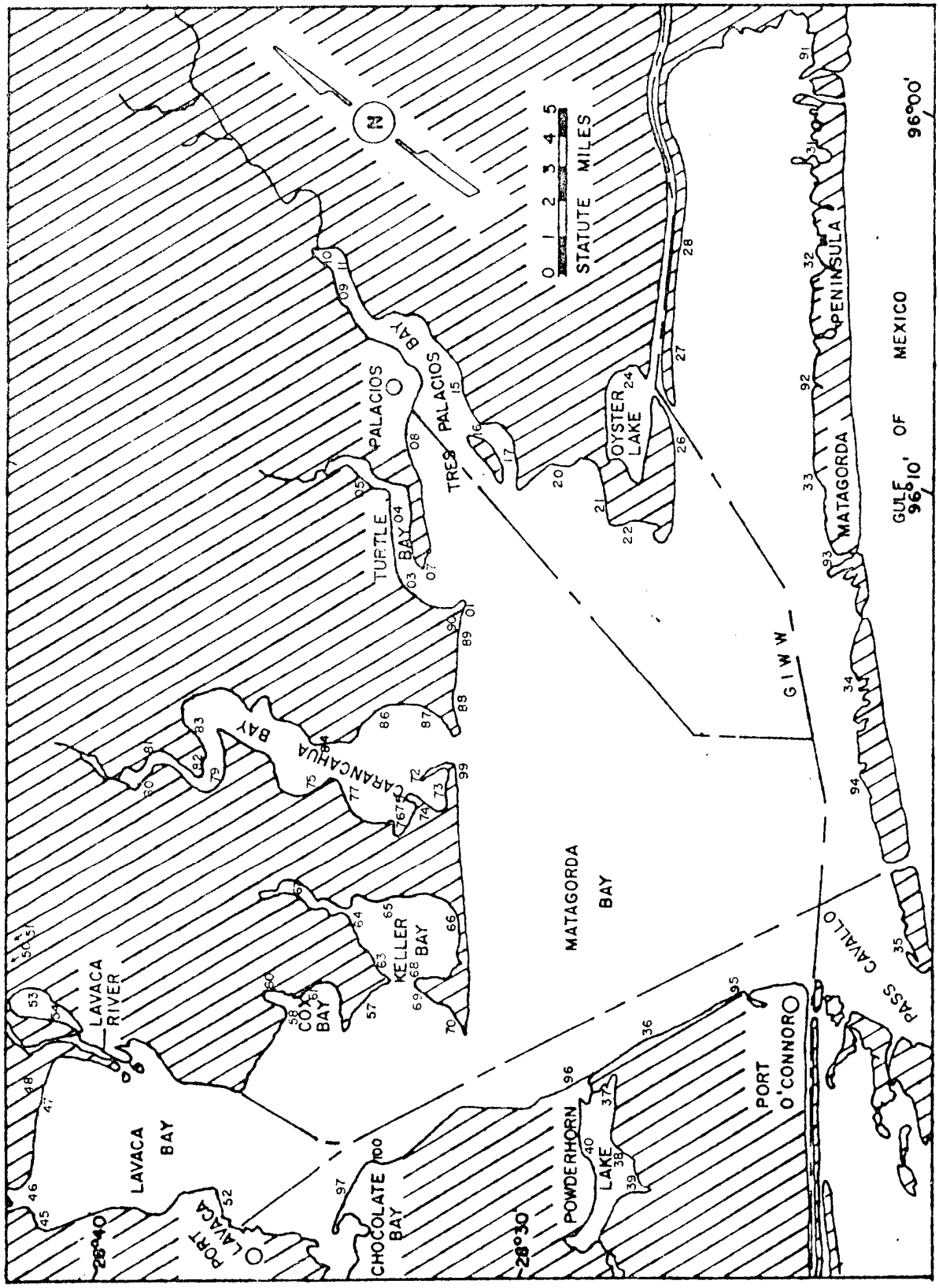

Figure 4. Bag seine sample sites (indicated by numbers) in the Matagorda Bay System, October 1980-September 1981. From: Hegen (1982)

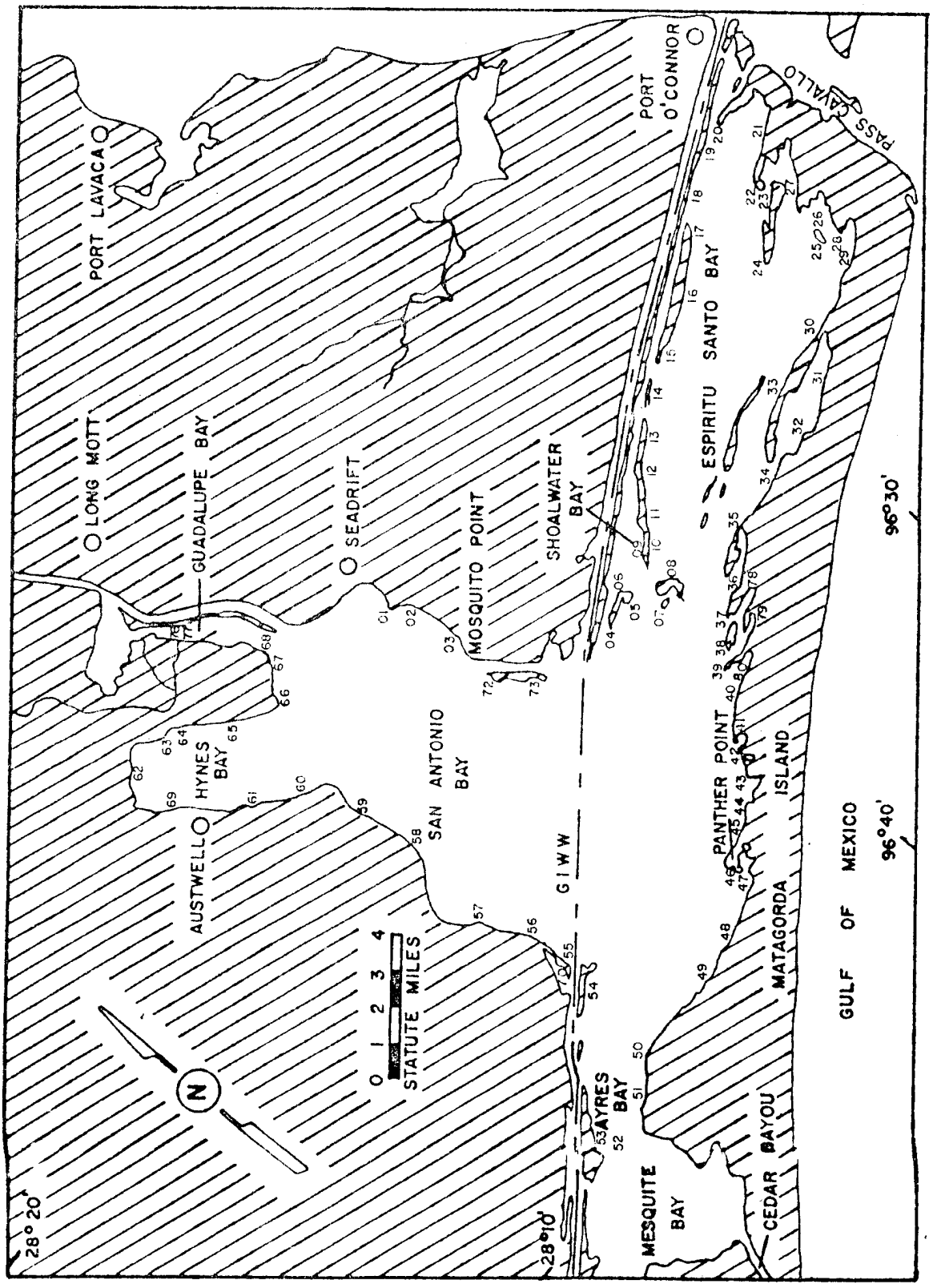

Figure 5. Bag seine sample sites (indicated by numbers) in the San Antonio Bay System, October 1980-September 1981. From: Hegen (1982)

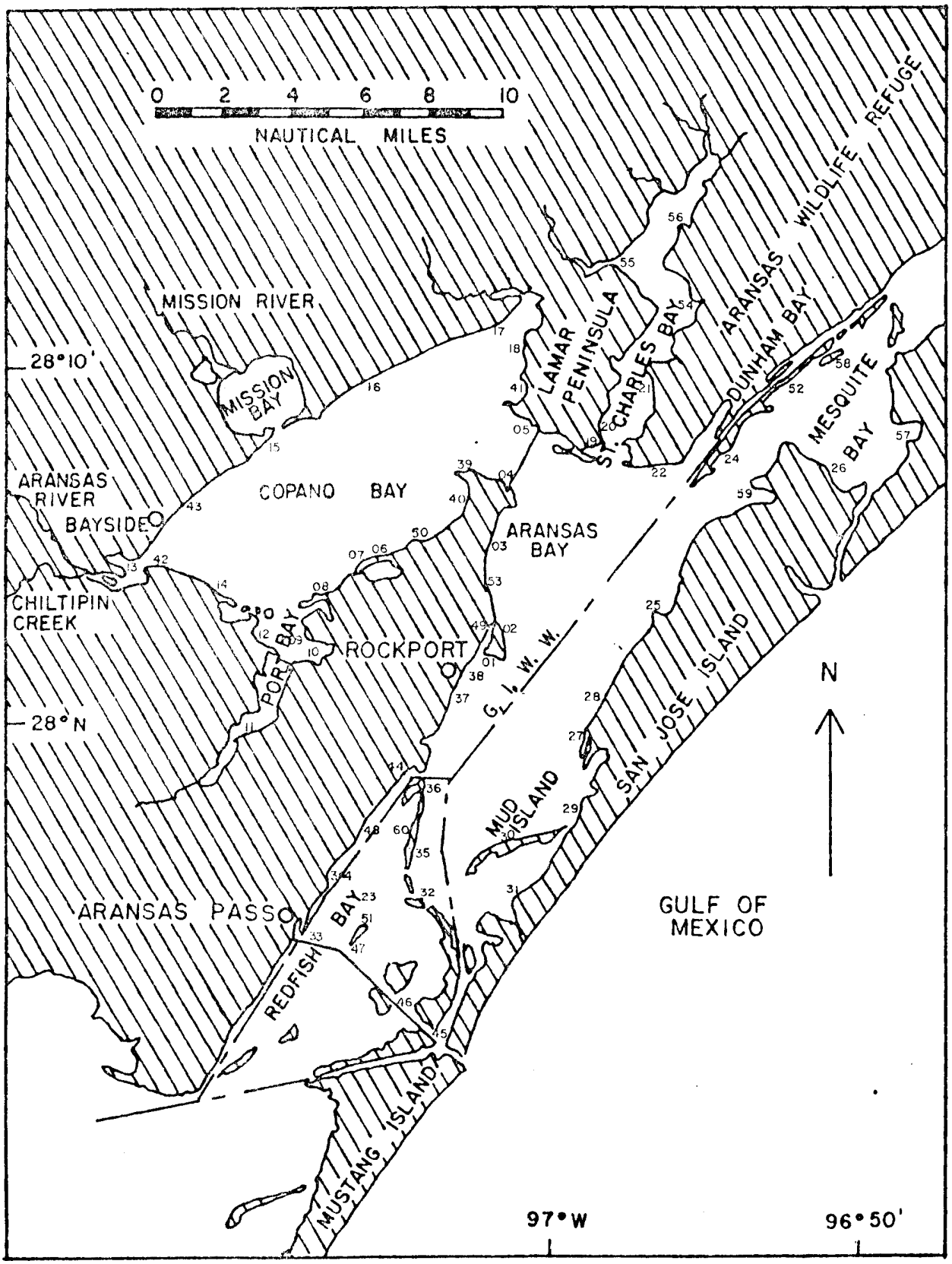

Figure 6. Bag seine sample sites (indicated by numbers) in the Aransas Bay System, October 1980-September 1981. From: Hegen (1982)

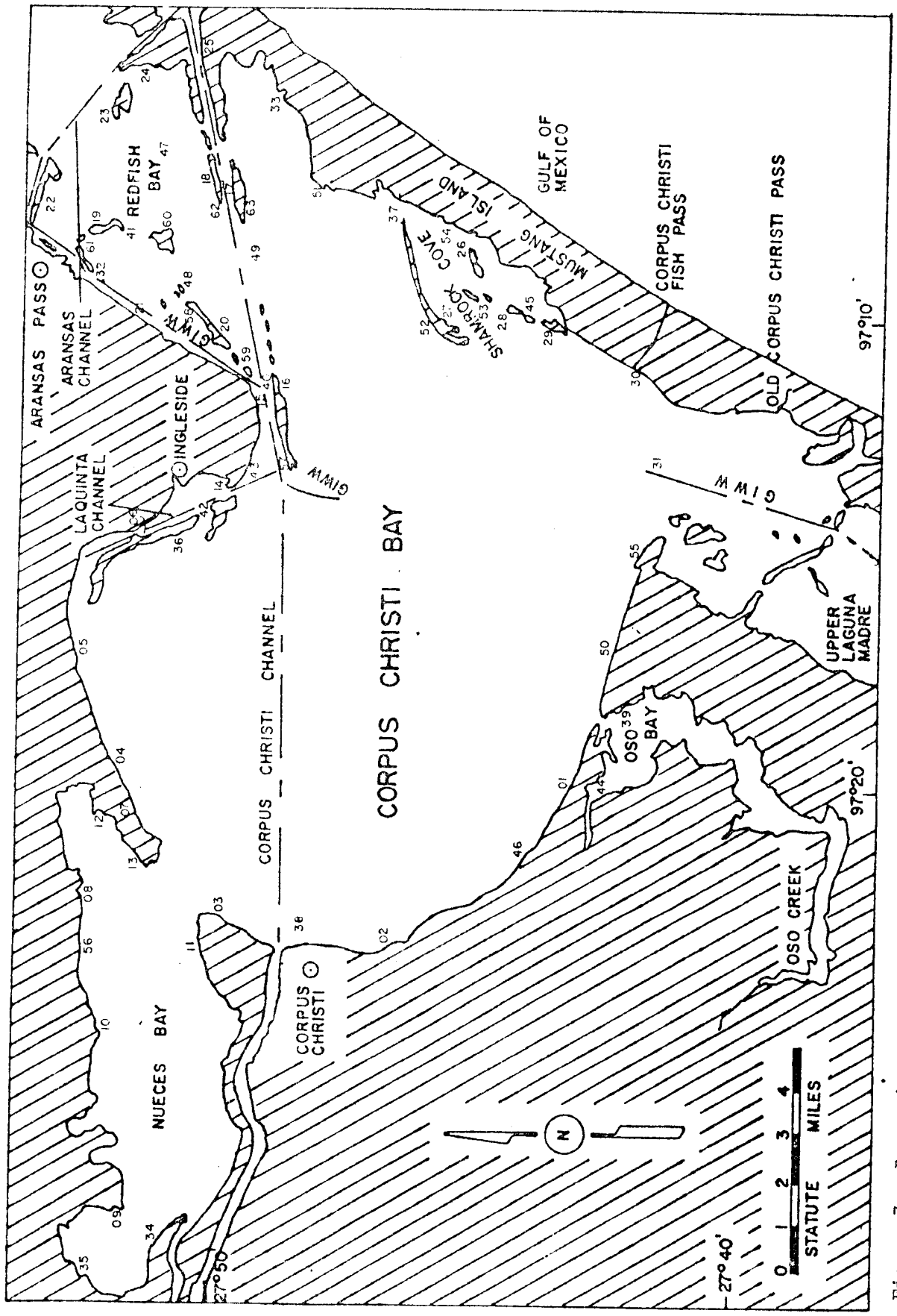

Figure 7. Bag seine sample sites (indicated by numbers) in the Corpus Christi Bay System, October 1980–September 1981. From: Hegen (1982)

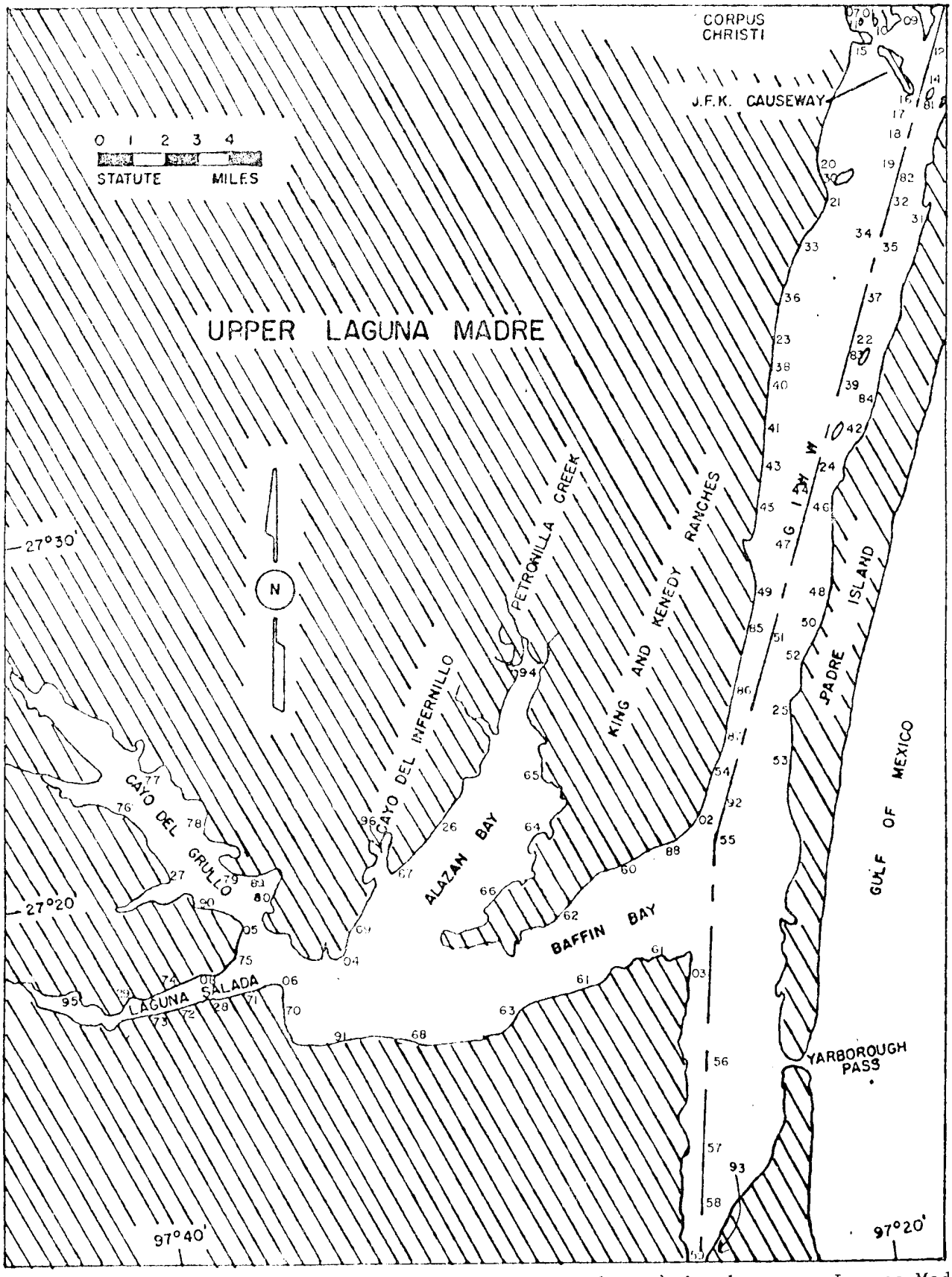

Figure 8. Bag seine sample sites (indicated by nubmers) in the upper Laguna Madre Bay System, October 1980-September 1981. From: Hegen (1982)

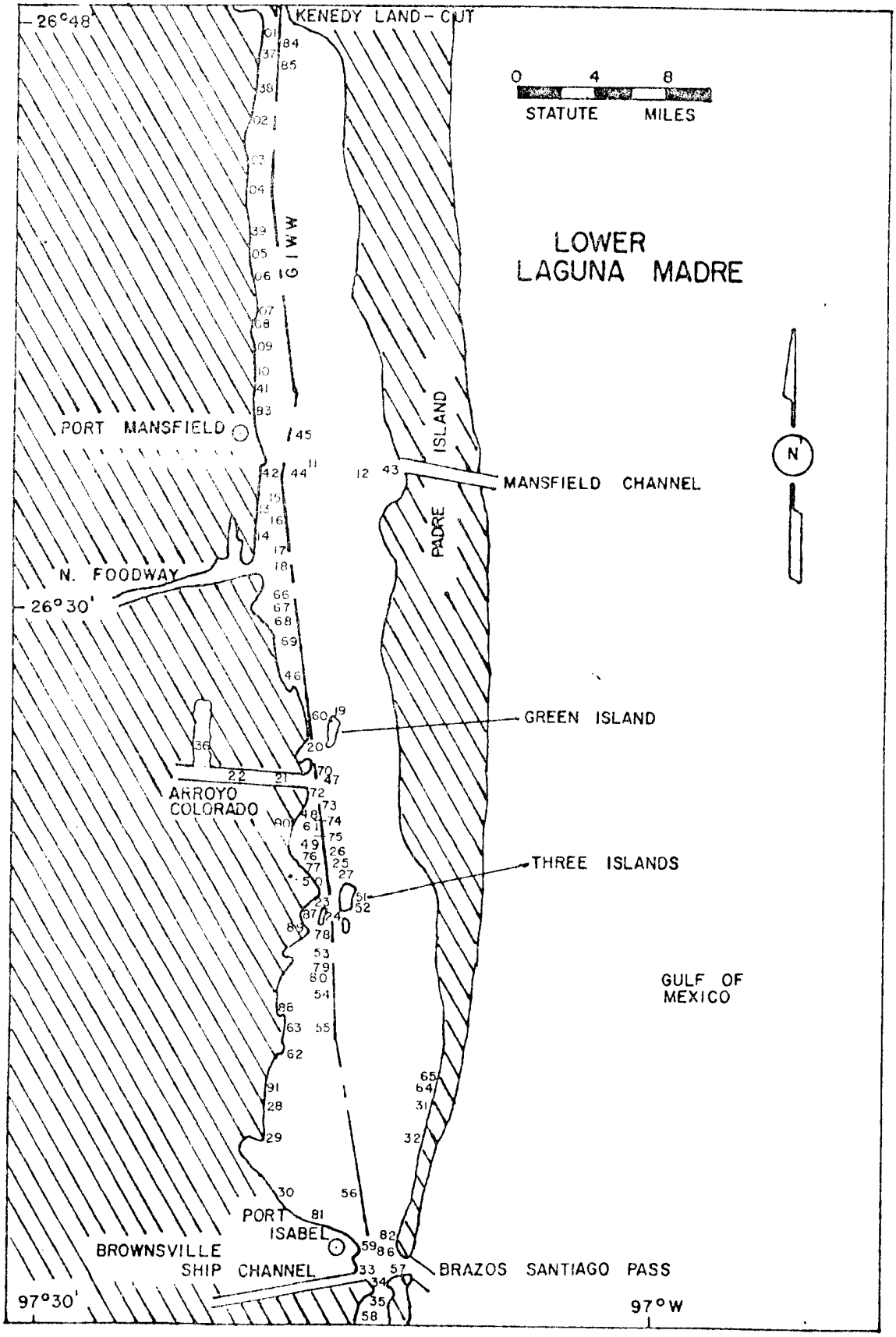

Figure 9. Bag seine sample sites (indicated by numbers) in the lower Laguna Madre Bay System, October 1980-September 1981. From: Hegen (1982)

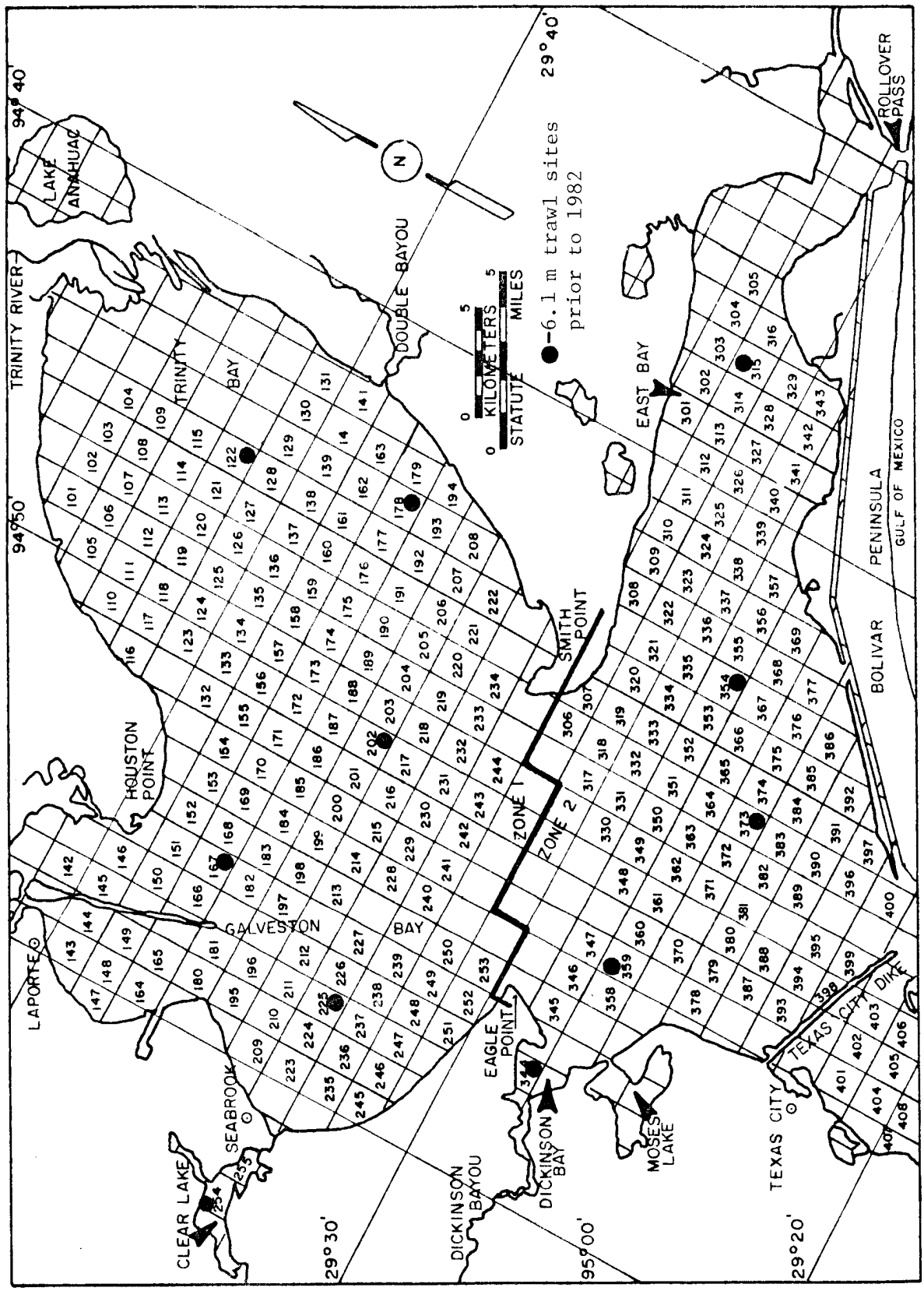

Figure 10. Trawl sample grid locations (indicated by numbers) in the Galveston Bay System, 1982.

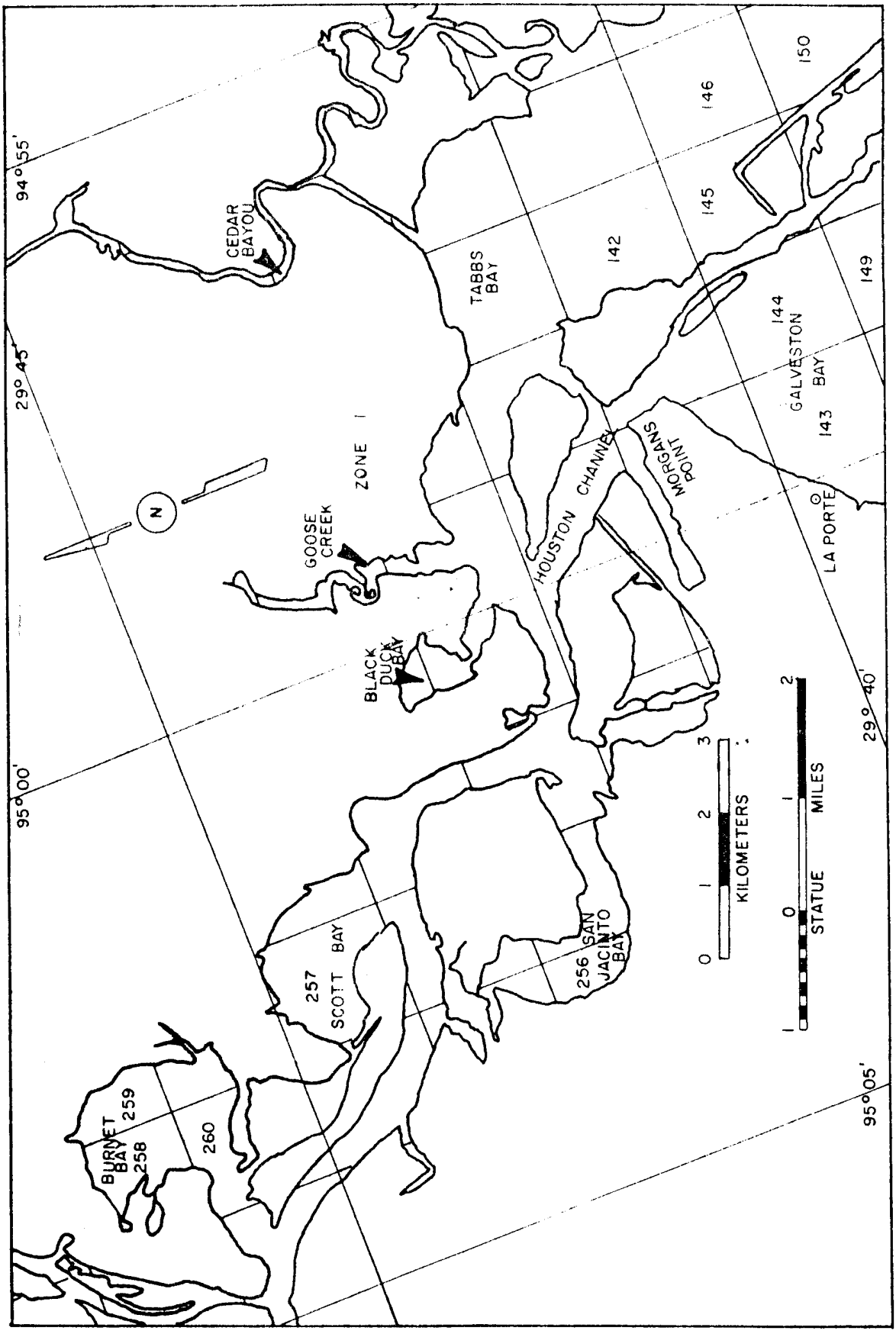

Figure 11. Trawl sample grid locations in the Galveston Bay system, 1982.

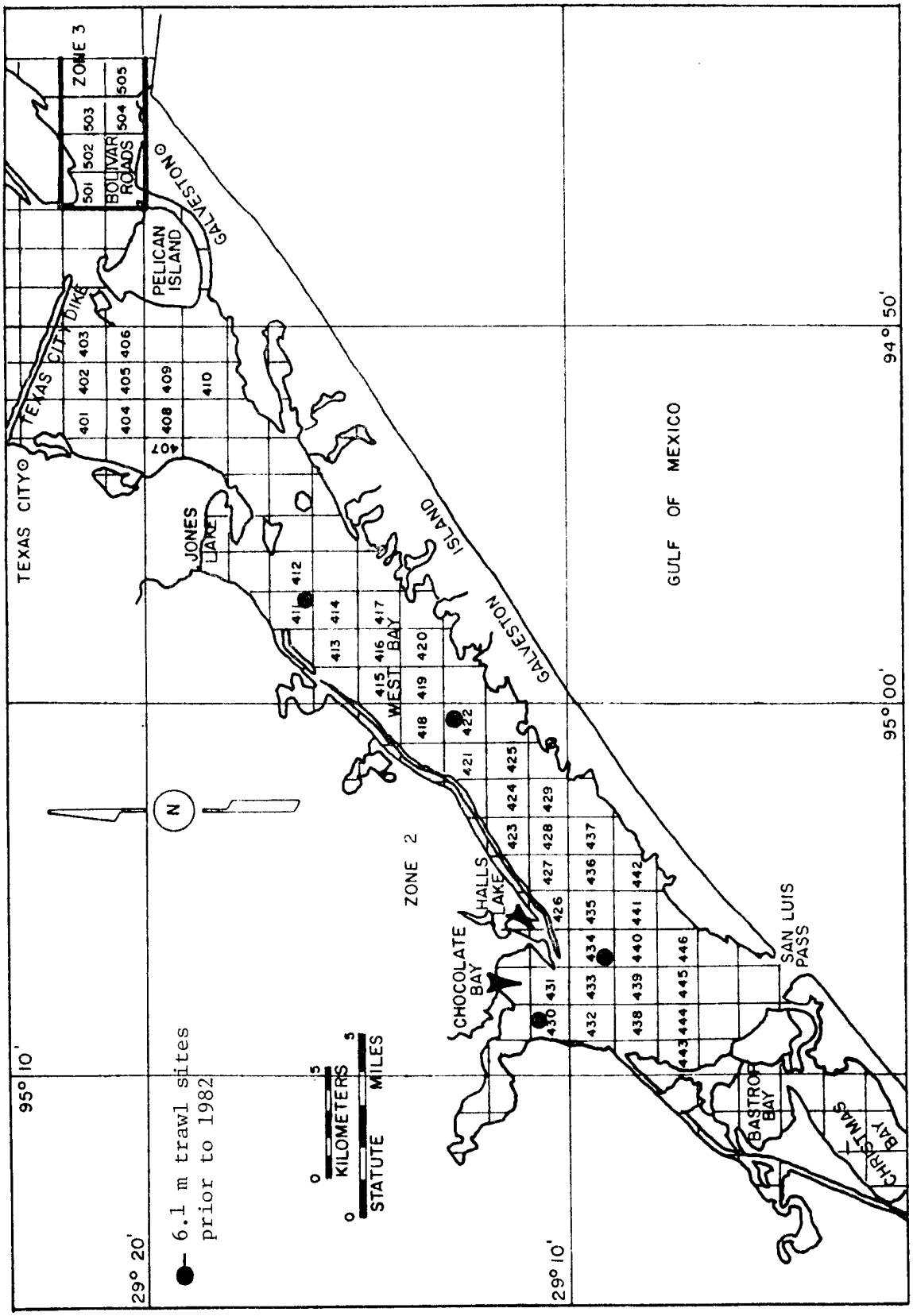

Figure 12. Trawl sample grid locations (indicated by numbers) in the Galveston Bay System, 1982.

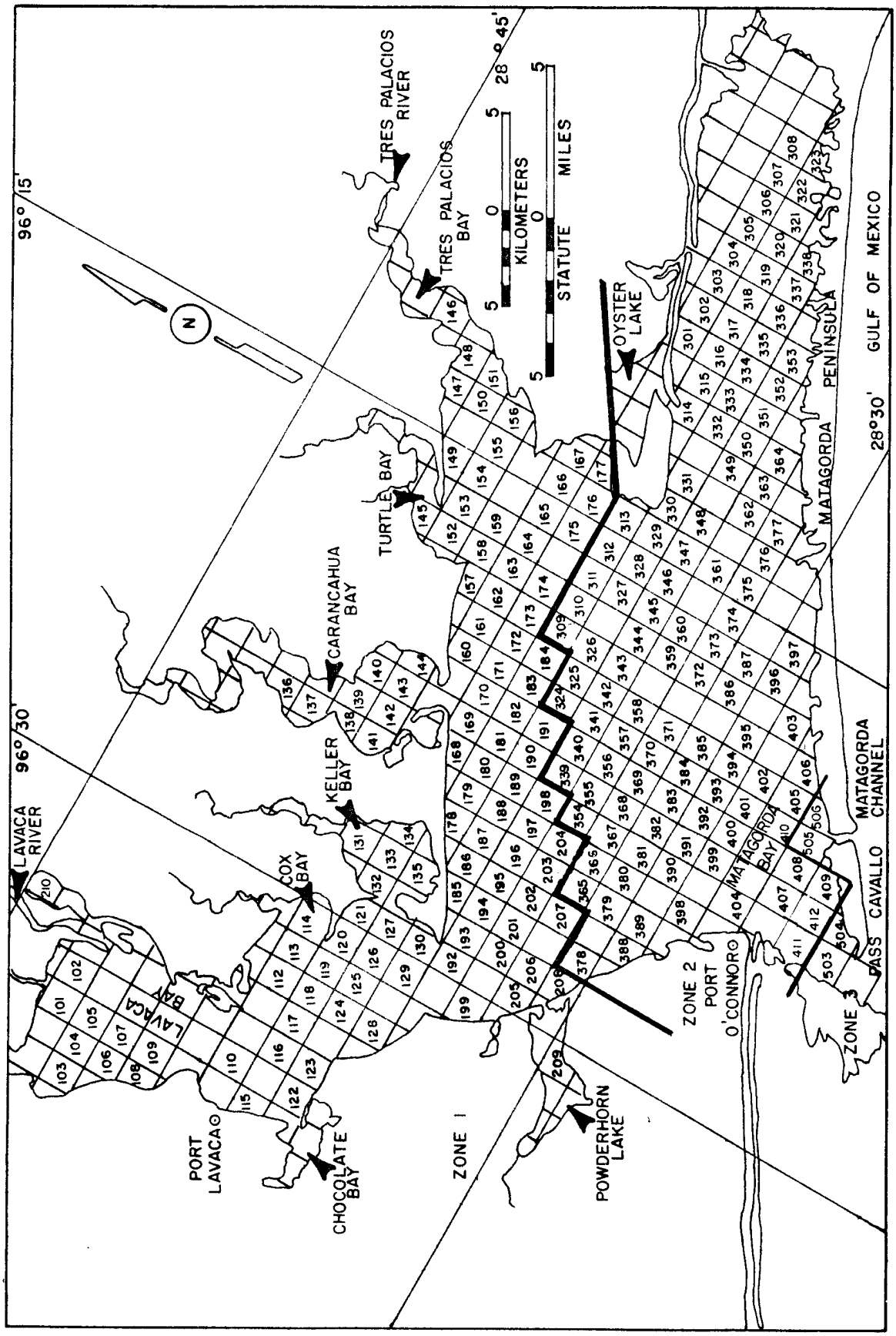

Figure 13. Trawl sample grid locations (indicated by numbers) in the Matagorda Bay System, 1982.

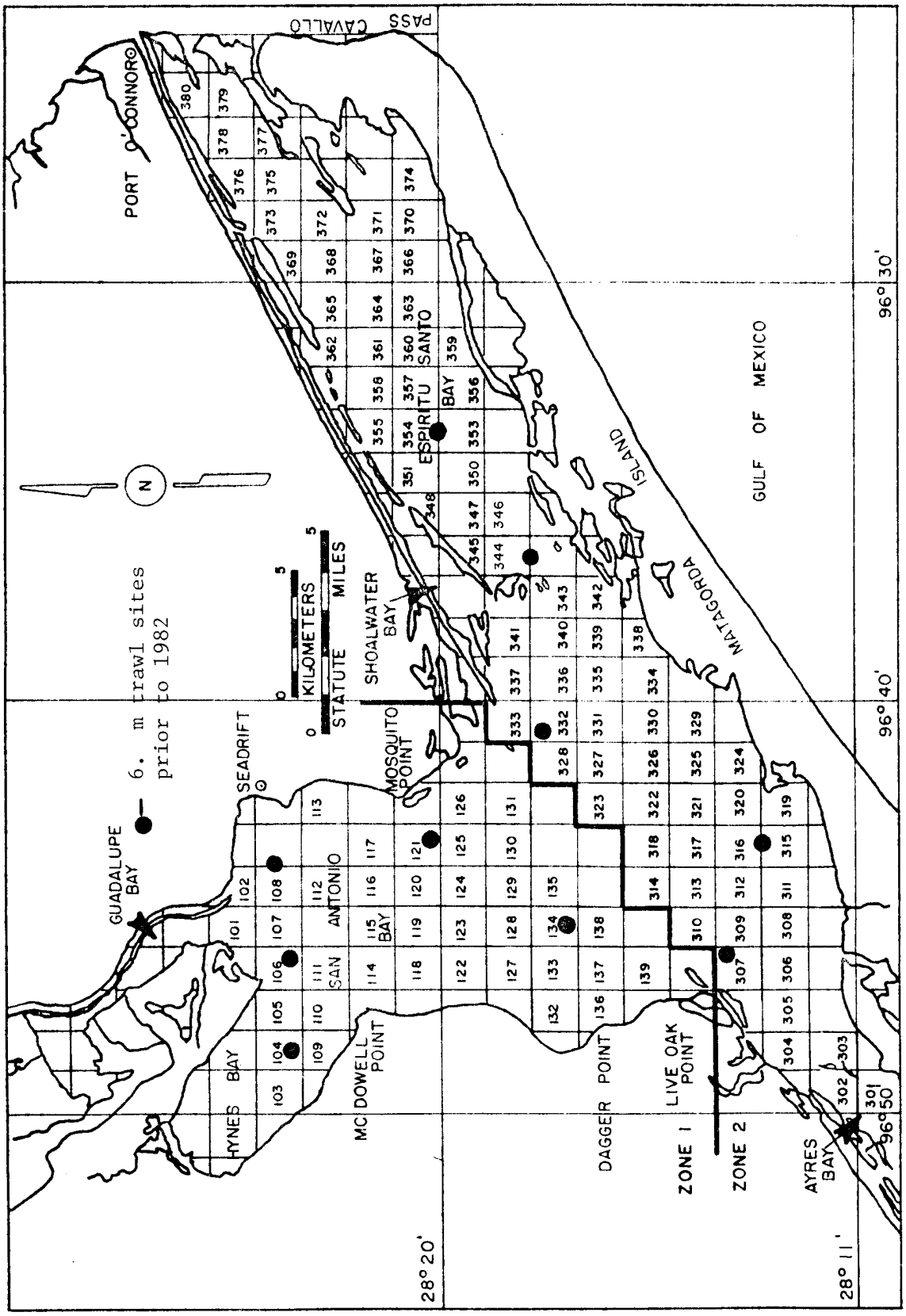

Figure 14. Trawl sample grid locations (indicated by numbers) in the San Antonio Bay System, 1982.

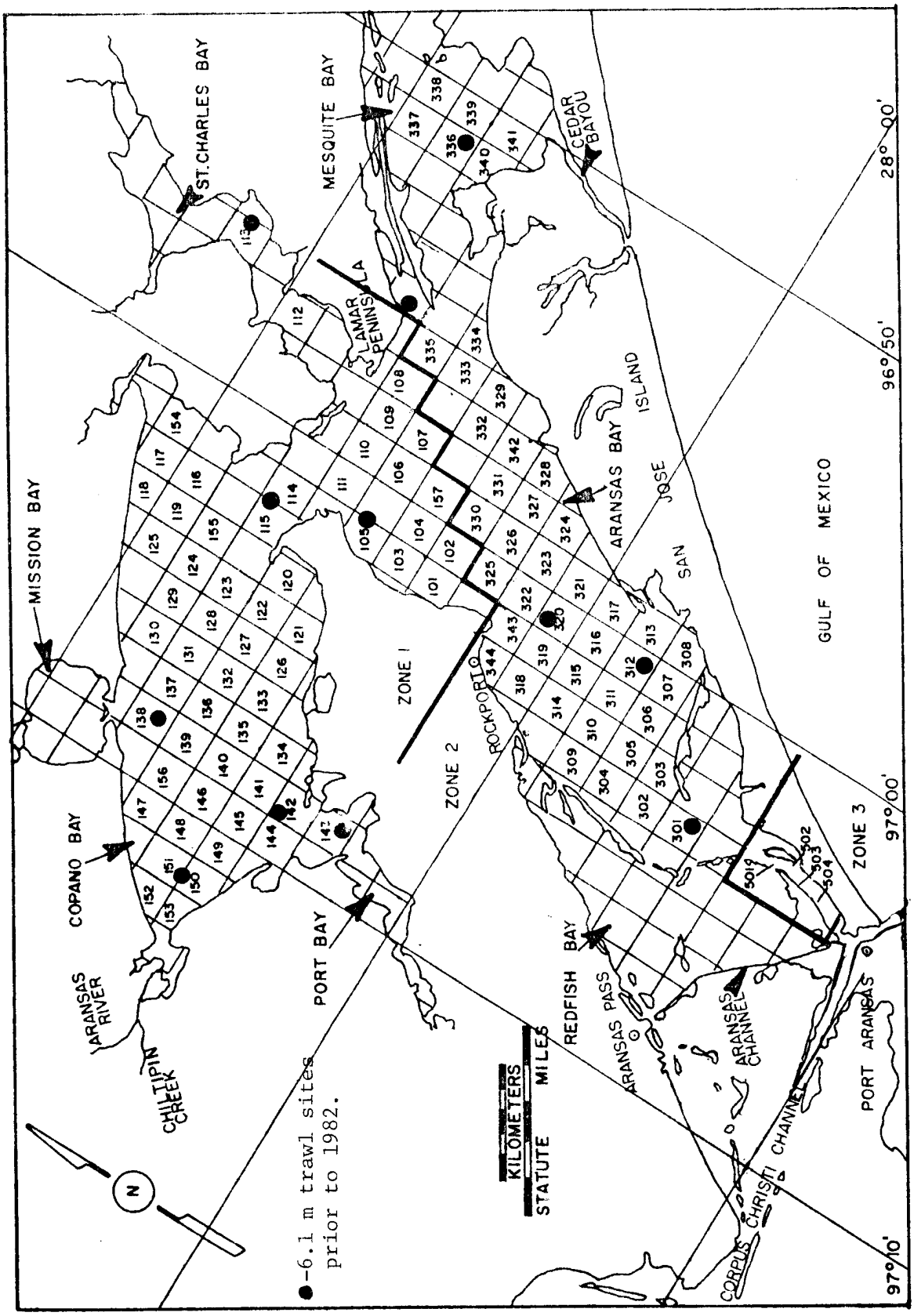

Figure 15. Trawl sample grid locations (indicated by numbers) in the Aransas Bay System, 1982.

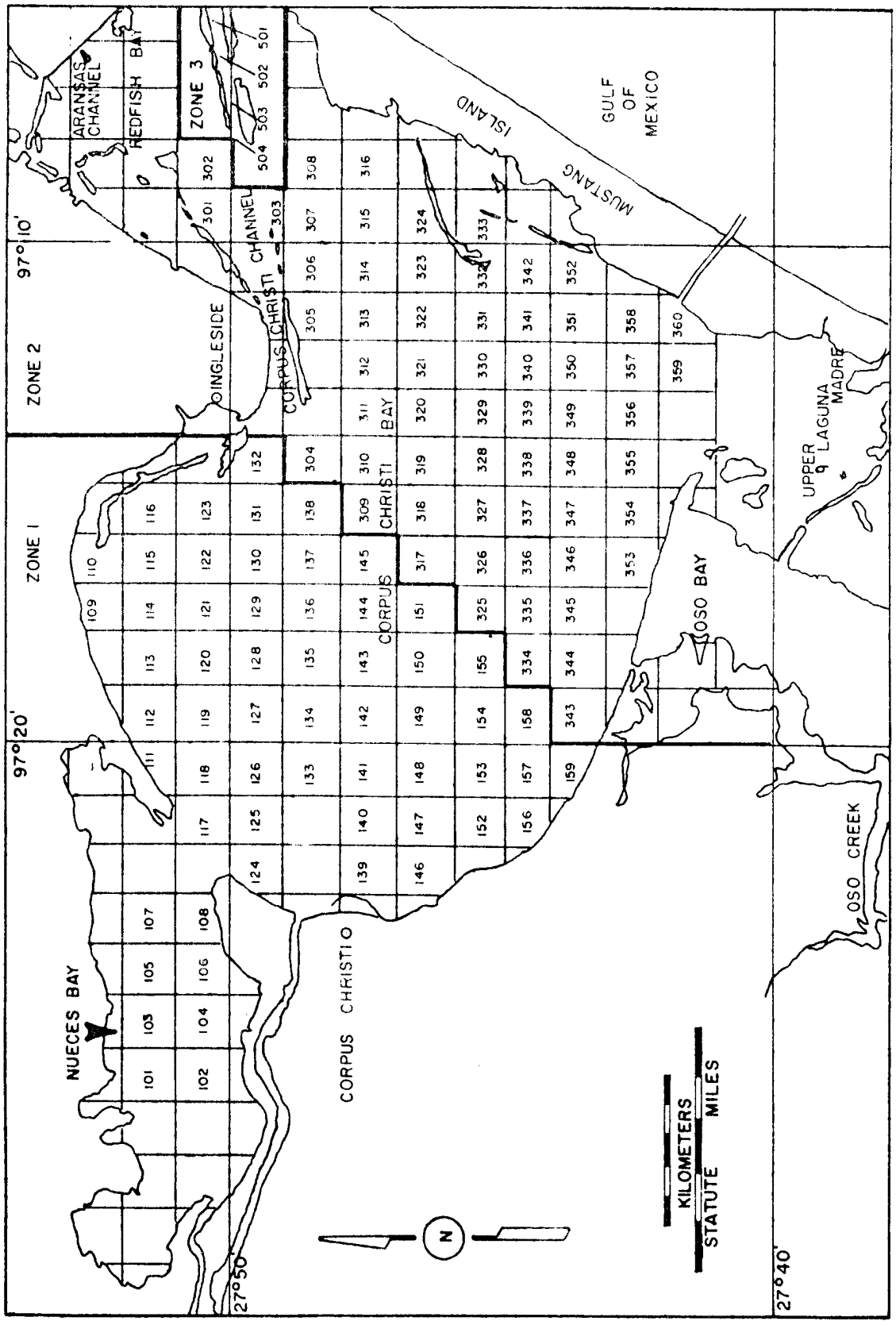

Figure 14 Trawl sample grid locations (indicated by numbers) in the Corpus Christi Bay System, 1982

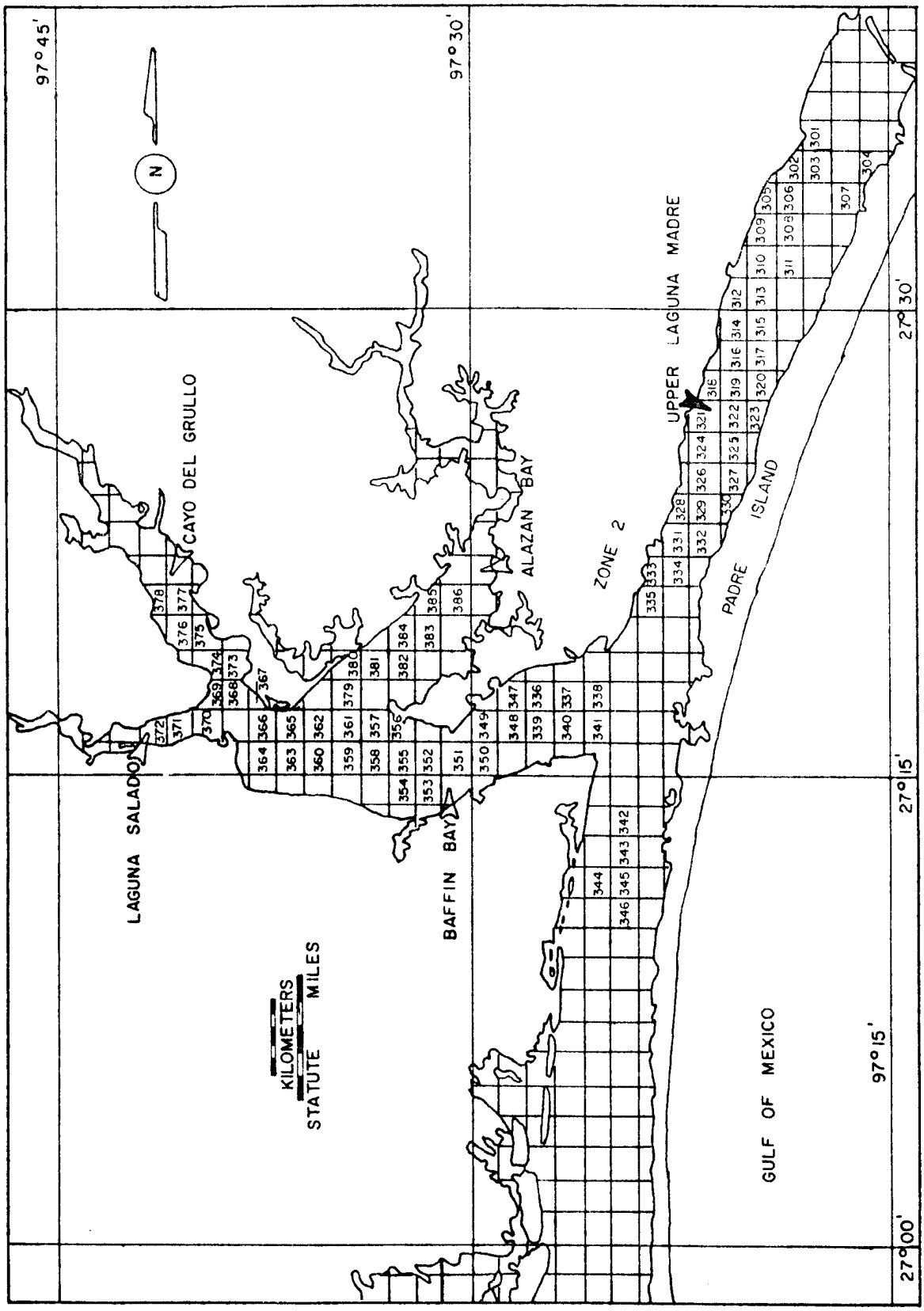

Figure 17. Trawl sample grid locations (indicated by numbers) in the upper Laguna Madre, 1982.

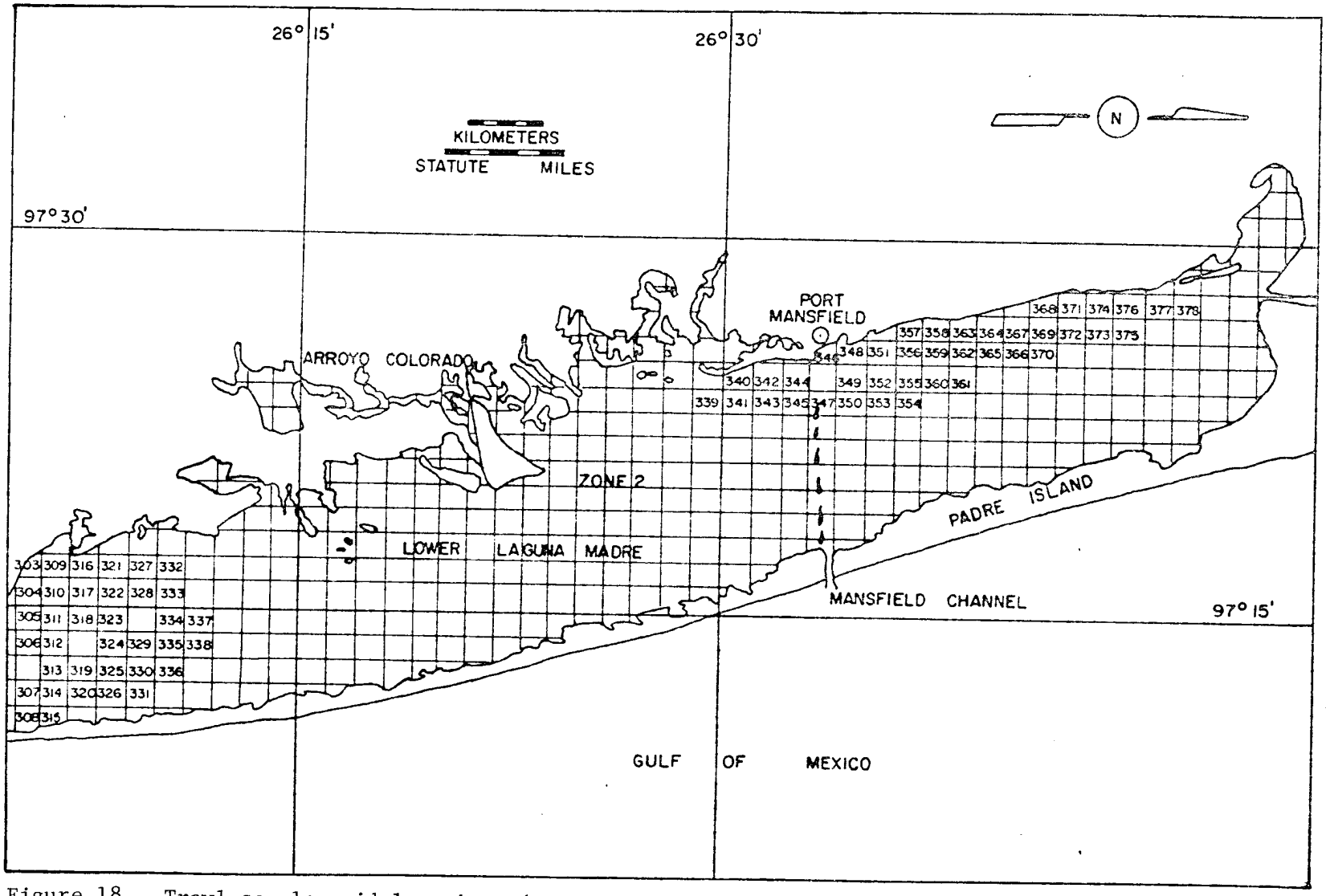

Figure 18. Trawl sample grid locations (indicated by numbers) in the lower Laguna Madre, 1982.

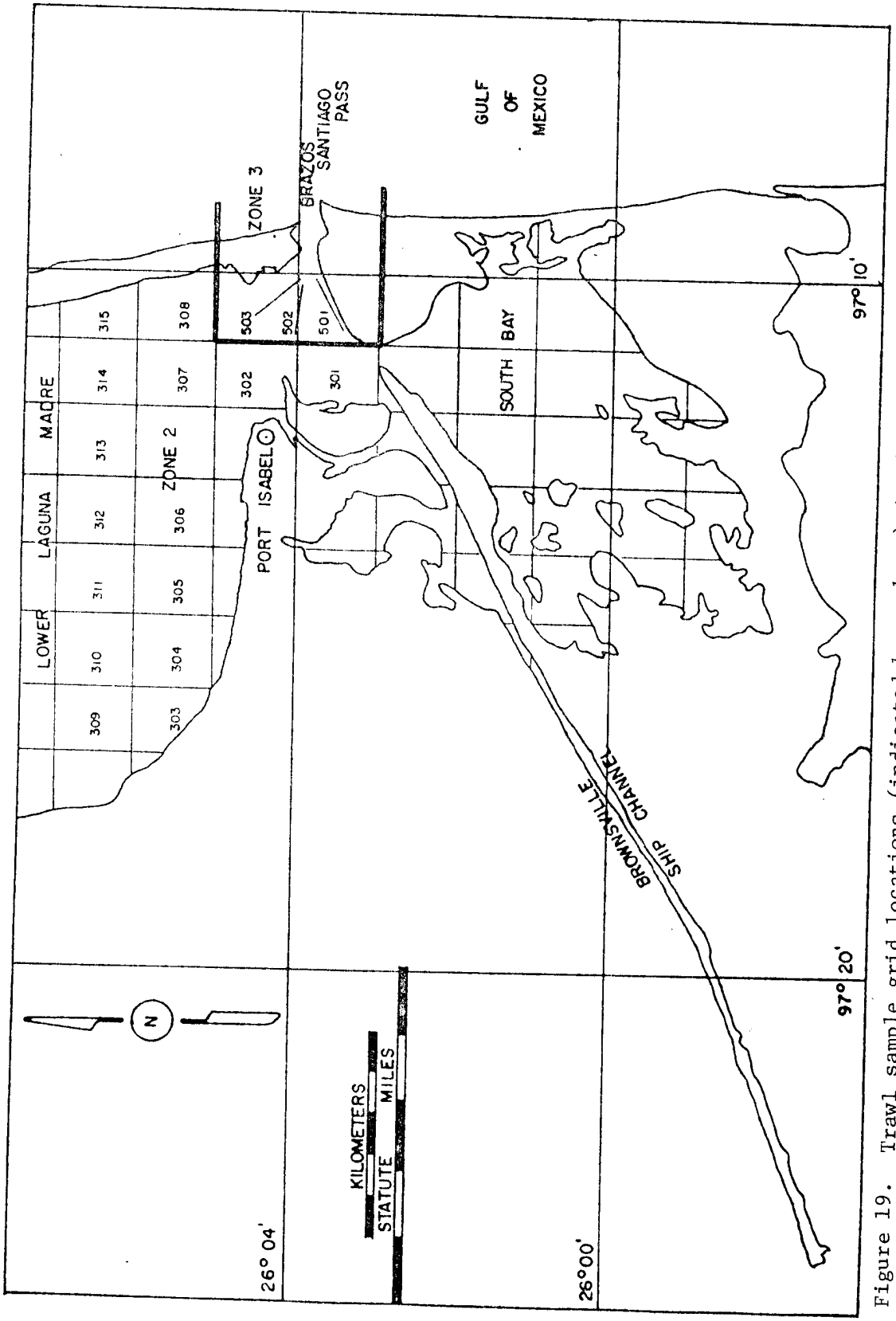

Figure 19. Trawl sample grid locations (indicated by numbers) in the lower Laguna Madre, 1982.

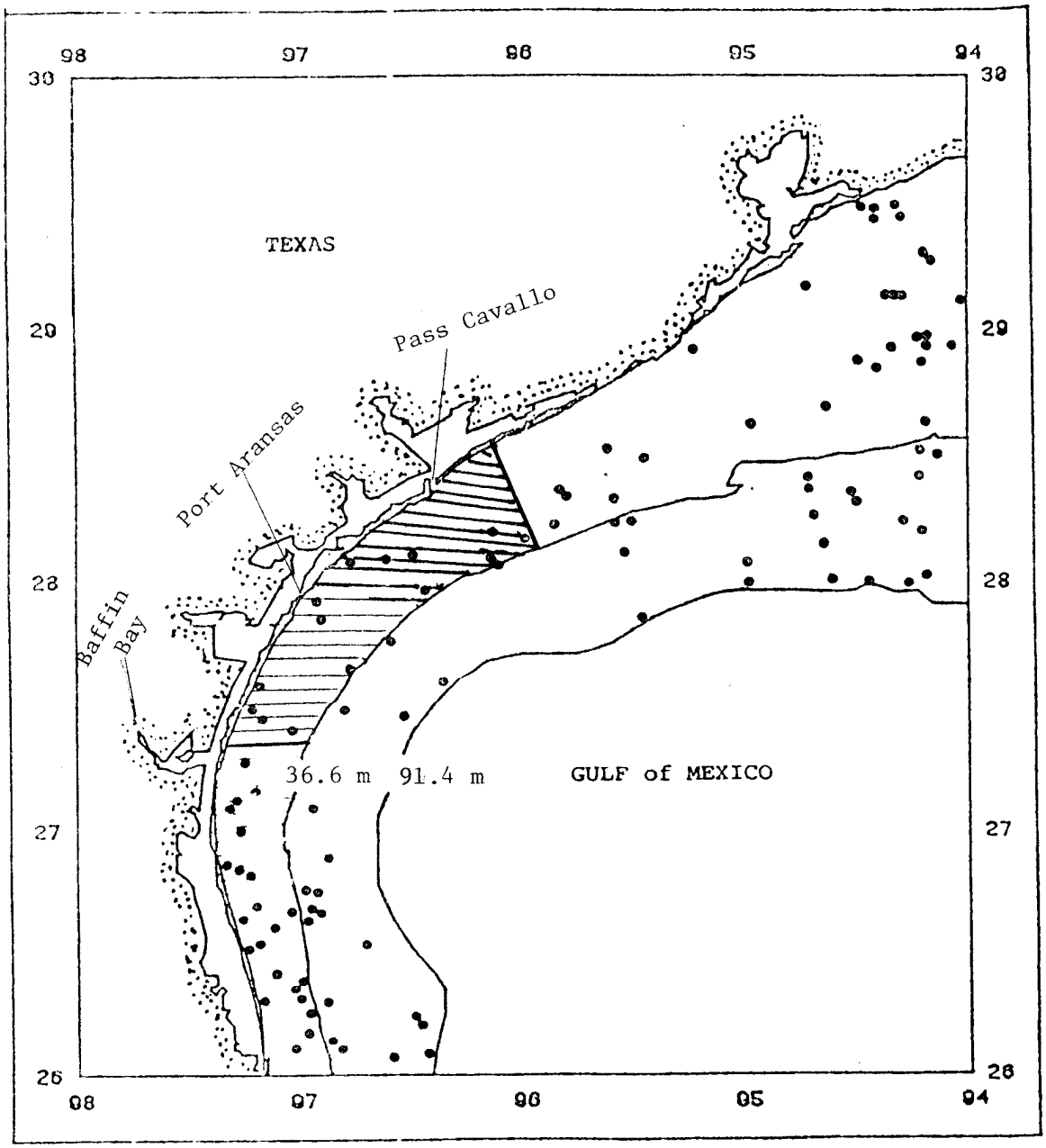

Figure 20. Sampling stations in Gulf of Mexico 1982 (indicated by dots). Samples in shaded areas collected during latter half of June. Sampling was done 22 June-13 July 1982 as cooperative fishery independent Southeast Area Monitoring and Assessment Program (SEAMAP).

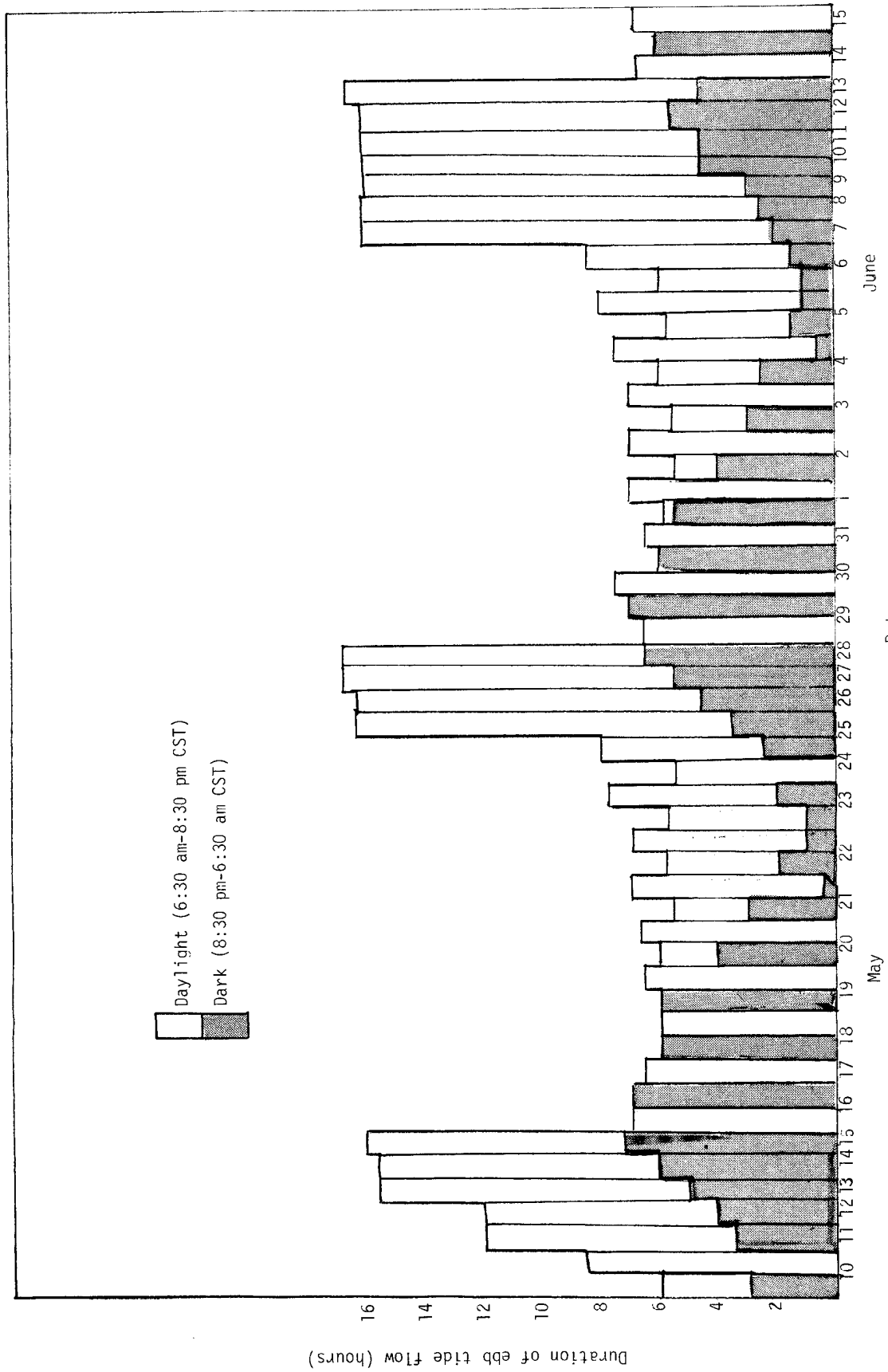

Figure 21. Duration of ebb tide flow in hours at Galveston Bay 10 May-15 June 1982. (Source NOAA Nautical Chart No. 11326). Longer spacing between dates indicates more than 2 daily tidal movements (shorter tide durations).

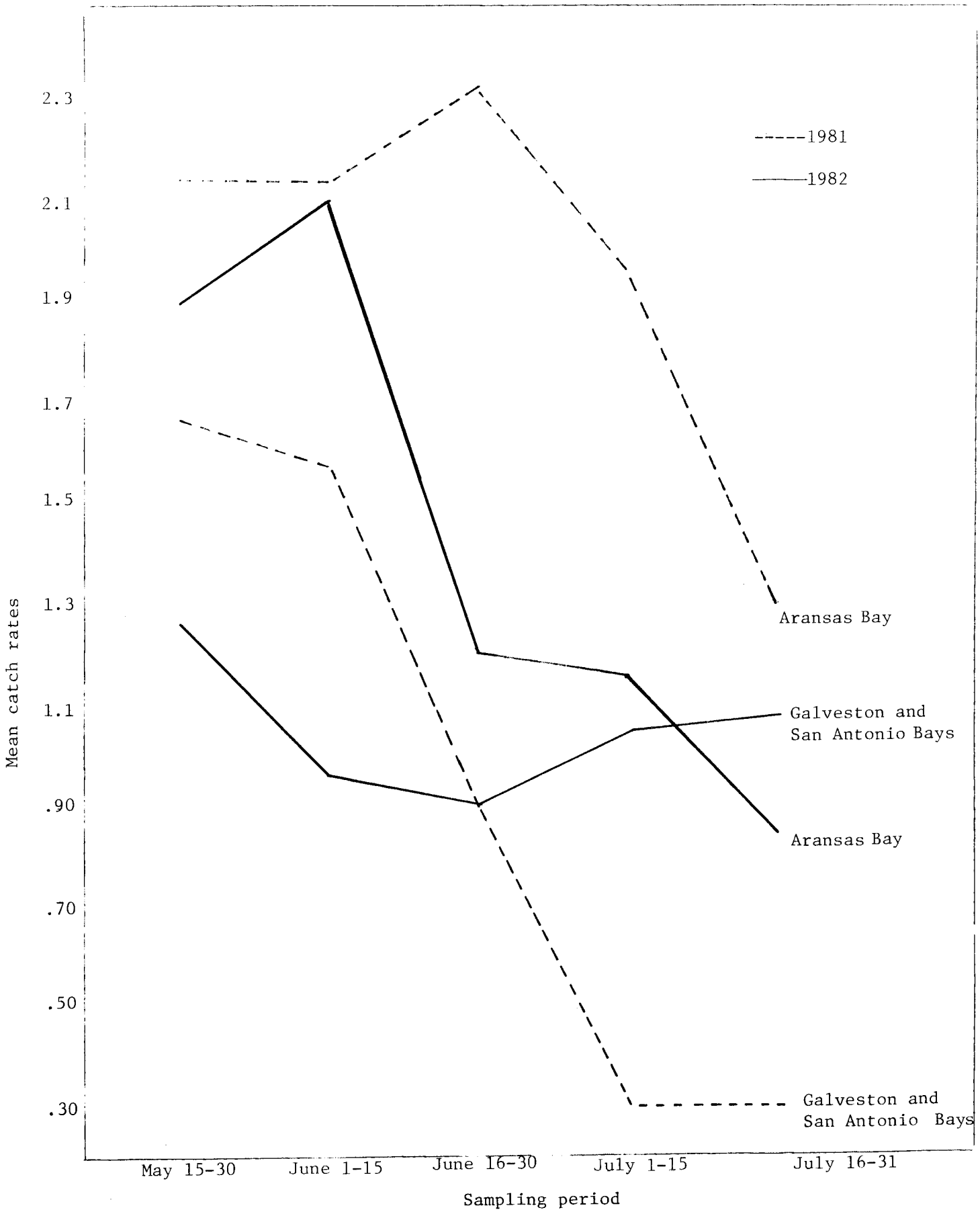

Figure 22. Mean catch rates of brown shrimp (P. aztecus) collected with 6.1 m trawls in Galveston, San Antonio. and Aransas Bay Systems 15 May-31 July 1981 and 1982. Mean catch rates = (No./15 minute tow +1) transformed to Log_{10}.

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