Relative Abundance and Size Distributions of Commercially Important Shrimp During the 1981 Texas Closure

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ABSTRACT — Relative abundances of commercial shrimp, Penaeus *spp., and lengths of brown shrimp,* Penaeus aztecus, *are determined for Texas shelf waters during the 1981 Texas closure, 22 May-15 July. A total of 274 samples were collected in water where bottom depths ranged from 4 to 45 fathoms in four statistical subareas covering the Texas Gulf coast. Greatest abundances of* Penaeus *were found between 10 and 20 fathoms in each subarea. Shrimp were more abundant in the southern subareas (20 and 21) than in the northern ones (18 and 19). Relative abundances during the 1981 closure were usually greater than those calculated from the 1961-65 Bureau of Commercial Fisheries' and the 1975-80 Texas Parks and Wildlife Department's (TPWD) historical shrimp collections from similar months.*

Mean total lengths of brown shrimp in waters where bottom depths were from 4 to 10 fathoms were close to 100 mm, those in 11-20 fathoms were close to 115 mm, and those in 21-30 fathoms were close to 130 mm. When mean total lengths of brown shrimp were compared among the three data sets, means of the 1981 closure surpassed those of the two historical data sets where bottom depths were from 4 to 10 fathoms during June. Closure mean lengths between 11 and 20 fathoms were less than those from Bureau of Commercial Fisheries data and were greater than those from Texas Parks and Wildlife Department data. Closure mean lengths in 21-30 fathoms were smaller than those from both agencies' data.

Introduction

A sustained yield of commercial shrimps off the Texas coast is economically important to Texas and to the United States. On the average, 56 percent of the brown shrimp, *Penaeus aztecus,* caught in the offshore waters of the Gulf of Mexico each year, are caught off Texas (NMFS, 1974-79). The annual shrimp harvest on the Texas Gulf coast between 1973 and 1977 has averaged 32.4 million pounds (heads-off), which amounted to an average annual contribution of $100 million to the coastal economy (at $3.10/pound). The annual shrimp harvest in Texas' offshore waters consists of 82 percent brown shrimp, about 18 percent white shrimp, *P. setiferus,* and less than 0.01 percent pink shrimp, *P. duorarum.*

Increased fishing pressure on shrimp during recent years (Christmas and Etzold, 1977; Gulf of Mexico Fishery Management Council, 1980) and the apparent reduction in the average size of shrimp caught (Caillouet et al., 1980) have caused serious concern over the possible depletion of the shrimp stock. Such concern led to the 1981 "Texas Closure," which was the simultaneous closing of the Fishery Conservation Zone (FCZ) and Texas territorial waters (Fig. 1) to shrimping

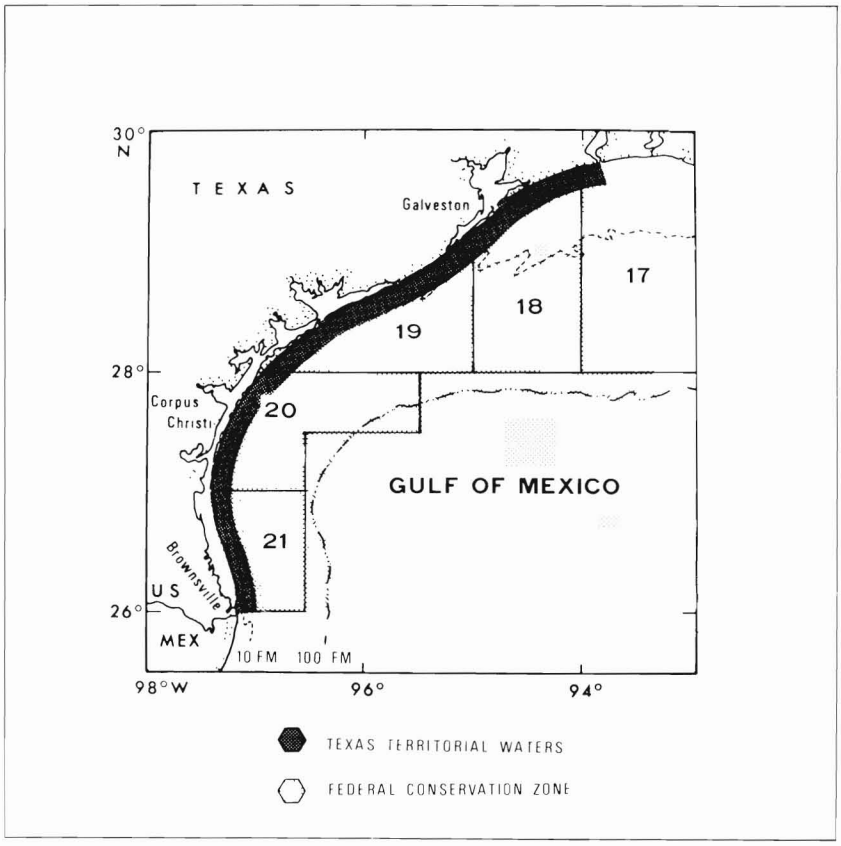

Figure 1.—A map of the Texas coast showing the four important statistical subareas (18-21), Texas territorial waters, and the Federal Conservation Zone.

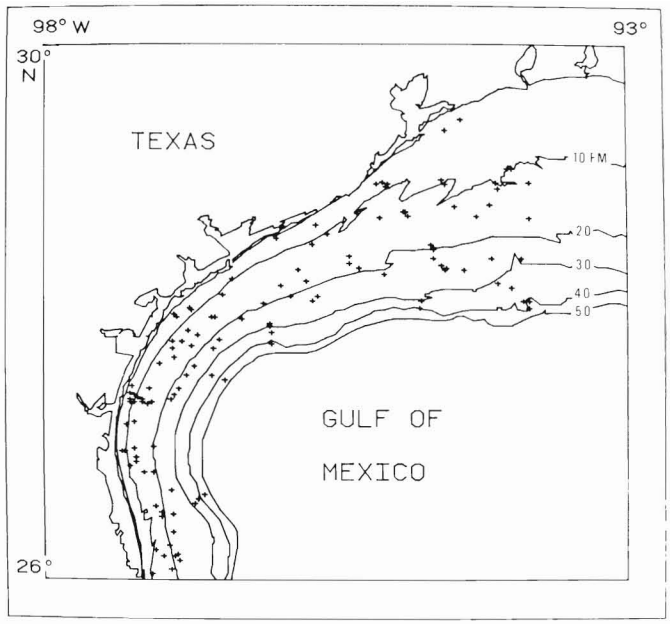

Figure 2.—Stations (+) sampled by the NMFS aboard the FRS *Oregon II* during the Texas Closure, 22 May-15 July 1981.

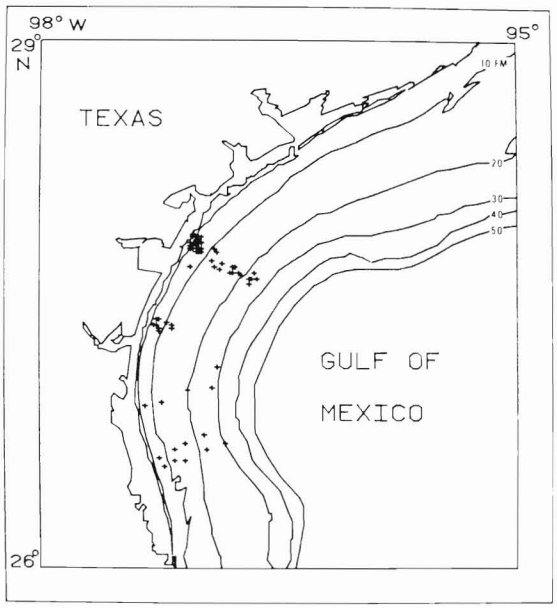

Figure 3.—Stations (+) sampled by the TPWD aboard the RV *Western Gulf* during the Texas Closure, 22 May-15 July 1981.

from 22 May through 15 July. There was a total ban on shrimping during the closure, except for the use of 25-foot or smaller nets inside bottom depths of 4 fathoms (fm) during daylight, which coincided with the annual mass migration of juvenile and subadult brown shrimp from the bays into the shallow shelf areas of the Gulf.

The objectives of this study were to: 1) Identify relative abundance distributions of commercial shrimp along the Texas Gulf coast during the closure, 2) identify relative size (length) distributions of brown shrimp during the closure, and 3) compare these distributions from the 1981 closure with historical data from similar months.

Methods

Texas Closure Sampling Procedures

A cooperative sampling program, which covered Texas shelf waters out to 50 fm, was established between the National Marine Fisheries Service (NMFS) and the Texas Parks and Wildlife Department (TPWD). There were 274 samples collected by NMFS personnel aboard the 170-foot FRS *Oregon II* and by TWPD personnel aboard the 67-foot RV *Western Gulf* (Table 1). NMFS personnel collected from 100 randomly selected sites within depth zones 1, 2, and 3, which extended from bottom depths of 0-10 fm, 11-20 fm, and 21-30 fm, respectively. They also collected from four selected sites each in depth zones 4 (31-40 fm) and 5 (41-50 fm) covering the Texas coast (Fig. 2). TPWD personnel collected in four transect areas along the south Texas coast, the major transect being at Aransas Pass (Fig. 3). All NMFS and TPWD sites deeper than 6 fm were sampled at night; TPWD sites within 6 fm were sampled during the day. To simplify data analysis, sites were grouped into four subareas that corresponded with "statistical subareas 18-21" (Fig. 1). Statistical subareas are used by NMFS to report commercial landings (Klima, 1980).

Table 1.—Distribution of 274 trawl samples taken by the NMFS (N) and TPWD (T) during the 1981 Texas Closure.

Stat. subarea	Depth zone	May		June		July	
		N	T	N	T	N	T
18	1	ns[1]	ns	9	ns	ns	ns
	2	ns	ns	14	ns	4	ns
	3	ns	ns	9	ns	2	ns
	4	ns	ns	2	ns	1	ns
	5	ns	ns	ns	ns	1	ns
19	1	ns	ns	15	ns	2	ns
	2	ns	ns	14	ns	ns	ns
	3	ns	ns	3	ns	ns	ns
20	1	ns	30	16	35	ns	12
	2	ns	4	22	9	ns	3
	3	ns	2	10	2	ns	1
	4	ns	ns	1	ns	ns	ns
	5	ns	ns	1	ns	ns	ns
21	1	ns	1	6	1	ns	2
	2	ns	2	19	1	ns	5
	3	ns	1	2	ns	ns	6
	4	ns	ns	2	ns	ns	ns
	5	ns	ns	2	ns	ns	ns
Sub-total		0	40	147	48	10	29
Totals		40		195		39	

[1]ns = no samples collected.

Each NMFS sample consisted of a 30-minute tow (rarely as short as 20 minutes) made with a 40-foot semiballoon shrimp trawl (2-inch stretched mesh), rigged with a tickler chain and spread by 40×96-inch doors. Each TPWD sample also consisted of a 30-minute tow (rarely as short as 15 minutes) made with either a 45-foot flat or a 47-foot semiballoon shrimp trawl (2-inch stretched mesh). Both TPWD trawls were equipped with a tickler chain and spread by 36×84-inch

doors. The NMFS samples collected between 5 and 30 fm were restricted to traversing a bottom depth change of 1 fm, and samples collected beyond 30 fm were allowed to traverse bottom depth changes of 5 fm. No such restrictions were applied to the TPWD samples; however, the duration of the tow effectively limited them to traversing only 1 or 2 fm along the bottom.

The NMFS and TPWD samples were analyzed similarly. In each sample, the *Penaeus* shrimp were culled from the total catch and separated by species. A total weight was recorded for the aggregate of each species and a subsample was drawn of either 200 specimens (only 50 specimens by the TPWD) or the entire aggregate, whichever was less. Sex and total length were determined for each individual in the subsample. Total length was measured from tip of rostrum to tip of telson. As a measure of relative abundance, a catch-per-unit effort (CPUE) value was calculated for each sample. The total weight (pounds) of *Penaeus* shrimp in the catch divided by the number of minutes towed and multiplied by 30 gives the pounds of *Penaeus* shrimp caught per 30-minute tow using a 40-foot, semiballoon shrimp trawl.

Since two different size vessels and three different size nets were used during the sampling, a series of nine paired samplings were made with the two vessels to determine if a regular bias existed. (When a regular bias is found, a standardization factor can then be used to correct for it.) Each vessel towed two nets during each paired sampling. The *Oregon II* towed a pair of 40-foot, semiballoon shrimp trawls, and the *Western Gulf* towed a 40-foot, semiballoon trawl on the port side and a 47-foot, semiballoon on the starboard side. The 45-foot flat net was not tested, but was assumed to catch like the 47-foot net. Using the sign test, no significant differences were found between the two vessels' mean total catches[1], port net catches, or starboard net catches (Table 2). Thus, the two vessels and their nets could be considered as equivalent samplers without standardization.

Table 2.—Total catches (pounds) and sign test results for the nine paired samplings made by the FRS *Oregon II* and the RV *Western Gulf* off the south Texas coast during the 1981 Texas Closure.

	Oregon II			*Western Gulf*		
Sample no.	Port (40-ft)	Starboard (40-ft)	Mean	Port (40-ft)	Starboard (47-ft)	Mean
1	31	28	29.5	30	29	29.5
2	32	26	29.0	43	36	39.5
3	100	69	84.5	109	109	109.0
4	142	117	129.5	101	95	98.0
5	192	153	172.5	158	138	148.0
6	175	135	155.0	170	131	140.5
7	120	114	117.0	38	48	43.0
8	35	25	30.0	34	24	29.0
9	22	27	24.5	38	37	37.5

Sign Tests:
1) Port net vs. Port net: $N = 9$, $X = 3$, $P = 0.254$ ns.
2) Starboard net vs. Starboard net: $N = 9$, $X = 4$, $P = 0.500$ ns.
3) Mean vs. Mean: $N = 8$, $X = 3$, $P = 0.362$ ns.

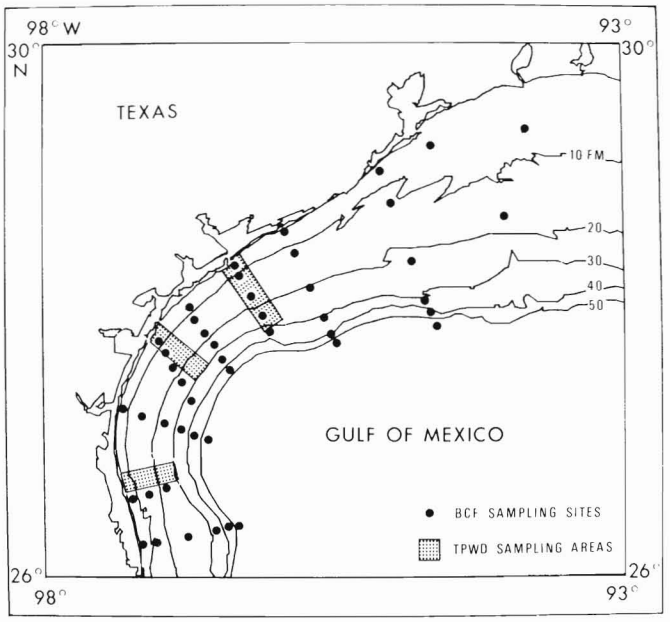

Figure 4.—Sampling sites and areas for BCF and TPWD historical shrimp data collections.

Historical Collections

The Bureau of Commercial Fisheries (BCF, now NMFS) and the TPWD surveyed shrimp distributions of Texas shelf waters from 1961-65 and 1975-80, respectively. Both sampled with 45-foot gulf shrimp trawls of 2-inch stretched mesh. The BCF used 60-minute trawls taken from the *Gus III,* an 85-foot commercial shrimp trawler. Tows were taken irrespective of time of day (Lyon and Baxter, 1974). The TPWD used 15- to 30-minute trawls taken from the RV *Western Gulf*. In TPWD surveys, sites shallower than 6 fm were sampled during the day; all others were sampled at night (Cody[2]). Locations of the BCF sampling sites and the TPWD sampling areas are shown in Figure 4. The total number of samples collected during 1961-65 by the BCF and during 1975-80 by the TPWD, by statistical subareas and depth zones for May-August, is shown in Table 3.

Trawl catches were processed differently by the BCF and the TPWD. In each BCF sample, all penaeid shrimp were identified to species and counted. Length and sex of up to 100 specimens

[1]G. A. Matthews and S. L. Hollaway. A report on the distributions of *Penaeus* spp. along the Texas coast, during the 1981 Texas Closure (May-July). NMFS, SEFC Galveston Laboratory, 4700 Avenue U, Galveston, TX 77550. 80 p.

[2]Cody, T. J. 1981. Texas Parks and Wildlife Department, 715 S. Bronte Street, Rockport, TX 78382. Pers. commun.

of each species were determined. In each TPWD sample, all penaeid shrimp were removed and their total weight recorded to ±1 ounce. The shrimp were then separated by species, and length and sex were determined for up to 50 specimens of each species. To standardize the measure of relative abundance between BCF and TPWD collections, CPUE's were calculated by the following formulae:

$$CPUE_{bcf} = \tfrac{1}{2} \times N \times L \times W$$

$$CPUE_{tpwd} = \frac{30}{T} \times C$$

where: N = total number of *Penaeus* caught,
L = mean length of *P. aztecus* caught,
W = length-weight conversion factor for *P. aztecus* using the mean length (Fontaine and Neal, 1971),
T = duration of the tow in minutes, and
C = pounds of *Penaeus* caught.

Definitions

The term "new-year-class" shrimp refers to young shrimp that are less than 1-year-old and have just migrated from the bays into the Gulf. These shrimp generally have mean total lengths between 80 and 105 mm during the May-June period (Trent, 1967; Copeland, 1965). "Previous-year-class" shrimp are defined as those that have overwintered in shallow coastal Gulf water and have mean total lengths between 125 and 180 mm during the same period. Given 30-45 days in the Gulf and sufficient food, the new-year-class shrimp are expected to grow to total mean lengths comparable to the shorter of the previous-year-class shrimp (Parrack, 1979).

In July 1981, Texas repealed its minimum size requirement for shrimp caught in the Gulf of Mexico. Prior to this date the legal limit was a minimum of 39 shrimp (heads-on) per pound, which converts to a mean total length of 114 mm. This size is used for reference in figures of length-frequency distributions.

Table 3.—Distribution of 612 trawl samples taken by the BCF (B) (1961-65) and the TPWD (T) (1975-80) for surveys of shrimp distributions along the Texas gulf coast in four statistical subareas (SS) and up to six depth zones (DZ).

		May		June		July		August	
SS	DZ	B	T	B	T	B	T	B	T
18	1	11	ns[1]	10	ns	10	ns	14	ns
	2	6	ns	9	ns	4	ns	7	ns
	3	5	ns	7	ns	2	ns	6	ns
	4	1	ns	1	ns	1	ns	2	ns
	5	3	ns	1	ns	2	ns	2	ns
	6	2	ns	2	ns	1	ns	2	ns
19	1	8	6	8	8	5	8	7	6
	2	1	5	1	6	1	6	1	4
	3	1	1	1	3	1	2	1	1
20	1	6	28	8	27	4	23	5	21
	2	10	21	8	23	6	23	8	21
	3	8	9	8	10	6	9	8	9
	4	5	ns	5	ns	5	ns	5	ns
	5	1	ns	3	ns	3	ns	3	ns
	6	1	ns	3	ns	2	ns	3	ns
21	1	2	1	4	1	3	2	3	1
	2	2	2	3	2	3	2	3	2
	3	2	2	4	2	3	2	4	2
	4	ns	ns	1	ns	1	ns	1	ns
	5	ns	ns	1	ns	ns	ns	1	ns
Subtotals		75	75	88	82	63	77	85	67
Totals		150		170		140		152	

[1]ns = no samples collected.

Results

Relative Abundance of the Genus, *Penaeus*

Abundances of *Penaeus* shrimps, all species combined, were examined relative to 1-fm depth changes across the bottom (strata) and in terms of 10-fm depth changes (depth zones) as they were found in each of the statistical subareas. The abundances during the 1981 closure by depth zones and subareas were also compared with those from BCF and TPWD historical data sets.

During the closure, several samples were taken in various 1-fm strata and their mean CPUE's determined. These samples showed considerable variability in relative abundances over short distances (Fig. 5). This variability was evident in all four subareas despite the uneven number and distribution of samples among the strata in each statistical subarea. Mean CPUE's for each stratum ranged from just over 60 pounds to under 1 pound. The highest means were usually located between 9 and 15 fm and the lowest were usually beyond 30 fm. Large increases and decreases in mean CPUE's occurred particularly among strata near 10 fm, but also among strata throughout the 10-20 fm ranges in all subareas. Fairly regular decreases in mean CPUE's for each stratum occurred from about 15 fm out to 45 fm, particularly in statistical subareas 20 and 21 and less so in subarea 19.

Table 4.—Mean CPUE's for all *Penaeus* species combined (heads-on). Collections were made during the 1981 Texas Closure.

Stat. subarea	Depth zone	No. samples	CPUE (lb.)	S.D.	PCCPN[1] (lb.)
18	1	9	14.6	11.7	1,402
	2	18	15.0	12.9	1,440
	3	9	2.1	1.6	202
19	1	17	14.3	16.5	1,373
	2	14	19.3	17.8	1,853
	3	3	5.1	0.2	490
20	1	55	12.5	12.9	1,200
	2	40	35.7	17.7	3,427
	3	15	9.6	6.3	922
21	1	10	15.5	12.1	1,488
	2	27	32.6	16.2	3,130
	3	9	13.9	8.7	1,334

[1]Calculations of potential commercial catch per 12-hour night (PCCPN) are based on 4 × the number of nets and 24 × the time interval for closure CPUE's.

When a mean CPUE was calculated for each depth zone in each subarea, the greatest means were found for depth zone 2 in all subareas and the next highest were for depth zone 1 (Table 4). In depth zone 2, mean CPUE's for subareas 18 and 19 were similar, 15.0 and 19.3 pounds, respectively; likewise, those for subareas 20 and 21 were similar, 35.7 and 32.6 pounds. In depth zone 1, mean CPUE's were similar among all four subareas, only ranging from 12.5 to 15.5 pounds. In depth zone 3, mean CPUE's increased in fairly regular increments in line along the coast from only 2.1 pounds in subarea 18 to 13.9 pounds in subarea 21. In 7 of 12 cases, the standard deviations associated with mean CPUE's for depth zones were within ±25 percent of their respective means. Despite the sizable standard deviations, differences in mean CPUE's for the statistical subareas and depth zones were very highly signifi-

Table 5.—Results from a two-way ANOVA testing shrimp CPUE for depth zones 1-3 in statistical subareas 18-21. CPUE values were transformed by $ln(x+1)$. Individual tows were collected in May-June during the 1981 Texas Closure.

Source of variation	Degrees of freedom	Sums of squares	F	Significance level (P)
Subareas	3	14.41	9.68	0.000***
Depth zones	2	26.56	26.76	0.000***
Interaction	6	0.87	0.29	0.940
Error	214	106.22		

*** $+P<.001$

cant when tested in a two-way ANOVA (Table 5).

For each of the historical data sets, samples collected at night in May, June, and July of each year were grouped by depth zone and statistical subarea in order to calculate overall mean CPUE's for all years combined. Data were adequate only for depth zones 1-3. Mean CPUE's of the 1981 closure data were greater than those of the BCF data in every case (depth zone in a subarea), and were greater than those of the TPWD data in all cases except for depth zone 3 in subarea 19 (Fig. 6). Standard deviations associated with mean CPUE's in all three data sets were usually substantial, suggesting that many of these apparent differences among CPUE's from data sets may not be statistically significant. Because of suspected differences in variances among the data sets for each case, the non-parametric Mann-Whitney U test (Siegel, 1956) was used to test for differences in CPUE's between data sets (Table 6). No significant differences were found where small differences in means existed (Fig. 6). Also, the large differences in means of depth zone 3 in subarea 19 and of

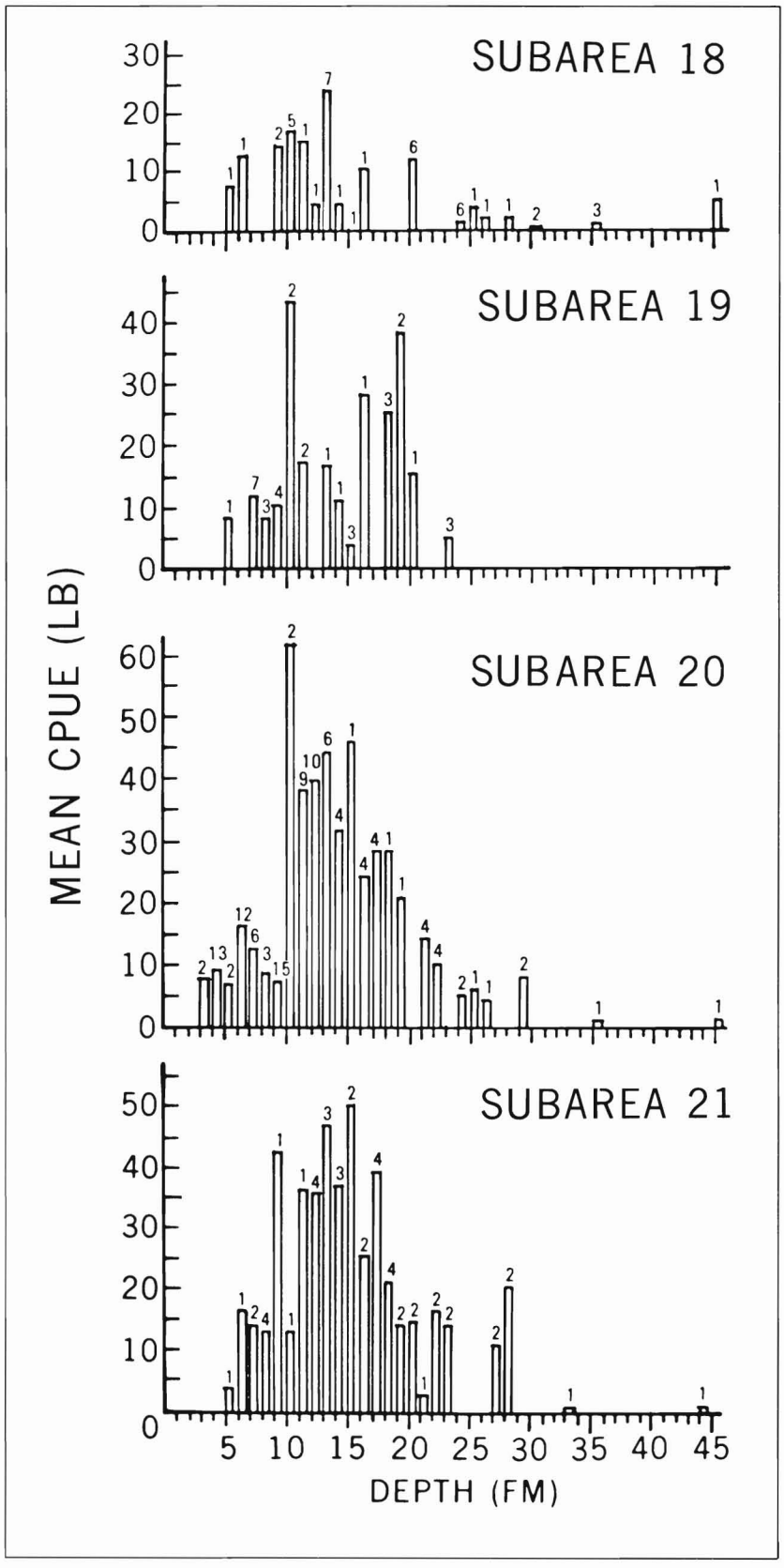

Figure 5.—Mean CPUE's of *Penaeus* shrimps from samples collected during the Texas Closure, May-July 1981, for individual 1 fm depth strata in statistical subareas 18-21 are shown by vertical bars. Numbers over each bar represent the number of samples taken in that stratum.

depth zone 1 of subarea 21 were not significant. Mean CPUE's for 6 of 12 cases during the 1981 closure were twice those belonging to the nearest of the other two data sets, and these differences were statistically significant. Thus, there was a greater than usual abundance of shrimp in Texas shelf waters during the 1981 closure period.

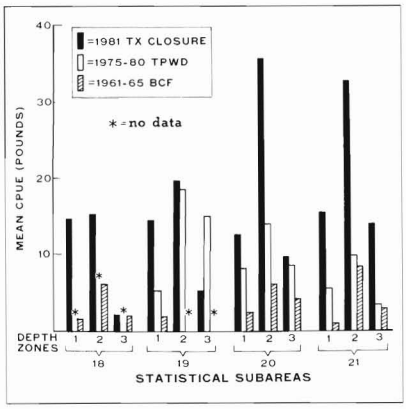

Figure 6.—A comparison of relative abundances of *Penaeus* shrimps in depth zones 1-3 (0 to 30 fm) in statistical subareas 18-21. Comparisons were made among three data sets. CPUE's were in terms of pounds of *Penaeus* caught per 30-minute tow with a 40-foot shrimp trawl.

Table 6.—Results of Mann-Whitney U tests comparing CPUE's of *Penaeus* shrimp between data sets[1].

SS	DZ	CLOS vs. TPWD	CLOS vs. BCF	TPWD vs. BCF
18	1	nd	3	nd
	2	nd	1	nd
	3	nd	0	nd
19	1	3	3	1
	2	0	nd	nd
	3	0	nd	nd
20	1	3	3	1
	2	3	3	1
	3	0	2	1
21	1	0	0	0
	2	3	2	0
	3	1	1	0

[1]Key: SS = Statistical subarea.
DZ = Depth zone.
nd = No data or insufficient data.
0 = Not significant.
1 = Significant.
2 = Very significant.
3 = Most significant.
CLOS = 1981 Texas Closure data.
TPWD = 1975-80 Texas Parks and Wildlife Department data.
BCF = 1961-65 Bureau of Commercial Fisheries data.

Length-Frequency Distributions of Brown Shrimp

Length-frequency distributions for brown shrimp caught in statistical subareas 18-21 during the 1981 closure are given in Figures 7-10. Samples taken in May (TPWD only) in subareas 20-21 clearly showed that two separate year classes of shrimp existed in these subareas. The small new-year-class shrimp that had just migrated to the shallow Gulf (depth zone 1) from the bays had mean lengths of 80 and 76 mm in subareas 20 and 21, respectively, and their lengths ranged from 48 to 144 mm (Table 7). Shrimp in depth zone 2 showed respective mean lengths of 120 and 114 mm in subareas 20 and 21. This depth zone contained previous-year-class shrimp of 130-190 mm as well as new-year-class shrimp. The previous-year-class shrimp predominated in depth zone 3, where respective mean

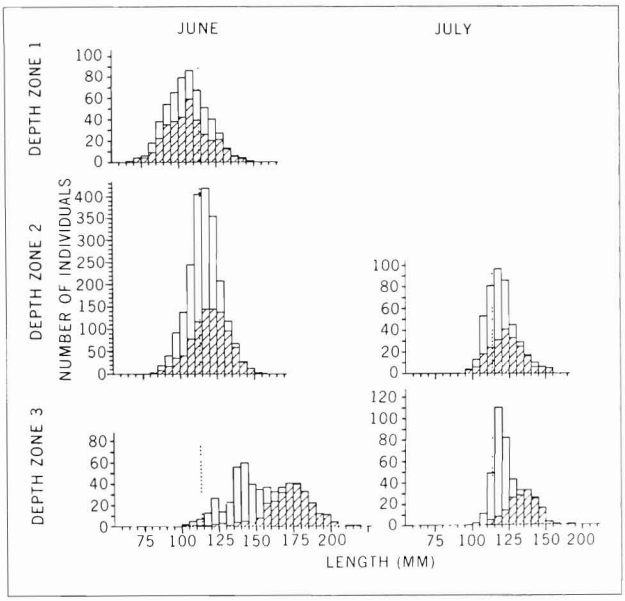

Figure 7.—Length-frequency distributions of *Penaeus aztecus* collected in statistical subarea 18 during the 1981 Texas Closure. Clear and hatched portions of the bars represent males and females, respectively. The dotted lines represent the old "legal-sublegal" size break, 114 mm.

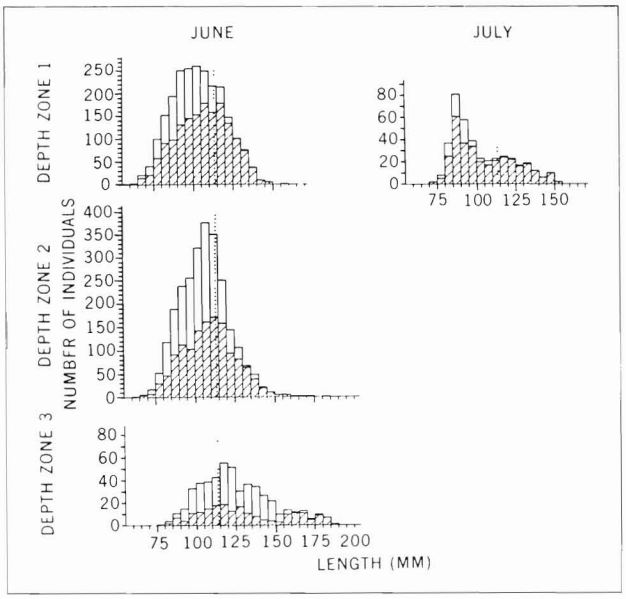

Figure 8.—Length-frequency distributions of *Penaeus aztecus* collected in statistical subarea 19 during the 1981 Texas Closure. Clear and hatched portions of the bars represent males and females, respectively. The dotted lines represent the old "legal-sublegal" size break, 114 mm.

lengths were 157 and 140 mm for subareas 20 and 21.

In June, shrimp lengths in depth zone 1 in all statistical subareas showed a typical normal distribution around a mean of 100 mm. Mean lengths in subareas 18 and 19 were slightly above, while those in subareas 20 and 21 were slightly below, 100 mm. Furthermore, lengths in depth zone 2 in all subareas also appeared normally distributed around a higher mean (110 mm) than in zone 1. Means for subareas 18 and 21 were slightly above 110 mm and those in subareas 19 and 20 were slightly below. According to length-frequency distributions, previous-year-class shrimp comprised about 80 percent of the stock in depth zone 3 of subarea 18, but only about 20 percent of the same in subareas 19-21.

Length-frequency distributions in July showed the continued presence of small new-year-class shrimp. In depth zone 1 of statistical subareas 19 and 20, two waves of new-year-shrimp were evident. The mean length of the earlier wave had increased from about 100 mm to about 120 mm in subarea 19 and to about 110 mm in subarea 20. Means of the more recent wave were about 90 and 80 mm for subareas 19 and 20, respectively. On the other hand, in depth zone 2 of subareas 18, 20, and 21 (no data for 19), shrimp mean lengths were 120, 122, and 113 mm, respectively, only a slight increase over June values. For depth zone 3, changes in lengths from June to July stocks varied among subareas. In subarea 18 the new-year-class shrimp now comprised 80 percent of the stock, and the previous-year-class comprised only 20 percent. This increase in the new-year-class component lowered the mean length to 120 mm from 151 mm the previous month. Although only one sample was taken in subarea 20, it showed only new-year-class shrimp of the same size as found in June. In subarea 21 there was a slight decrease in mean length, and the length-frequency distribution of depth zone 3 closely resembled that of zone 2.

Although May statistics were not compared, June and July mean lengths of brown shrimp in each of depth zones 1-3 were compared among the three data sets (Fig. 11). Only in June in depth zone 1 of all subareas and in depth zone 2 of subarea 21 were mean lengths of brown shrimp greater for the 1981 closure than for the 1961-65 BCF data; in all other cases the BCF means were greater. Mean lengths of the brown shrimp in the 1975-80 TPWD data were very close to those of the 1981 closure. TPWD means were slightly lower for depth zones 1

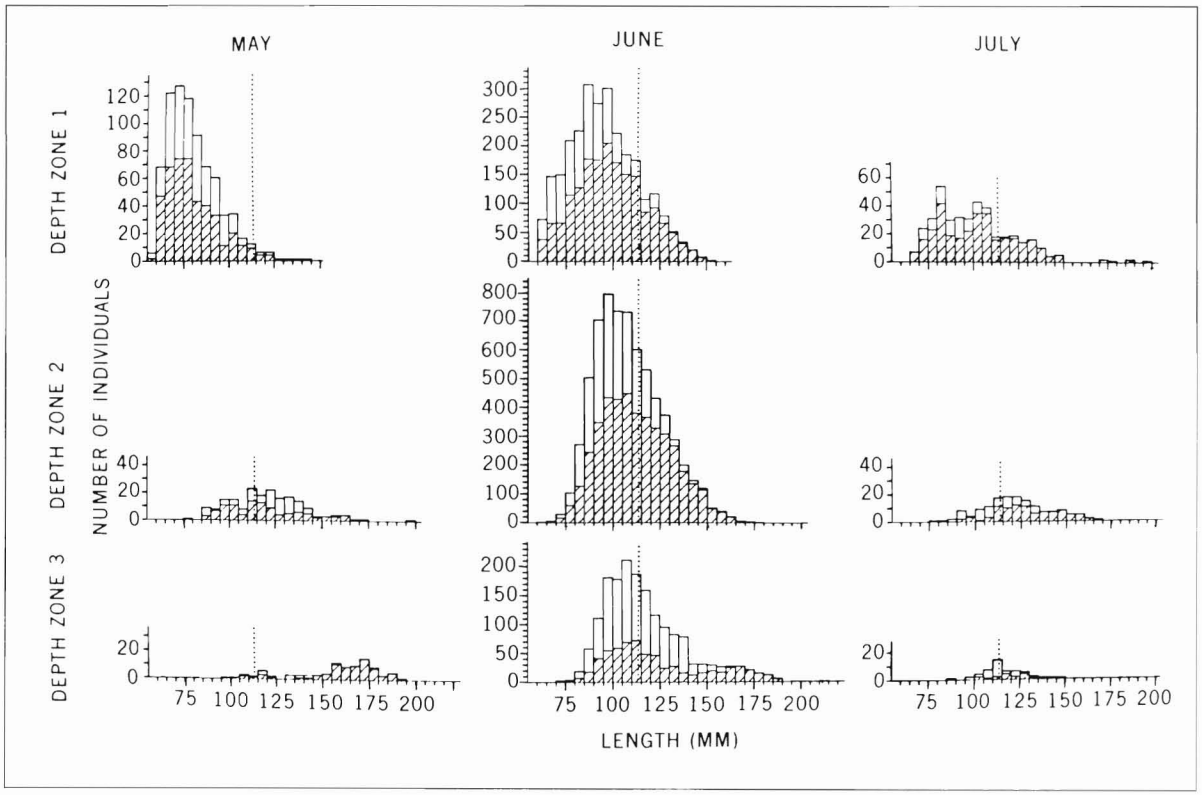

Figure 9.—Length-frequency distributions of *Penaeus aztecus* collected in statistical subarea 20 during the 1981 Texas Closure. Clear and hatched portions of the bars represent males and females, respectively. The dotted lines represent the old "legal-sublegal" size break, 114 mm.

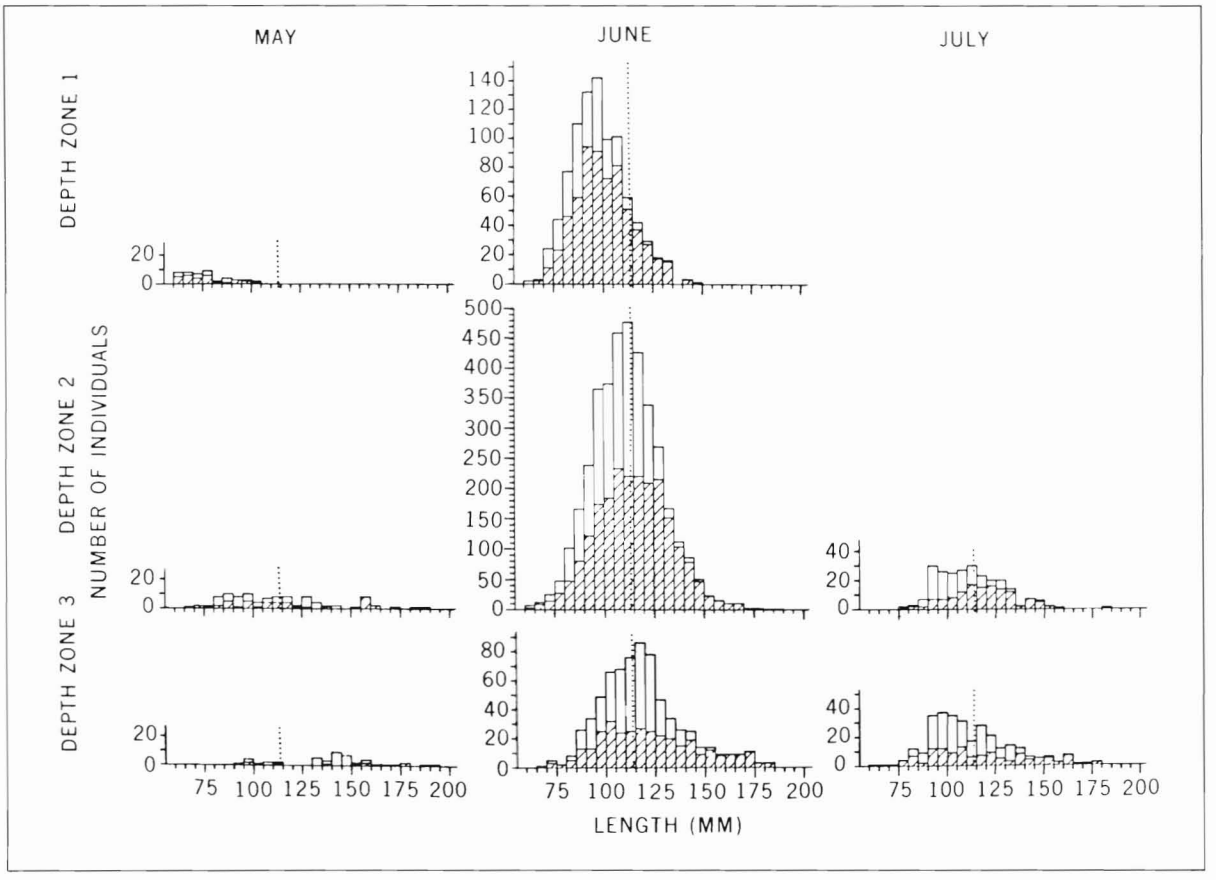

Figure 10.—Length-frequency distributions of *Penaeus aztecus* collected in statistical subarea 21 during the 1981 Texas Closure. Clear and hatched portions of the bars represent males and females, respectively. The dotted lines represent the old "legal-sublegal" size break, 114 mm.

and 2, but were slightly greater in depth zone 3.

Length-Frequency Distribution of Other Penaeid Species

Pink and white shrimp accounted for about 5 percent of the total shrimp catches in the four statistical subareas. Pink shrimp were taken mainly between 4 and 20 fm, whereas white shrimp were taken mainly between 4 and 10 fm (Table 8). Since so few of these species were caught and their catches were unevenly distributed, their length-frequency distributions in relation to time and depth were not firmly established. Sometimes, increases in mean lengths of pink shrimp through time and with depth were found; however, the opposite trend was noted about as often. The same was true for white shrimp. Length-frequency distributions of pink shrimp showed a mixture of small new-year-class shrimp with large previous-year-class shrimp in all depth zones and subareas where 10 or more shrimp were measured. On the other hand,

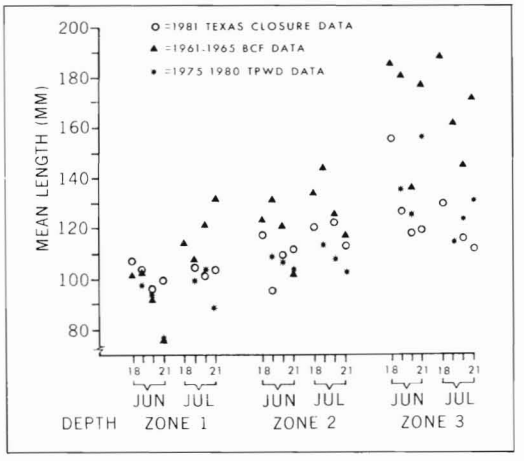

Figure 11.—Mean lengths of *Penaeus aztecus* in statistical subareas 18, 19, 20, and 21 for June and July and in depth zones 1-3 compared among three data sets. No collections were made in statistical subarea 18 by the TPWD.

length-frequency distributions showed that white shrimp stocks were composed almost exclusively of large previous-year-class shrimp. Only in June in subarea 21 and in July in subarea 20 were a few small new-year-class white shrimp found.

Data were insufficient to warrant comparisons of lengths of pink and white shrimps among the three data sets.

Table 7.—Total length (mm) statistics for brown shrimp derived from NMFS and TPWD trawl samples from depth zones 1-5 and statistical subareas 18-21 along the Texas shelf during the 1981 Texas Closure.

	Statistical subareas									
	18		19		20			21		
Item	June	July	June	July	May	June	July	May	June	July
Depth Zone 1: 0-10 fm										
No. measured	560		2,320	406	773	2,698	401	47	902	2
Length										
Min.	70		60	72	48	54	67	58	58	95
Max.	146		157	152	144	177	197	104	149	113
Mean	107		104	104	80	96	101	76	99	104
S.D.	13		16	18	14	18	21	18	13	8
Depth Zone 2: 11-20 fm										
No. measured	2,165	446	2,901		192	6,695	150	100	3,785	246
Length										
Min.	78	97	56		78	63	78	69	58	76
Max.	157	153	184		198	179	166	187	188	182
Mean	117	120	105		120	109	122	113	112	113
S.D.	11	9	36		19	17	18	26	16	16
Depth Zone 3: 21-30 fm										
No. measured	555	410	517		95	1,711	50	47	703	300
Length										
Min.	104	110	78		98	67	86	93	68	64
Max.	216	172	189		192	213	147	191	185	177
Mean	156	130	126		157	118	116	140	119	112
S.D.	21	10	22		23	21	11	23	20	21
Depth Zone 4: 31-40 fm										
No. measured	30	3				1			32	
Length										
Min.	155	182				146			94	
Max.	216	208				—			180	
Mean	177	192				146			131	
S.D.	16	14				—			24	
Depth Zone 5: 41-50 fm										
No. measured		49				8			4	
Length										
Min.		123				159			95	
Max.		223				192			147	
Mean		168				169			130	
S.D.		20				12			20	

Discussion

In 1981, for the first time, both the Texas territorial waters and the Fishery Conservation Zone were closed to shrimping during the spring period of brown shrimp migration. The main purpose of this closure was to prevent the wasteful catching and discarding of shrimp below marketable size. Although this study's primary objective was to determine the effects of the 1981 closure on the shrimp stock, with special reference to abundance and length-frequency changes through time and location, a few specific questions should also be considered: 1) How typical was the 1981 migratory stock? 2) How closely did the closure data depict the stock as reflected by later commercial catches? And, 3) to what extent were the closure's objectives fulfilled?

Emigration of juvenile and subadult brown shrimp from Texas Bays to shallow waters in the Gulf of Mexico typically occurs from May through July each year. The typical peaks in emigration, through tidal passes that have been studied, occurred in late May or early June. Also, this exodus apparently occurs in waves superimposed on a base level of emigration. These patterns have been noted in Bolivar Roads which connects Galveston Bay with the Gulf (Trent, 1967), in Cedar Bayou which connects Mesquite Bay and San Antonio Bay with the Gulf (King, 1971), and in Aransas Pass which connects Aransas Bay and Corpus Christi Bay with the Gulf (Copeland, 1965). The timing of the emigrations held true for all six years covered by these studies—1963, 1964, 1966, 1968, 1969, and 1970.

Furthermore, the sizes of emigrating brown shrimp showed considerable uniformity through the various years and among the areas of the three studies cited above. Mean total length for the brown shrimp in early June was near 85 mm in each study, with the majority of these emigrating brown shrimp between 75 and 95 mm. Trent (1967) was the only one to note a definite increase in mean lengths of emigrants from May through July. Copeland (1965) reported small differences in mean lengths of brown shrimp moving through Aransas Pass in May 1963 and May 1964. Thus, both the month and year can be expected to show small differences in the lengths of emigrating brown shrimp.

The TPWD also sampled shrimp directly off Aransas Pass in 10 fm in June 1968 (King, 1971) where the majority were between 80 and 100 mm in total length. This was about 5 mm greater than shrimp migrating through Cedar Bayou at the same time. In May 1981 the new-year-class brown shrimp in depth zone 1 were averaging between 76 and 80 mm. Based on this "pass to 10-fm" size change on the typical sizes of the emigrating shrimp, and on the sizes of the brown shrimp in depth zone 1 and in May and June 1981, it appears the early establishment of the closure was a wise step. This measure protected the large wave of emigrating small brown shrimp that must have occurred in late May.

Klima et al.[3] analyzed the July commercial brown shrimp catches and found over 40 percent of the catch belonged to 31-40 heads-off count shrimp. This converts to total lengths ranging from 130 to 140 mm according to Fontaine[4]. These total length values

[3]E. F. Klima, K. N. Baxter, and F. J. Patella. A review of the offshore shrimp fishery and the 1981 Texas closure. NMFS, SEFC Galveston Laboratory, 4700 Avenue U, Galveston, TX 77550. 68 p.

[4]C. T. Fontaine. A chart showing tail lengths and total lengths for each shrimp count category. NMFS, SEFC Galveston Laboratory, 4700 Avenue U, Galveston, TX 77550. 10 p.

Table 8.—Total length (mm) statistics for pink and white shrimp derived from NMFS and TPWD trawl samples from several depth zones and statistical subareas 18-21 along the Texas shelf during the 1981 Texas Closure.

	Statistical subareas									
	18		19		20			21		
Item	June	July	June	July	May	June	July	May	June	July
Pink shrimp, *Penaeus duorarum*										
Depth Zone 1: 0-10 fm										
No. measured	68		100	2	193	3,171	19	16	312	111
Length										
Min.	104		88	107	71	84	102	52	74	104
Max.	178		166	122	155	178	181	143	176	154
Mean	129		118	114	101	127	135	116	116	128
S.D.	13		12	7	16	11	18	23	15	10
Depth Zone 2: 11-20 fm										
No. measured	339	22	244		3	6	0	10	155	0
Length										
Min.	98	93	80		84	97	—	78	59	—
Max.	198	127	175		166	148	—	116	159	—
Mean	135	113	119		114	124	—	98	102	—
S.D.	15	7	15		37	17	—	10	19	—
Depth Zone 3: 21-30 fm										
No. measured	3	5	14		0	0	0	0	1	0
Length										
Min.	138	110	90		—	—	—	—	115	—
Max.	175	151	128		—	—	—	—	—	—
Mean	151	129	104		—	—	—	—	115	—
S.D.	17	14	9		—	—	—	—	—	—
White shrimp, *Penaeus setiferus*										
Depth Zone 1: 0-10 fm										
No. measured	119		356	142	453	462	154	0	1	0
Length										
Min.	137		139	155	125	138	73	—	82	—
Max.	192		205	210	197	198	190	—	—	—
Mean	164		173	176	165	172	167	—	82	—
S.D.	11		12	11	15	10	18	—	—	—
Depth Zone 2: 11-20 fm										
No. measured	37	0	0		2	22	0	0	1	0
Length										
Min.	153	—	—		158	154	—	—	161	—
Max.	193	—	—		169	197	—	—	—	—
Mean	172	—	—		164	175	—	—	161	—
S.D.	10	—	—		5	11	—	—	—	—

were slightly larger than the July means calculated from closure data for depth zones 2 and 3 in all subareas for which data were available, and are within the expected size range that shrimp would attain given the 2- to 3-week growing period between the early July closure sampling and the late July commercial shrimping. This observation provides supportive evidence that the closure sampling and analyses were fairly accurate in depicting sizes of brown shrimp in the stock.

The 1981 sampling during the closure indicated a high relative abundance of shrimp. It appeared that the 1981 harvest would be bountiful once shrimping began. Based on catch-per-unit-effort statistics from the closure samples, the greatest concentrations of shrimp were found in depth zone 2 of each of the four subareas covering the Texas coast. The second largest concentrations were in depth zone 1, followed by depth zone 3, and still lesser concentrations were found at deeper levels. CPUE's for depth zone 2 were about twice as great in subareas 20 and 21 as in 18 and 19. It is uncertain whether this difference was due to a greater influx of immigrant shrimp from southern bays or whether it was a result of preferences for depths encompassed by depth zone 2 by the 95- to 125-mm size shrimp, coupled with narrower and smaller bottom areas for depth zone 2 in subareas 20 and 21. A third possibility is that the majority of samples in subareas 20 and 21 were taken directly out from the major tidal passes and thus in the mainstreams of the migrating shrimp. Many samples were collected directly in front of Aransas Pass in statistical subarea 20, but not in front of the passes in subarea 21. Since both 20 and 21 had high CPUE's, it is most likely that the first two explanations were of greater importance in determining the CPUE's for the subareas than was the third explanation.

Commercial shrimp catches for July and August 1981 efforts along the Texas coast were outstanding, amounting to 10.3 million pounds (heads-off) in July and 14.6 million in August, according to Klima et al. (footnote 3). They calculated the mean July CPUE by shrimpers in Texas at 1,125 pounds (heads-off) per 12-hour shrimping night. Additionally, they noted the maximum CPUE's were found in subareas 20 and 19 in July. Based on the closure samplings in June and July in depth zones 1-3, the potential commercial catch per 12-hour shrimping night was calculated to be 1,522 pounds (heads-on). This value shows very close agreement for the two separate calculations and is an additional indication that the closure sampling was able to depict fairly well the abundance of the brown shrimp stock along Texas. On the other hand, it was somewhat disconcerting to note that the high CPUE's found during the closure for statistical subarea 21 were not evident in the commercial catches during July. Likewise, another point of difference is that the high CPUE found by shrimpers in subarea 19 in July was not found during the closure. Both sampling design and shrimp migrations along the coast may have been responsible for these discrepancies.

Major contributions of this 1981 closure study include delineation of the abundance distribution of brown shrimp based on catch-per-unit-effort and description of the length-frequency distributions of the brown shrimp on the major commercial shrimping grounds off Texas. As a further contribution, the changes in mean lengths of these shrimp stocks were identified, and the causes of these changes were explained through the analyses of length-frequency distributions of brown shrimp. The minor discrepancies made in depicting the stocks in specific areas have suggested a revision of the future sampling design. On the whole, however, it appears the closure

accomplished its objectives: It protected the small new-year-class shrimp from harvest until they had grown to marketable size, and it appears to have enhanced the total catch for the season.

Summary

1) Relative abundance measured by mean CPUE's for individual 1-fm depth changes showed considerable uniformity in the size of the *Penaeus* shrimp stock at 5-10 fm in all four subareas. Brown shrimp comprised 85 percent of this shrimp stock.

2) The variability in mean CPUE's from one individual single-fathom depth stratum to another in depth zone 2 (11-20 fm) showed considerable patchiness in the *Penaeus* shrimp stock over these small depth changes and short distances.

3) Despite their patchiness, *Penaeus* shrimp stocks were greatest in depth zone 2 in all statistical subareas, and were second highest in depth zone 1. Mean CPUE's for depth zone 2 were 35 and 32 pounds in subareas 20 and 21 (southern), respectively, and were 15 and 19 pounds in subareas 18 and 19 (northern), respectively. Mean CPUE's for depth zone 1 in the four subareas were between 12 and 15 pounds.

4) Mean CPUE's for each of depth zones 1-3 in each subarea were greater during the 1981 closure than during the 1961-65 BCF collections or during the 1975-80 TPWD collections, with only one exception. In 8 of 10 cases (depth zone in a statistical subarea), the 1981 closure CPUE's were significantly greater than those of the 1961-65 BCF data set, and in 5 of 9 cases the closure CPUE's were significantly greater than those of the 1975-80 TPWD data set. In all other cases, there were no significant differences between 1981 closure CPUE's and corresponding CPUE's from the other two historical data sets.

5) Length-frequency distributions in May showed small new-year-class brown shrimp in depth zone 1, a mixture of new-year-class and previous-year-class shrimp in depth zone 2, and mostly previous-year-class shrimp in depth zone 3. These findings were for subareas 20 and 21 only; no data were obtained in subareas 18 and 19 for May.

6) Length-frequency distributions in June showed new-year-class brown shrimp in depth zone 1 of all subareas. In depth zone 2 the stock was composed of new-year-class shrimp which were 5-10 percent longer than those in depth zone 1. In depth zone 3 the stock was composed of both year classes; new-year-class shrimp comprised 20 and 80 percent of the stocks in subarea 18 and subareas 19-21, respectively.

7) Length-frequency distributions in July showed new-year-class shrimp comprising almost the entire stock throughout depth zones 1-3. In subareas 19 and 21, probably two waves of new-year-class shrimp were evident in depth zone 1.

8) Mean total lengths of brown shrimp increased with depth out to 40 fm in May and in June in all depth zones in all subareas where data were available. In July, mean lengths increased only from depth zone 2 to zone 3 in subarea 18 and from depth zone 1 to zone 2 in subareas 20 and 21. Offshore migration of small new-year-class shrimp counteracted increases from growth in deeper zones to maintain or decrease mean lengths in these stocks in deeper waters, especially in July.

9) In comparing brown shrimp mean total lengths for June, those of the 1981 closure were: A) Larger than those of the historical BCF and TPWD data sets in depth zone 1, B) smaller than those of the BCF in depth zone 2, and C) smaller than both BCF and TPWD means in depth zone 3.

10) In comparing brown shrimp mean total lengths for July, those of the 1981 closure were smaller than those of the BCF data and larger than those of the TPWD in subareas 19 and 21 for depth zone 1. In depth zone 2, the 1981 means were smaller than the BCF's and larger than the TPWD's in all depth zones in all subareas where data were available. In depth zone 3, the 1981 means were smaller than those of the BCF and the TPWD where data was available.

11) Pink shrimp accounted for less than 5 percent of the total number of *Penaeus* caught during the 1981 closure sampling. Mean total lengths were similar to those of brown shrimp, and in subareas 20 and 21 where most pinks were caught, they showed an increase in mean lengths with time. New-year-class and previous-year-class pinks were present in most cases.

12) White shrimp comprised less than 1 percent of the number of *Penaeus* caught during the 1981 closure, mainly because their main habitat —2-6 fm—was rarely sampled. About 98 percent of the white shrimp were previous-year-class shrimp.

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