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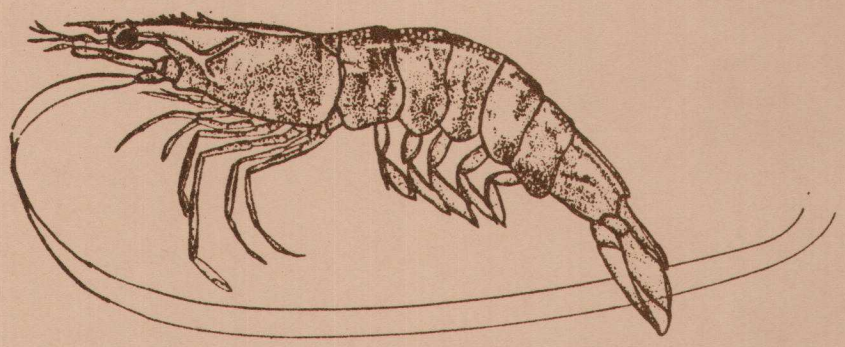

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U.S. DEPARTMENT OF COMMERCE
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ABSTRACT

A study of offshore commercial shrimp populations in Texas and Louisiana waters was conducted during 1961 and 1962. Seasonal abundance, distribution, and size composition are described for brown (Penaeus aztecus), white (P. setiferus), and pink shrimp (P. duorarum). Spawning seasons and areas, determined from histological examination of 9,424 ovarian slides, are delineated. Of particular interest was the observation that brown shrimp apparently spawn throughout the year at depths of 64 m to 110 m.

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INTRODUCTION

The shrimp fishery of the northwestern Gulf of Mexico (hereafter referred to as Gulf) is one of the most valuable fishery resources of the United States. The industry is supported by landings of three species of penaeid shrimps: brown (*Penaeus aztecus*, white (*P. setiferus*), and pink (*P. duorarum*). Annual landings of these species during 1960 through 1968 were valued at an average of 52.8 million dollars and increased to an average of 105.4 million dollars from 1968 through 1975.

In this report we describe the results of a study of offshore commercial shrimp populations in the Gulf conducted during 1961 and 1962. Our objectives are: (1) to determine spawning seasons and areas, and (2) to describe seasonal abundance, distribution, and size composition. Brusher et al. 1972 discussed the biology of nine other species of penaeid shrimps.

The life histories of *Penaeus* spp. in the Gulf are generally understood (Farfante 1969, Lindner and Cook 1970, Cook and Lindner 1970). Spawning takes place in offshore waters where resulting planktonic larvae undergo a series of metamorphoses. Postlarvae then enter estuaries where they grow rapidly for several months and pass through juvenile stages before returning to the Gulf to complete their life cycle.

Much of the earliest biological research on Gulf shrimps was carried out in Louisiana. The reports of Viosca (1920) and Tulian (1920) were among the first to provide a general outline of the white shrimp's life history. Weymouth et al. (1933) presented details of the size distribution, sexual development, spawning seasons, and other aspects of white shrimp biology not only in Louisiana but in North Carolina, Georgia, and

Texas. The papers by Burkenroad (1934, 1939), although primarily taxonomic, furnished many additional facts about shrimp biology.

Because species of Penaeus are most accessible to reseachers during their estuarine phase, much is known about juveniles. The studies of Gunter (1950), Williams (1955), Chin (1960), Tabb et al. (1962), Kutkuhn (1966), Saloman (1968), and Subrahmanyam (1971) have contributed materially to our knowledge of the seasonal abundance, growth rates, distribution patterns, and ecology of juvenile shrimp.

Comparatively few studies have been done on adult shrimp in offshore waters. Lindner and Anderson (1956) and Klima (1964, 1974) reported on the growth, migrations, spawning, and size distributions of white shrimp in offshore as well as estuarine areas. Eldred (1958), Eldred et al. (1961), and Cummings (1961) studied sexual development, spawning seasons, and size distributions of pink shrimp in the Sanibel-Tortugas area. Surveys of shrimp fishing grounds in the Gulf by Hildebrand (1954, 1955) and Lyon and Baxter (1974), plus Kutkuhn's (1962) analysis of commercial shrimp statistics, furnished additional information on spatial and seasonal abundance of the exploited shrimp populations within the Gulf.

METHODS AND MATERIALS

Beginning in January 1961, 11 stations, indicated by triangles in Fig. 1, were occupied at three-week intervals. The sampling area was expanded in October 1961 by the addition of 24 stations shown as squares in Fig. 1. At that time, frequency of sampling was changed to a monthly basis. Further changes in the station pattern occurred in January 1962 when 28 more stations (shown as circles) were added, and sampling at three central stations was discontinued. In its final form, the sampling pattern consisted of 60 stations along 10 transects and encompassed roughly 32,000 square miles of offshore waters from Mexico to the Mississippi Delta. The six stations comprising each transect were located in depths of 14, 27, 46, 64, 82, and 110 m.

Most of the commercial shrimp fleet operated in the four shallower depths.

A concerted effort was made to standardize sampling procedures. A 13.7-m (headrope length) otter trawl with 5.7-cm stretched mesh was towed for 1 h. The net was spread by otter boards measuring 2.1 by 0.9 m between which was attached a "tickler chain". This gear is similar to that used by most shrimp fishermen in the Gulf. The duration of the tow was timed and towing speed measured so that towed distance over the bottom could be estimated. All catches reported herein have been standardized to a tow distance of 5,000 m.

All specimens of Penaeus spp. caught at each station were identified and counted. In samples containing large numbers of shrimp, at least 100 specimens of each species were sexed and measured (tip of rostrum to end of telson).

The paired ovaries of the shrimp lie on either side of the dorsal midline, extending from the cardiac region in the cephalothorax to the sixth abdominal somite (Fig. 2). King (1948) and Cummings (1961), studying P. setiferus and P. duorarum, respectively, concluded that egg development was consistent throughout the ovary. Such appeared to be the case in a number of other penaeid species examined histologically during this study. Therefore, examination of only one portion of the ovaries to determine spawning condition was deemed sufficient.

All samples of ovaries for histological determination of spawning condition were taken from anterior portions of the abdominal ovarian lobe of freshly-caught females. Samples were fixed immediately in Bouin's solution which was replaced after 24 h with 50 % ethyl alcohol. In the laboratory, tissues were dehydrated, embedded in paraffin, sectioned at 10 to 15 u thickness, and stained with hematoxylin and eosin. Of the 19,600 ovarian samples, only 9,424 were used to show seasonal spawning characteristics because all slides from females

less than 139 mm long were not considered, and staining or mechanical imperfections caused some slides to be rejected.

DETERMINATION OF MATURITY AND SPAWNING

The development of white shrimp ovaries from immaturity to the spent condition was traced in a histological study by King (1948). With slight modifications, his definitions of the stages of ovarian development formed the basis for our classifications of ovaries of white, brown and pink shrimp. Following are brief descriptions of the stages recognized in stained sections of ovaries examined during our study.

Undeveloped (Fig. 3A). The ovaries range from undetectable to a diameter less than that of the dorsal abdominal artery and show no noticeable differentiation.

Early developing (Fig.3B). Each abdominal ovarian lobe has a diameter equal to or slightly smaller than the diameter of the dorsal abdominal artery. There is little apparent organization within the ovary. The oocytes and small ova stain blue with hematoxylin and possess indistinct nuclei.

Developing (Fig. 3C). At this stage, the diameter of the ovary may range from slightly larger to several times larger than the size of the distended gut. Developing eggs stain blue with hematoxylin, have a finely granular cytoplasm, and possess a nucleus with a distinct wall. Cummings (1961) stated that "the developing stage begins when a separate group of developing eggs separate from the stock of small eggs." In fully developed ovaries, large eggs surrounded by follicle cells completely fill the ovary.

Late developing (Fig. 3D). This stage is identical to the yellow stage described by King (1948). Ovaries are fully distended and filled with large, irregular ova which stain red with eosin. Egg cytoplasm has a grainy consistency and chromatin material is present as blue stained clumps within the nucleus.

Ripe (Fig. 3E). Eggs in ripe ovaries are easily recognized by the presence of peripheral or cortical bodies (Duronslet et al. 1975) arranged in radial patterns around the cell nuclei. These peripheral bodies, which stain a lighter shade of red than the cytoplasm, are spherical in early ripe stages, but become elongate with increasing maturity.

Spent (Fig. 3F). Ovaries are much reduced in diameter at this stage and sometimes appear flacid and collapsed. Vacant spaces surrounded by follicle cells from which ripe eggs have been evacuated are present, and a few unspawned ripe eggs usually remain. The cytoplasm and nuclei of these unspawned ripe eggs are reabsorbed more rapidly than the peripheral bodies. As a result, a ring of peripheral bodies often remains as evidence of absorption of an unspawned egg.

Resting (Fig. 3G). The majority of females, particularly of white shrimp, apparently spawn only during warmer months (Lindner and Cook 1970). Our histological examinations indicate that during winter months females enter a dormant or resting condition, the ovaries become much reduced in size and have relatively thick walls. Small eggs scattered randomly throughout the ovary give the appearance that there is a period of arrested development. At the zone of proliferation, few oocytes are being generated, and ova in some resting ovaries appear to be disintegrating. The resting stage resembles the early developing ovary, making the two stages difficult to distinguish in some seasons.

With such a variety of stages of ovarian development, it was necessary to choose a single stage as an indicator of spawning. When all described stages of development were present, the ripe stage occurred in about 10 % of the ovaries, suggesting that females pass through the ripe stage in a comparatively shorter time than other ovarian developmental stages. Developing and late developing stages occurred in at least 75 % of the ovaries and therefore appeared to

require longer periods to complete than the ripe stage. Laboratory tests conducted concurrently with this study showed that the spent stage may persist as long as several weeks after spawning. Thus, the ripe stage provided the best available indication of imminent spawning.

Because our main concern was to follow spawning activities of adults, immature females were excluded from consideration. Length distributions of the three species were graphed to determine the approximate size at which females first became capable of spawning (Fig. 4). Although a few females less than 140 mm possessed ovaries in advanced stages, the majority were in early developing and developing stages. Accordingly, 140-mm total length was chosen as the size at which females were considered to be capable of spawning. Females less than this length were excluded in determination of spawning seasons. As will be shown later, most females shorter than 140 mm in the offshore populations were young that had recently arrived from inshore nursery areas.

RESULTS AND DISCUSSION

Of the 65,345 shrimp caught during this field study, 79.6% were brown, 18.8% were white, and 1.6% were pink. Pink shrimp were generally in low abundance in the Gulf area (Costello and Allen 1970). However, most of the 896 successful trawl hauls made during this study were at stations beyond 27-m depth, hence the relative abundance of white shrimp, which is seldom found deeper than 27 m, was not accurately represented.

In the following sections, each species is characterized with regard to seasonal abundance, size distributions, and spawning. Males showed similar patterns as females and are omitted from the following graphical presentations.

Brown Shrimp

Brown shrimp occur throughout the Gulf, with centers of abundance off Texas, Louisiana, and eastern Mexico (Cook and Lindner 1970). This shrimp is distributed from estuaries to about 160-m depths, and is usually caught at night, although young brown shrimp may occasionally be taken in larger numbers during the day.

Seasonal Abundance

In general, brown shrimp were most abundant at 14- and 27-m stations during summer and early fall (Fig. 5). At 46-m and deeper stations, greatest abundance occurred during fall and winter months. Catch per unit of effort was higher in most seasons at 27- and 46-m depths than at either shallower (14-m) or deeper stations. Stations west of Galveston were generally more productive than those to the east.

Size Distribution

The most obvious feature in the size distribution patterns of brown shrimp was the offshore movement of young-of-the-year (Fig. 6). Most females left estuarine nursery areas and appeared in 14-m catches in May at lengths from 75 to 130 mm. These new recruits to the offshore population were in evidence at 14 m throughout the remainder of the year. The relative scarcity of females longer than 150 mm suggested that most move to deeper waters before attaining this length.

In January and February, most females (73%) in 27-m depths measured 120 to 170 mm in length. This group of females gradually increased in size so that the majority was 160 to 200 mm long in May. In June, however, young-of-the-year females arrived causing a sharp decrease in mean length. After June, size distributions appeared to be influenced by young-of-the-year, which continued to arrive throughout the ensuing six months.

From January through June, the majority of female brown shrimp at 46 m was 170 to 200 mm long. Then, as a result of offshore migration of younger shrimp, females less than 170 mm long constituted a progressively larger percentage of those shrimp during the months of July, August, and September. Although not illustrated, females caught at stations beyond 46 m, with few exceptions, exceeded 170 mm in all seasons.

The relation of length to depth of capture is particularly important to shrimp fishermen, who are paid the highest prices for the largest shrimp. Iversen et al. (1960), investigating the size distribution of pink shrimp on the Tortugas fishing grounds, concluded that two patterns predominated: "One is the increased size with depth and the other is a size gradient in a northerly direction irrespective of depth." Our results show that the average size of brown shrimp also increases with depth.

Of 9,484 brown shrimp, 54% were females. In most samples, approximately equal numbers of males and females were present; however, 66% of the brown shrimp caught at 14 m were females. The smaller percentage of males in this depth may have been caused by net selection for the slightly larger females or by young males preceding females to deeper waters.

Spawning

The length-frequency data show that brown shrimp begin to leave estuaries and appear at 14 m in late spring. As these juveniles grow, they move to deeper waters so that the smallest, least mature individuals are at the shallowest depths. Only two ripe females among the 627 females from 14 m were found, indicating that brown shrimp do not ordinarily spawn in this depth.

At all stations deeper than 14 m, a consistently large proportion of brown shrimp had ovaries in either the developing or late-develop-

ing stages regardless of season or depth. The percentages of developing and late-developing ovaries over the entire sampling period were: 77.8% at 27-m stations, 76.5% at 46-m stations, and 77.4% at 64-, 82-, and 110-m stations.

Seasonal spawning activity of brown shrimp, as indicated by the frequency of occurrence of ripe females, is shown in Fig. 7. A chi-square test of independence showed that the proportions of ripe females from western and eastern areas were not significantly different for any area, depth, or year ($p > 0.01$). At 27 m, spawning continued from spring until early winter. Peak spawning in both years occurred in May and again in September. At 46-m stations, greater percentages of ripe females were present during most seasons than at either shallower (27 m) or deeper stations (>63 m). As at 27 m, two periods of heightened spawning activity at 46 m were present, the first in spring and the second in fall. At the 64-, 82-, and 110-m stations, spawning appeared to continue throughout the year with only slight seasonal variations in intensity. To summarize, it appeared that brown shrimp spawn year-round in depths of 64 to 110 m, with peak activity during late spring and in the fall at 27 and 46 m.

White Shrimp

The region between Apalachicola, Florida, and central Texas contains large concentrations of white shrimp. The peak population strength, however, is along the Louisiana coast (Kutkuhn 1962). In general, white shrimp inhabit areas nearer to shore than brown shrimp and, in contrast to the latter, are usually caught during daylight. Hildebrand (1954) stated that the bulk of white shrimp production in the western Gulf is obtained inside the 27-m contour.

Seasonal Abundance

White shrimp appeared at 14 m in largest numbers during fall and winter months (Fig. 8). A second, smaller period of increased catch

per unit of effort occurred in May and June 1961, but was not evident in 1962. The 14-m depths east of Galveston (Fig. 1) are, except for the one near the Mississippi Delta, much farther from shore than the western stations. Because most white shrimp tend to remain close to shore (<27 m), the western 14-m stations appeared more productive. Note also that except for winter, catches from the western 27-m stations (Fig.8) and eastern 14-m stations (which are approximately equal in distance from shore) were generally similar during this period.

Few white shrimp were caught from depths greater than 27 m. From January through April 1962, 30 individuals were counted from 46-m catches and one from 64 m. All were taken at stations nearest the Mississippi Delta. Burkenroad (1939) reported 15 white shrimp caught from depths of 64 to 72 m by the R/V ATLANTIS near the mouth of the Mississippi River during March and April 1937, and Springer and Bullis (1956) recorded four white shrimp at 80-m stations in May 1951 near the Mississippi Delta. Apparently, white shrimp may range to deeper waters but are seldom abundant beyond 40 m.

Size Distribution

Weymouth et al. (1933) showed that female white shrimp in offshore waters are generally larger than males and grow to a greater maximum length. Subsequent studies, including the present one, support these observations. Seasonal size distributions by depths of female white shrimp are illustrated in Fig. 9. In almost all months, females from 14-m stations east of Galveston were larger than those taken from western 14-m stations.

In January, most females from 14-m stations west of Galveston were young of the previous year, measuring less than 140 mm. Females from eastern stations included both young and older shrimp ranging from 105 to 200 mm. In the following months, the smaller females in both areas increased in size, so that by late summer most were 180 mm or longer. West of Galveston, young shrimp left estuarine nursery grounds and appeared at

14-m stations in September. Usually young-of-the-year appeared in 14-m catches east of Galveston at least one month later. During these early fall months, young white shrimp probably remained near shore after leaving estuaries so that equivalent eastern 14-m trawl hauls (located at considerable distances from shore) missed them.

Length-frequency data for white shrimp caught at 27 m were scarce except from November 1961 through April 1962, when 90.1% of the total (410) were measured. During this period the majority of females measured 160 to 190 mm, and all were more than 140 mm except for a group of small individuals, which had apparently moved seaward during December and January. According to tagging results of Lindner and Anderson (1956, Tables 32-34), large white shrimp remain in deeper waters during winter and return to near-shore areas in spring.

Of the more than 5,900 white shrimp, 55.7% were female. The percentage of females in monthly samples usually varied between 50% and 60%, possibly reflecting their slightly increased vulnerability to the nets.

Spawning

The sequence of ovarian development and spawning by female white shrimp (140 mm and longer) was well-defined. In January and February many females were in the "resting" stage, although some possessed ovaries in which ova were beginning the process of maturation. By March, a large percentage of the females had developing ovaries, and by April, many were in the late-developing stage. Spawning, as indicated by the presence of "ripe" females, is shown in Fig. 10. During 1961, ripe females were first caught at 14 m in May, and peak spawning activity came in May and June. In 1962, the first ripe females at 14 m were observed in April, with peak activity coming in May. In both years, spawning continued with diminishing intensity into fall. No ripe female white shrimp were observed at 14-m stations earlier than April nor later than October. In September 1961 and 1962, young-of-the-year females with immature ovaries appeared in offshore areas.

These young females did not mature during the fall and winter months but may have been responsible for much of the spawning during the following spring and summer.

Female white shrimp from 27 m were larger than those from 14 m. In February 1962, most had ovaries in developing or late-developing stages, and by March, they had begun to spawn, earlier than females at 14 m.

The results of chi-square tests of independence of the proportions of ripe females in 14-m depths indicated that significantly greater percentages were present in eastern stations than in western stations ($P<0.01$). The estimated proportions were: for 1961, 22.5% east and 10.1% west; for 1962, 12.8% east and 6.1% west.

Pink Shrimp

Pink shrimp, although found throughout the Gulf, are concentrated off southwestern Florida and southeastern Mexico (Costello and Allen 1970). In our catch totals, pink shrimp accounted for less than 2% of the total number of Penaeus. Pink shrimp inhabit coastal waters to depths of 65 m and exhibit the nocturnal habits of brown shrimp. However, they are sometimes caught on cloudy days or when the water is turbid.

Seasonal Abundance

Mean numbers of pink shrimp per standard tow taken at stations east and west of Galveston are shown in Table 1. Although the data are meager, spring and fall appeared to be seasons of increased pink shrimp abundance. There is some evidence indicating that the pink shrimp population in the survey area has its center of abundance along the central Texas coast. Gunter (1962) concluded from landing statistics for 1956-59 that most pink shrimp taken from Texas waters were caught in the vicinity of Aransas Pass.

Size Distribution

Compared with brown and white shrimp, male pink shrimp were consistently smaller than females but exhibited similar seasonal size patterns. Females comprised 57% of the 1,076 pink shrimp. Length-frequencies of females measured during both survey years are shown in abbreviated form in Table 2. Young shrimp 110 to 150 mm long were responsible for the spring and fall periods of increased abundance at 14-m stations. These influxes of small shrimp occurred about one month later at 27-m stations. Hoese and Jones (1963), working in Redfish Bay, Texas, showed that large juvenile and subadult pink shrimp left that area for Gulf waters in late May and June. In all seasons, females from 27 m averaged larger than those from 14 m. Only seven pink shrimp were taken in depths greater than 27 m, and these were 150 mm or longer.

Spawning

Of the 135 ovarian samples taken at 14 m only 19.3% were advanced beyond the developing stage, and just one ripe female was taken (Table 3). Apparently, the pink shrimp, like the brown shrimp, does not spawn in this depth along the Gulf coast.

At 27 m, 38.2% of the females had ovaries more mature than the developing stage. Spawning, as indicated by the presence of ripe females, probably extends from spring to late fall.

SUMMARY

Seasonal Abundance

Brown shrimp were virtually absent from near-shore areas during winter months. Young-of-the-year first appeared in offshore waters in early summer after having grown from postlarval to subadult size in estuaries. In the following months, young brown shrimp moved seaward, increasing the abundance of brown shrimp in successively greater depths. Peak abundance occurred from June through the remainder of the year in depths of 27 to 46 m.

White shrimp reached peak levels of abundance during fall and winter following migration of young-of-the-year from nursery grounds. Few white shrimp were found in depths beyond 27 m.

Pink shrimp, while not abundant in the northwestern Gulf, appeared to be more concentrated during spring and fall.

Seasonal Size Distribution

The average length of brown shrimp increased with depth. The 14-m depth zone was inhabited almost exclusively by young-of-the-year (70 to 120 mm), which left estuaries and near-shore areas from May through December. Most moved to deeper waters before reaching a length of 150 mm. In January, the majority of female brown shrimp at 27 m was 160 mm long or greater. In June, however, this mean size range decreased as young-of-the-year arrived. After June, shrimp ranging in size from 100 to 200 mm usually predominated at this depth. The 46-m depths were inhabited by large shrimp whose numbers were augmented in late summer and fall by large young-of-the-year (150 to 170 mm).

Young-of-the-year white shrimp appeared in 14 m in September and by January of the following year constituted the bulk of the white shrimp in

this zone. From January to September, they exhibited a steady increase in mean length. White shrimp taken at 27 m during winter months were larger than those in 14 m, suggesting that older shrimp remained in deeper waters in that season.

Young-of-the-year pink shrimp (110 to 150 mm) appeared at 14 m in the spring and again in late fall. In all seasons pink shrimp were larger at 72 m than at 14 m.

Spawning

Ovaries from 9,424 shrimp were examined histologically and classified by stage of development. Most females possessed developing or late-developing ovaries, indicating that these were the most prolonged stages in ovarian maturation. The presence of ripe ovaries was assumed to indicate imminent spawning, and the relative numbers of ripe females was assumed to be an index to the intensity of spawning activity.

Brown shrimp did not regularly spawn in 14-m depths. In 27 m, spawning continued from February through December, with largest numbers of "ripe" females occurring in spring and fall months. In depths of 46 to 110 m, spawning continued year-round with largest numbers of spawning females present during spring and fall.

White shrimp, in contrast to brown shrimp, spawned almost exclusively in depths less than 46 m. Spawning in 14-m depths continued from spring to early fall. White shrimp in 27 m spawned earlier than those in 14 m.

Pink shrimp in the northwestern Gulf may have spawned close to the 27-m contour from spring to late fall.

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1933. Preliminary report on the life history of the common shrimp Penaeus setiferus (Linnaeus). Bull. U.S. Bur. Fish. 48:1-26.

Williams, A. B.

1955. A contribution to the life histories of commercial shrimps (Penaeidae) in North Caorlina. Bull. Mar. Sci. Gulf Caribb. 5:116-146.

Table 1. Average monthly catch of pink shrimp per standard tow by depth and area caught west and east of Galveston, Texas 1961-62.

	14 meters		27 meters	
	West	East	West	East
Jan.			10	1
Feb.	2			
Mar.	1		1	1
Apr.	14		1	1
May	22	3	9	2
June	2	1	13	
July				3
Aug.				
Sept.	4		1	1
Oct.	10		3	5
Nov.	8		7	4
Dec.	3		3	5
	Day	Night	Day	Night
Total number of tows	104	85	82	100
Mean number per tow	1	6	1	4
Percent of tows taking pink shrimp	19	38	20	37

Table 2. Lengths of pink shrimp females measured during 1961-62.[1/]

	14 meters					27 meters				
Month	110	110-129	130-149	150-169	170	110	110-129	130-149	150-169	170
Jan.	1		1		1		1	10	14	30
Feb.		4		3	3				1	2
Mar.			1	1					2	6
Apr.	2	38	12	3					1	6
May	2	49	35	2	1		8	3	8	15
June	1	1	11	3			14	32	4	3
July			2	2	1				1	3
Aug.			2	2				2	4	1
Sept.			2	13	5			1	6	6
Oct.	21	9	7	3	2	2	1		15	17
Nov.	9	9	9	7	4	1	5	5	19	18
Dec.	2	5	4			1	2	2	11	19
Totals	38	115	86	39	17	4	32	55	86	126

[1/] Lengths in mm.

Table 3. Pink shrimp ovary conditions observed between January 1961 and December 1962.[1/]

Month	14 meters					27 meters				
	Early developing	Developing	Late developing	Ripe	Spent	Early developing	Developing	Late developing	Ripe	Spent
Jan.	1	1				3	34			
Feb.	3	4					1			
Mar.							8			
Apr.	13	7	2				1	3		1
May	27	16	4	1		5	6	9	4	3
June	3	6	2							
July	1		3				2	1	3	1
Aug.		4			1			1	1	
Sept.		1	12				3	3	3	1
Oct.	6	3			1	1	4	12		5
Nov.	17	6				1	19	4	4	
Dec.						1	13	4		
Total	69	40	23	1	2	11	91	37	15	11

1/ Females less than 140 mm excluded.

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Figure 1. - Locations of sampling stations within the northwestern Gulf of Mexico, 1961-62.

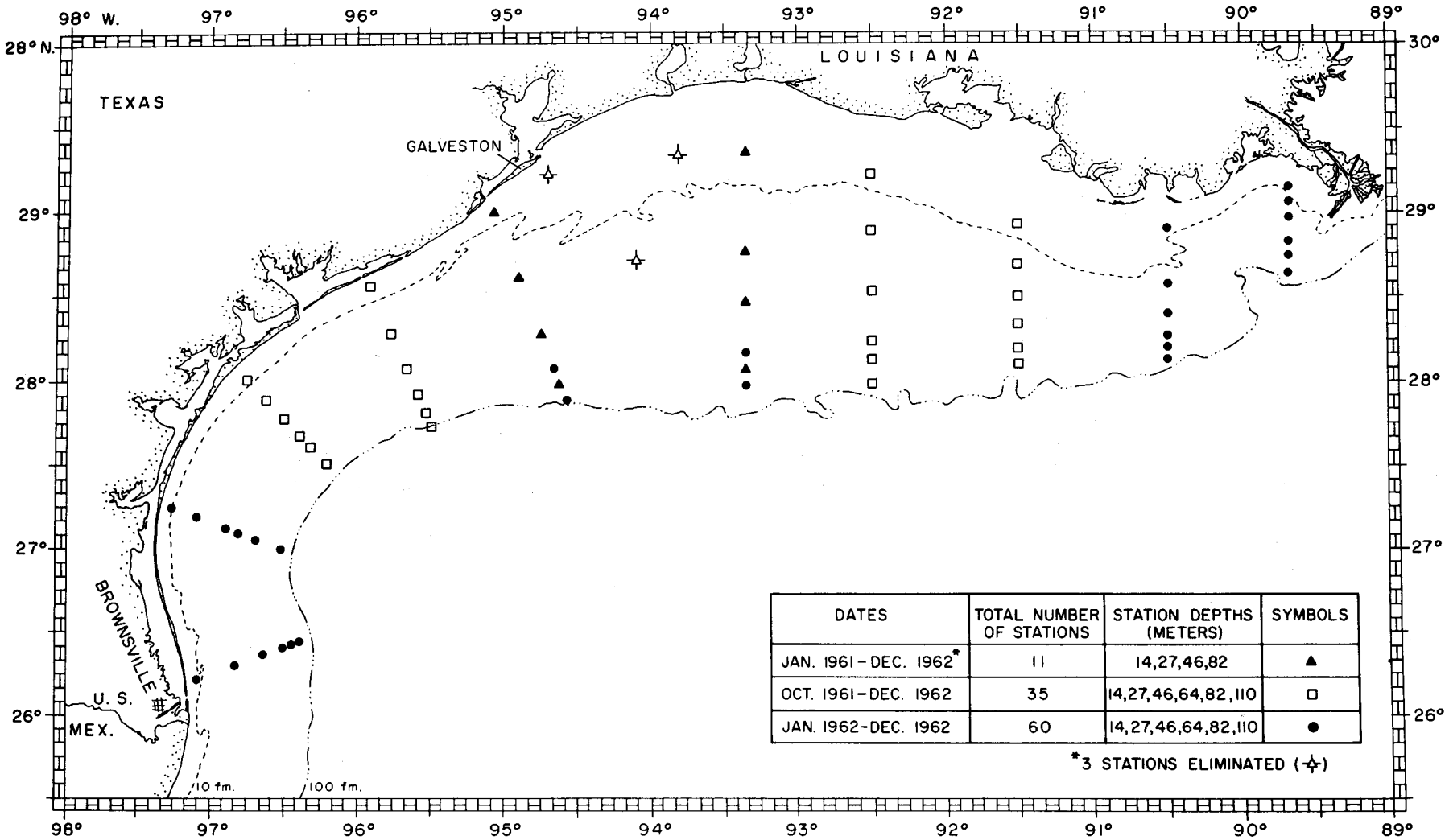
98° W.
97°
96°
95°
94°
93°
92°
91°
90°
89°
28° N.
29°
28°
27°
26°
30°
TEXAS
LOUISIANA
GALVESTON
BROWNSVILLE
U. S.
MEX.
10 fm.
100 fm.
DATES
TOTAL NUMBER OF STATIONS
STATION DEPTHS (METERS)
SYMBOLS
JAN. 1961 - DEC. 1962*
11
14,27,46,82
OCT. 1961 - DEC. 1962
35
14,27,46,64,82,110
JAN. 1962 - DEC. 1962
60
14,27,46,64,82,110
*3 STATIONS ELIMINATED

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Figure 2. - Cross-section through the dorso-anterior portion of the abdomen of a female penaeid shrimp.

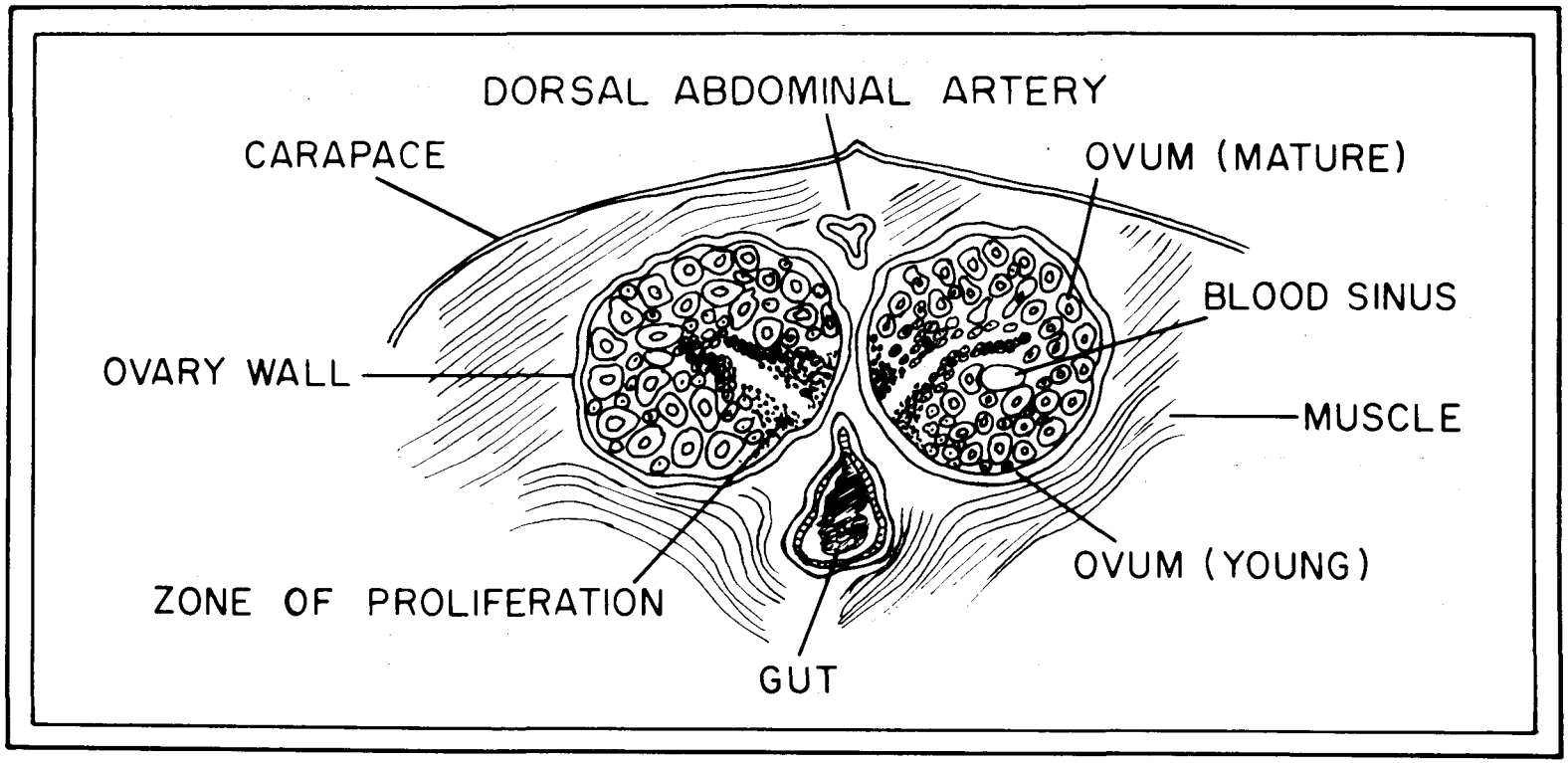
DORSAL ABDOMINAL ARTERY
CARAPACE
OVUM (MATURE)
BLOOD SINUS
OVARY WALL
MUSCLE
OVUM (YOUNG)
ZONE OF PROLIFERATION
GUT

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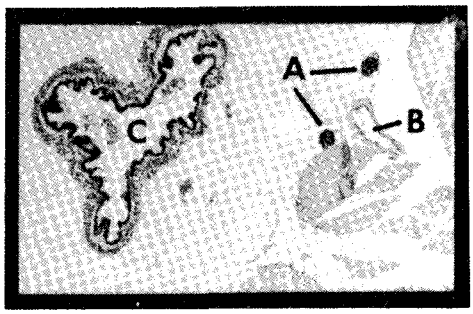
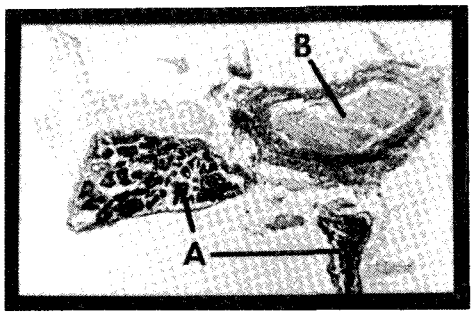
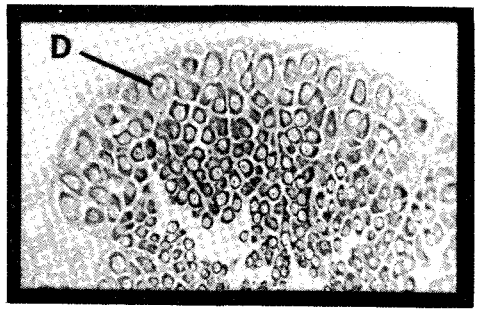
Figure 3.- Stages of ovarian development in penaeid shrimp (A - ovary, B - dorsal abdominal artery, C - gut, D - developing ova).



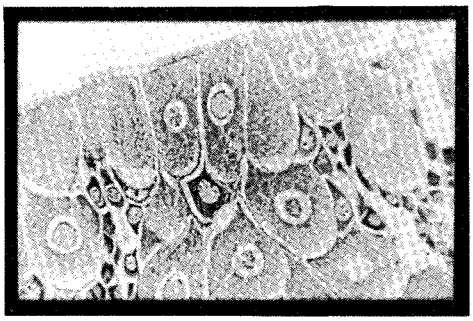
A. UNDEVELOPED



B. EARLY DEVELOPING

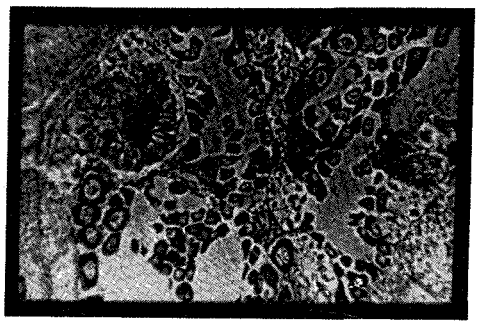


C. DEVELOPING

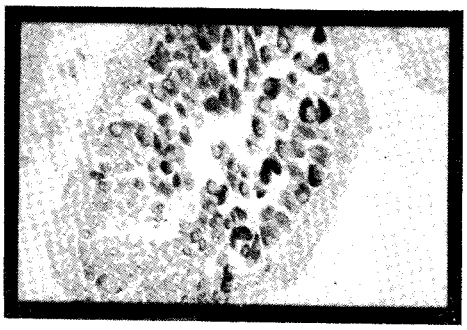


D. LATE DEVELOPING

E. RIPE



F. SPENT



G. RESTING

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Figure 4.- Lengths of brown, white, and pink shrimp females in various stages of ovarian development, 1961-62. Numbers indicate total numbers per ovarian stage.

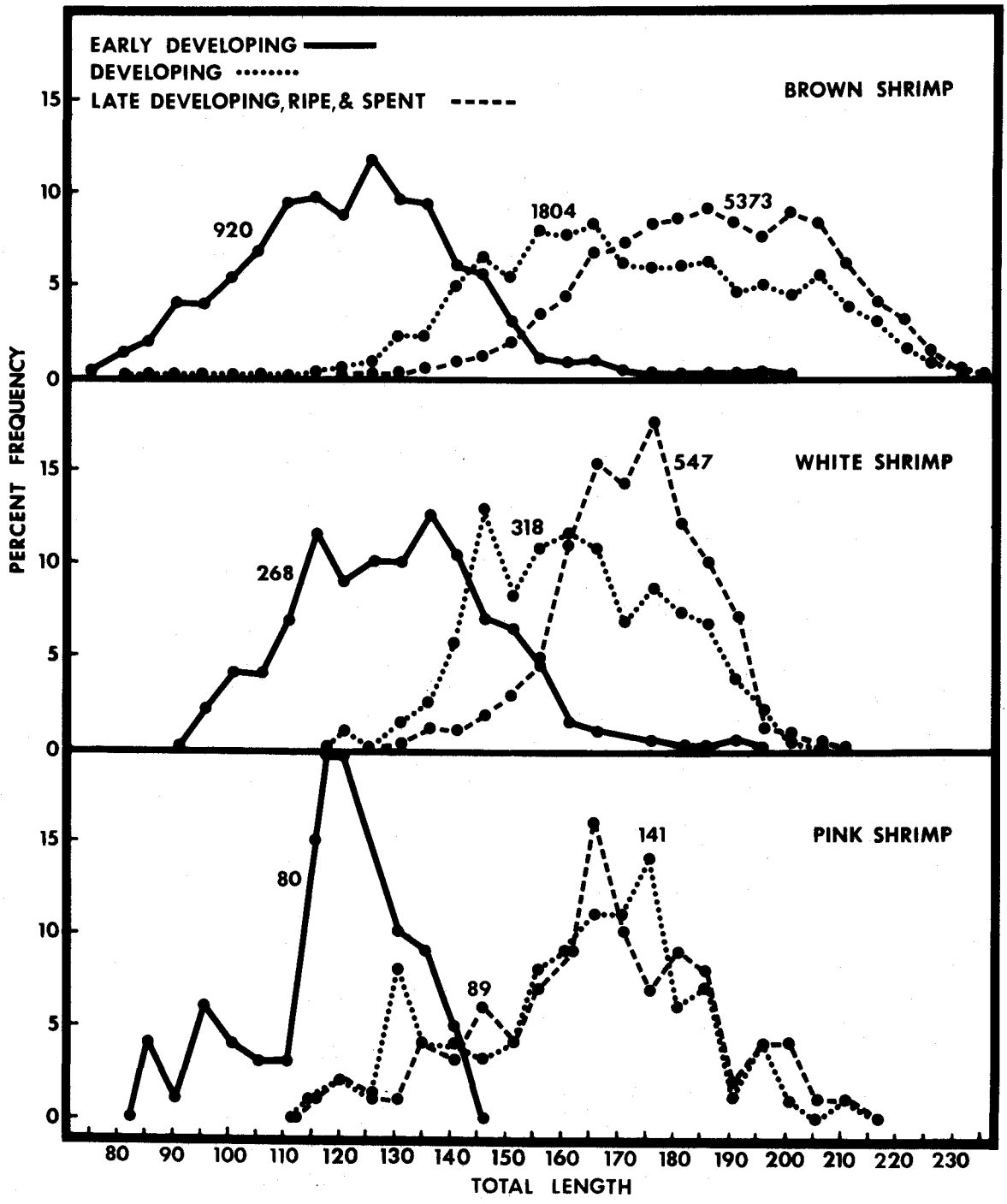
EARLY DEVELOPING
DEVELOPING
LATE DEVELOPING, RIPE, & SPENT
BROWN SHRIMP
920
1804
5373
WHITE SHRIMP
268
318
547
PINK SHRIMP
80
89
141
PERCENT FREQUENCY
0
5
10
15
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
TOTAL LENGTH

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Figure 5.- Catch per unit of effort for brown shrimp in various depths, 1961-62 (standard tows were 5,000 m with 13.7-m otter trawl).

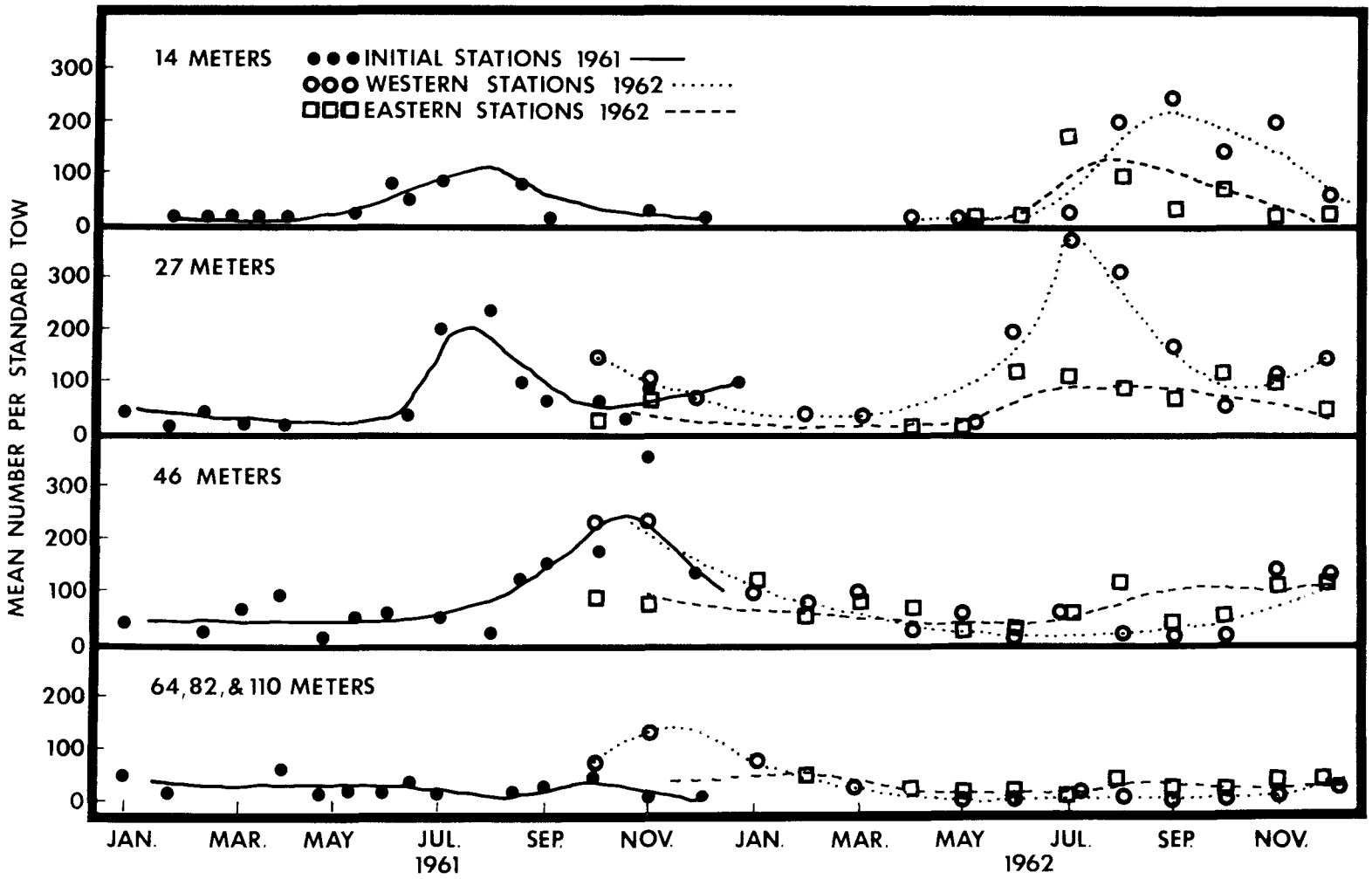
14 METERS
INITIAL STATIONS 1961
WESTERN STATIONS 1962
EASTERN STATIONS 1962
27 METERS
46 METERS
64, 82, & 110 METERS
MEAN NUMBER PER STANDARD TOW
300
200
100
0
JAN.
MAR.
MAY
JUL.
SEP.
NOV.
1961
1962

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Figure 6.- Length distribution of brown shrimp females caught in trawl hauls at 14-, 27-, and 46-m depths, 1961-62.

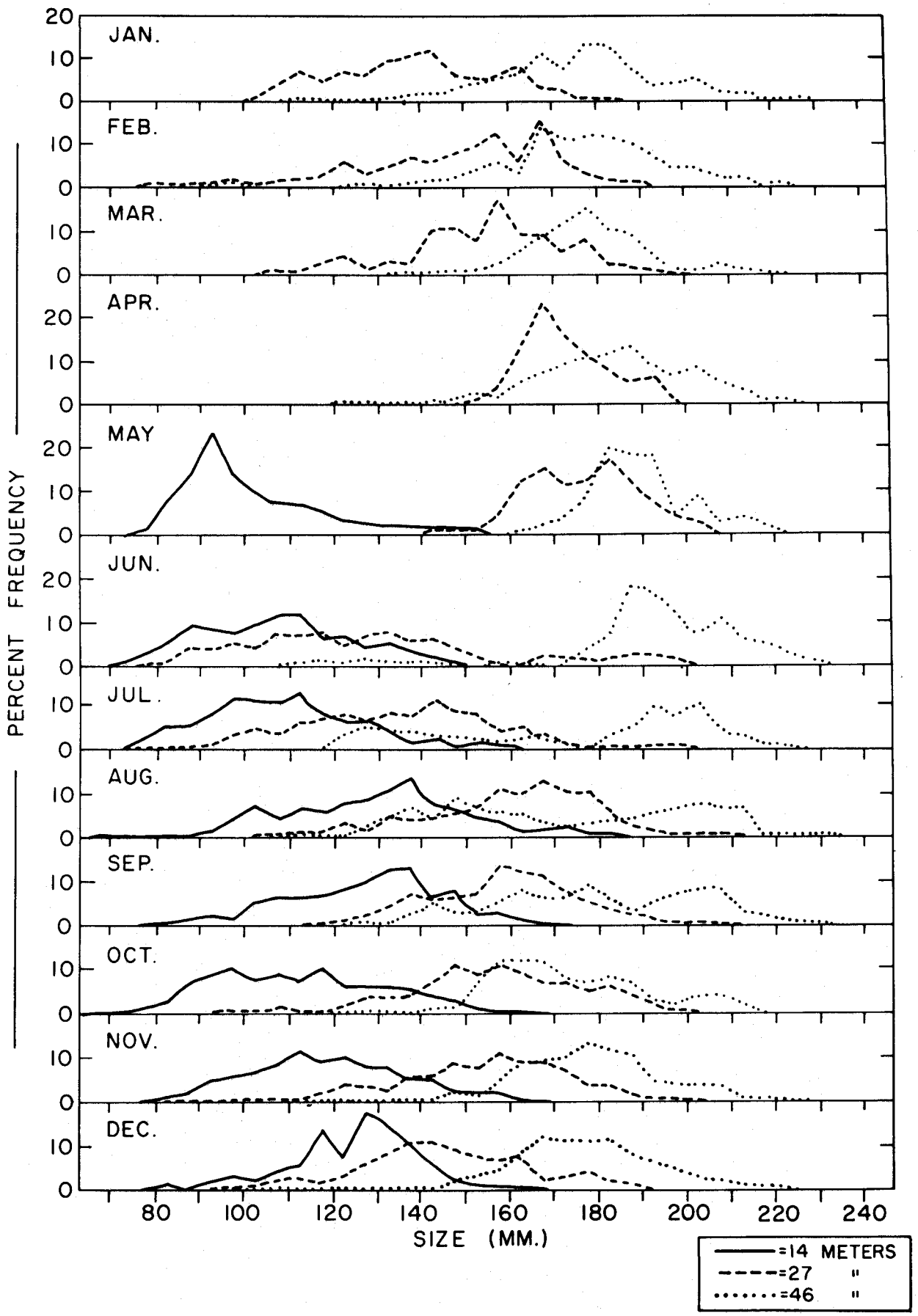
JAN.
FEB.
MAR.
APR.
MAY
JUN.
JUL.
AUG.
SEP.
OCT.
NOV.
DEC.
PERCENT FREQUENCY
SIZE (MM.)
=14 METERS
=27 "
=46 "

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Figure 7.- Percentage of ripe brown shrimp caught in various depths, 1961-62.

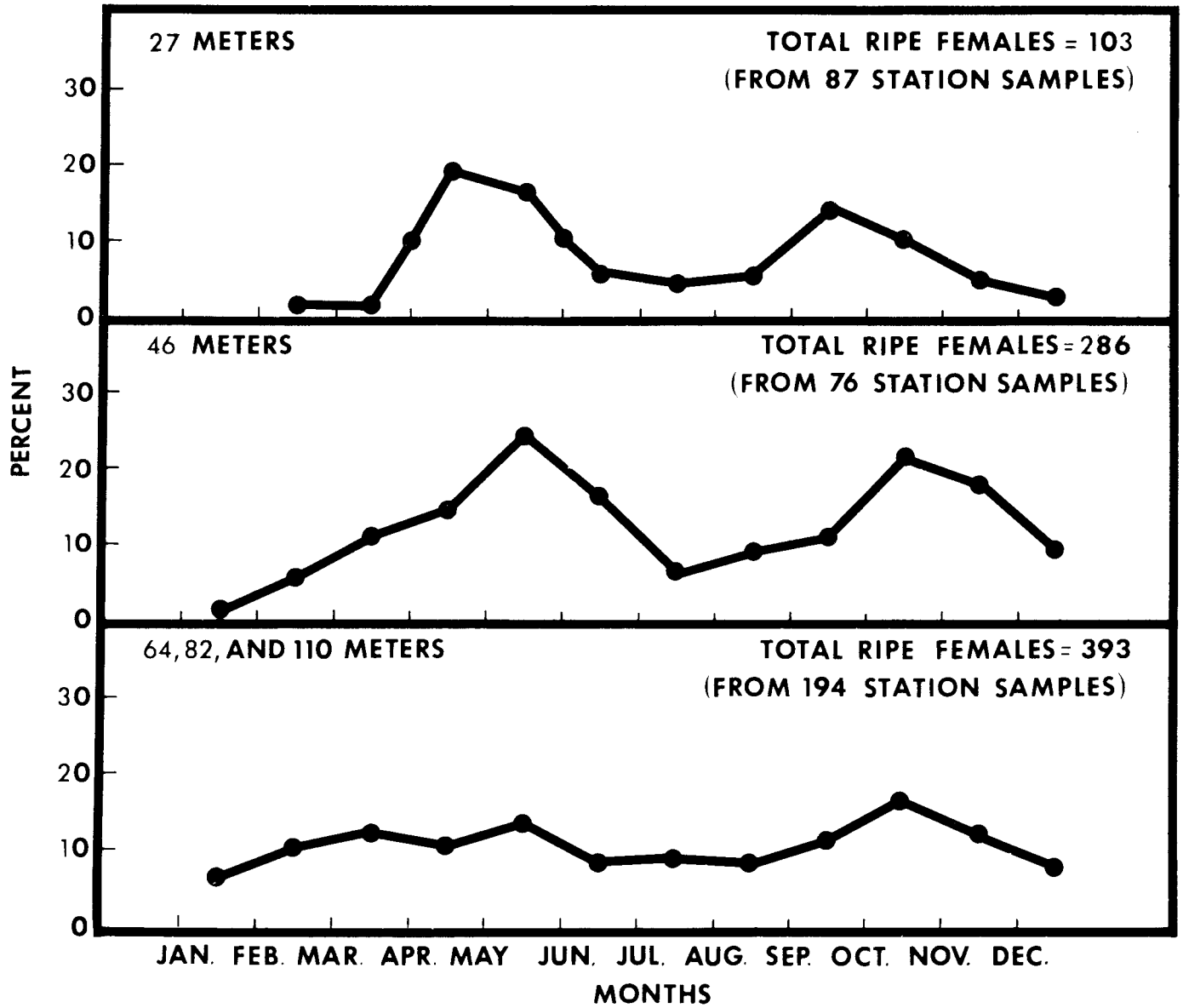
27 METERS
TOTAL RIPE FEMALES = 103
(FROM 87 STATION SAMPLES)
46 METERS
TOTAL RIPE FEMALES = 286
(FROM 76 STATION SAMPLES)
64, 82, AND 110 METERS
TOTAL RIPE FEMALES = 393
(FROM 194 STATION SAMPLES)
PERCENT
0
10
20
30
JAN. FEB. MAR. APR. MAY JUN. JUL. AUG. SEP. OCT. NOV. DEC.
MONTHS

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Figure 8.- Catch per unit of effort of white shrimp in various depths, 1961-62 (standard tows were 5,000 m with 13.7-m otter trawl).

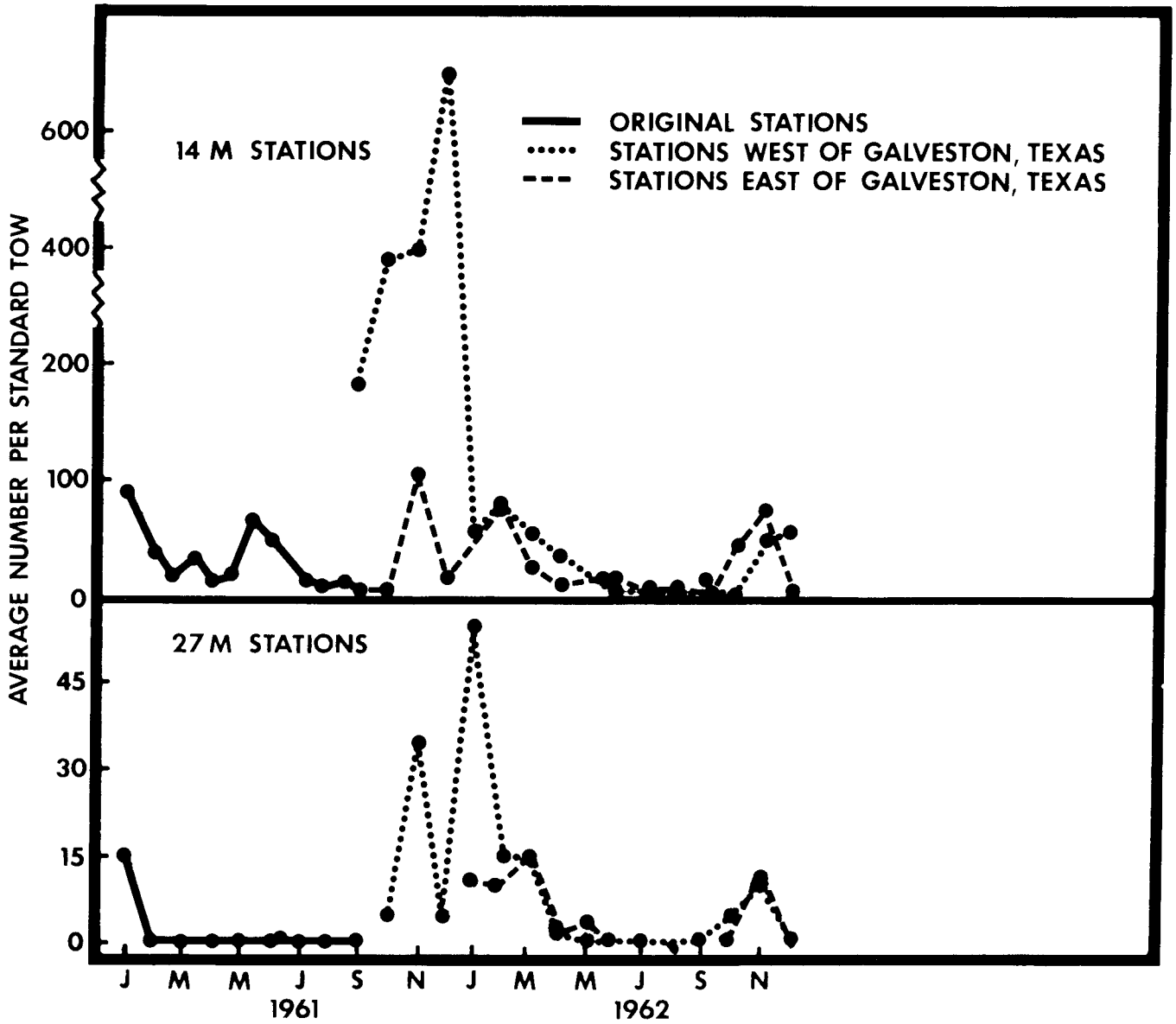
14 M STATIONS
27 M STATIONS
ORIGINAL STATIONS
STATIONS WEST OF GALVESTON, TEXAS
STATIONS EAST OF GALVESTON, TEXAS
AVERAGE NUMBER PER STANDARD TOW
600
400
200
100
0
45
30
15
0
J M M J S N J M M J S N
1961
1962

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Figure 9.- Length distributions of white shrimp females caught in trawl hauls at 14-m depths, 1961-62. Numbers indicate total numbers of individuals examined from each area.

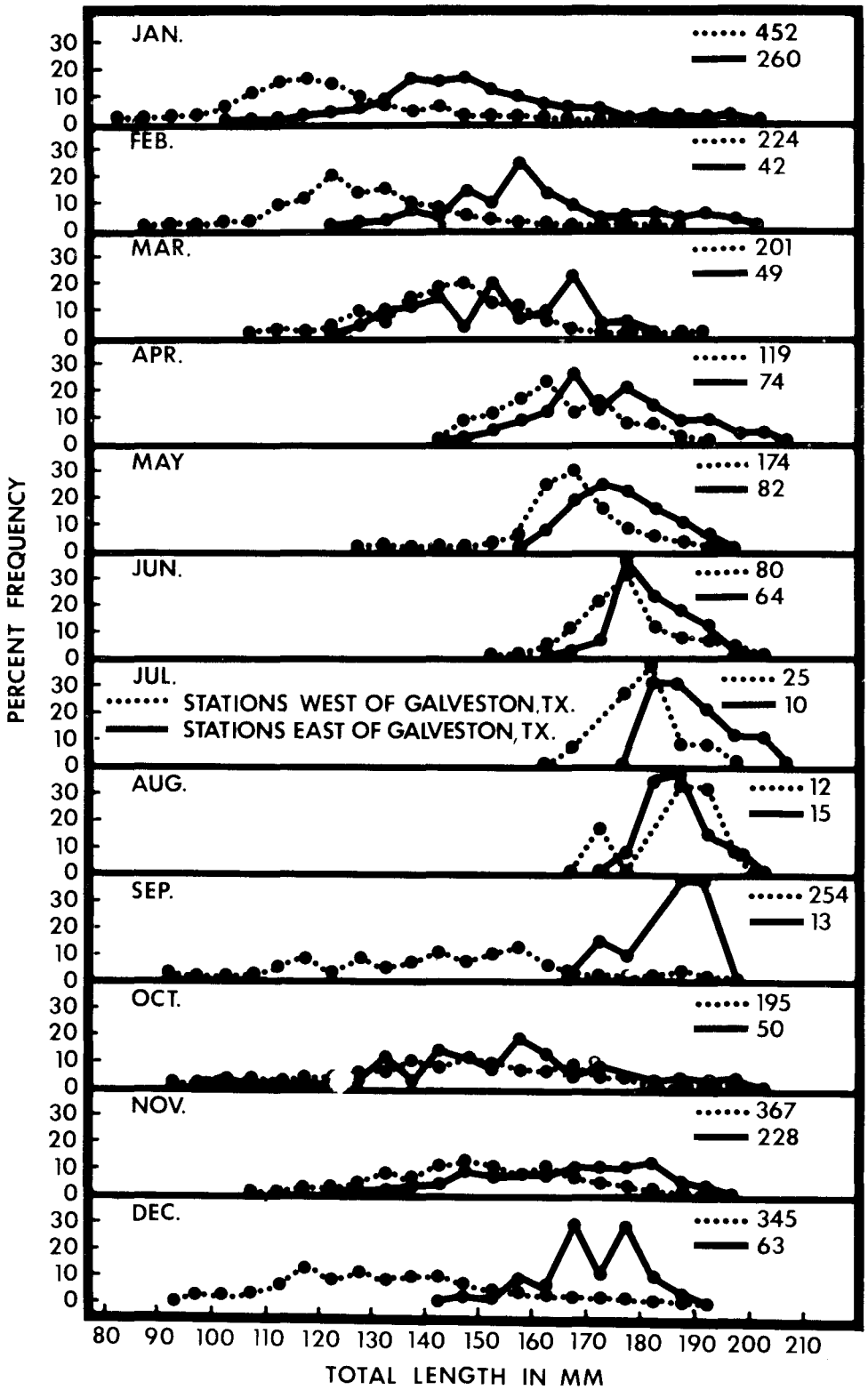
JAN.
452
260
FEB.
224
42
MAR.
201
49
APR.
119
74
MAY
174
82
JUN.
80
64
JUL.
25
10
STATIONS WEST OF GALVESTON, TX.
STATIONS EAST OF GALVESTON, TX.
AUG.
12
15
SEP.
254
13
OCT.
195
50
NOV.
367
228
DEC.
345
63
PERCENT FREQUENCY
0
10
20
30
80 90 100 110 120 130 140 150 160 170 180 190 200 210
TOTAL LENGTH IN MM

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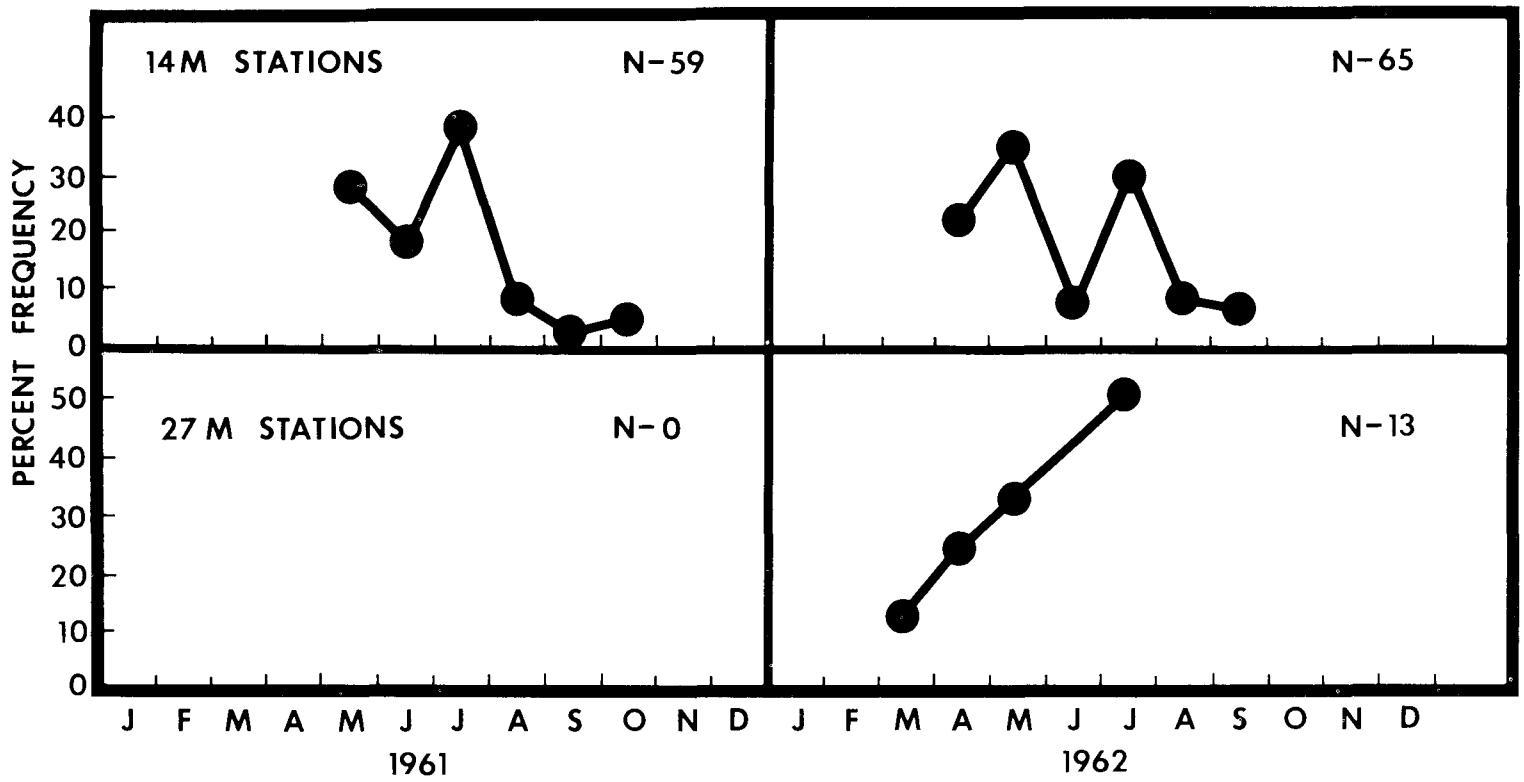
Figure 10.- Percent frequency of "ripe" female white shrimp caught at 14- and 27-m depths, 1961-62. N = Number of individuals.


14M STATIONS
N-59
N-65
27 M STATIONS
N-0
N-13
PERCENT FREQUENCY
40
30
20
10
0
50
40
30
20
10
0
J F M A M J J A S O N D
1961
J F M A M J J A S O N D
1962