GROWTH, MIGRATIONS, SPAWNING AND SIZE DISTRIBUTION OF SHRIMP *PENAEUS SETIFERUS*

BY MILTON J. LINDNER AND WILLIAM W. ANDERSON

FISHERY BULLETIN 106

UNITED STATES DEPARTMENT OF THE INTERIOR, Fred A. Seaton, *Secretary*
FISH AND WILDLIFE SERVICE, John L. Farley, *Director*

ABSTRACT

In order to establish growth and migration patterns, approximately 45,000 shrimp were tagged and released between 1935 and 1939, in separate areas of the coast from North Carolina to Mexico. Of the shrimp released, more than 7,000 were recaptured, having been at liberty up to 200 days.

Tagged shrimp grow rapidly from March through September, but growth almost ceases from October through February. At the growth rate inferred from an analysis of the short-term increments of the shrimp recaptured, they grow from 10 cm. in length in April to 16 cm. in July, and to 19 cm. by November of a single year. Or, if they are 10 cm. long in July, they measure 16 cm. by November.

Tagged shrimp released along the south Atlantic coast in the fall were recovered consistently to the south of the area of release; those released in early spring tended to be retaken to the north. Large shrimp, those longer than 13 cm., moved more extensively than did the smaller ones.

Gulf-coast releases demonstrated no consistent migration pattern, other than the movement from inside waters to outside oceanic areas. The movement to outside waters was discovered at all areas of release, and pertains largely to small shrimp. Few large shrimp were found in inside waters.

Although the eggs and larvae of the white shrimp have rarely been taken, the location of females with ripe ovaries leads one to infer that spawning takes place offshore. Ripe females were obtained in most areas from April through August, but there may be separate populations spawning in different months.

On the basis of size distribution, both of commercially caught shrimp and of those taken by research vessels, at least two separate groups of young shrimp move from inside to outside waters each year. One group enters the offshore areas in June, the other in August or September. The latter group was probably spawned in the spring of the same year; the former, in the summer of the previous year.

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GROWTH, MIGRATIONS, SPAWNING, AND SIZE DISTRIBUTION OF SHRIMP, *PENAEUS SETIFERUS*

By Milton J. Lindner, *Technical Adviser, Fishery Mission to Mexico,* and William W. Anderson, *Fishery Research Biologist*

A steady increase in the production of shrimp along the Atlantic and Gulf coasts of the United States had by 1930 made canned shrimp the most valuable fishery product in the region. At that time, anxiety about the future of the expanding industry resulted in many requests for a biological study of the heavily exploited shrimp resources.

In February 1931 an investigation was initiated when F. W. Weymouth and M. J. Lindner visited the chief shrimp ports to make a brief survey of the fishery and to arrange the details of cooperation offered by the various States in which shrimping was carried on. As this fishery extends over more than 3,000 miles of coastline, it was necessary to have the cooperation of several States in order to obtain as complete information as possible with the limited funds available. Georgia, Louisiana, and Texas entered into the joint program and contributed in various ways. Headquarters were established at New Orleans, while various parts of the investigations were pursued at a number of places between Beaufort, N. C., and Port Aransas, Tex.

Although three species of shrimp occur in the fishery through most of its range from North Carolina to the Mexican border, the major effort was directed toward learning the life history of the common white shrimp of the United States, *Penaeus setiferus* (Linn.). This species was at that time by far the most important, and comprised more than 95 percent of the commercial catch.

The approach to the problem was as diversified as funds and facilities permitted and included investigations of the life history, including spawning, embryology and larval history, postlarval growth, longevity, and migrations; abundance analyses; biometrical studies with respect to racial determinations; and the effect of fishing, in relation to gear, localities, and time, on the composition of the catch. Experimental trawling provided data to supplement those gathered from the commercial catch. Temperature and salinity data were accumulated as a basis for interpreting shrimp behavior in relation to hydrographic factors; and certain life-history details and behavior patterns were checked under laboratory conditions.

In December 1934, experiments were initiated on the use of tags for marking shrimp. Experiments on shrimp retained in pens showed that the celluloid-disk type of tag affixed to the first abdominal somite of the shrimp was probably the best method, as it apparently interfered less with movements and molting and was retained better than other devices. During the latter part of 1935 this method of tagging was first used in the field and resulted in recoveries of almost 25 percent. This new method provided much needed direct evidence on growth and migrations, and the tagging program was continued with marked success until curtailed by World War II. Much of the material in this report is based on results produced by this technique.

Throughout the years in which we made this study of shrimp we had many colleagues and associates, who contributed in one way or another to this report. Among these were C. Howard Baltzo, Albert W. Collier, Jr., Forrest Durand, the late J. Nelson Gowanloch, Gordon Gunter, J. S. Gutsell, Joseph E. King, C. W. McPhail, Kenneth H. Mosher, John C. Pearson, and F. W. Weymouth. We appreciate their help, and we appreciate also the analytical assistance of George A. Rounsefell and the help given by the conservation agencies of the various States, particularly Georgia, Louisiana, and Texas. We are indebted to Martin D. Burkenroad, Theodore M. Widrig, and Rolf L. Bolin for critical review of the manuscript.

GROWTH

TAGGING

We obtained our growth data from shrimp tagged in various areas from North Carolina to Texas. Thus our results embrace the entire fishery.

The tag used consisted of two small celluloid disks and a nickel pin (fig. 1). The disks, one white and the other red, were perforated in the center. The white disks were numbered consecutively, and the red ones bore instructions for returning the shrimp. The disks were of opaque celluloid, ten one-thousandths of an inch thick, protected by a layer of transparent celluloid five one-thousandths of an inch thick. Most disks used were three-eighths of an inch in diameter, although some of the smaller shrimp were tagged with disks five-sixteenths of an inch in diameter. The pins were of pure nickel wire. A pin, with a white, numbered disk mounted, was thrust through the side of the first abdominal somite about midway between the dorsal and ventral surfaces; a red disk was slipped over the end of the pin protruding from the other side of the shrimp, and a loop was made in the pin with surgical forceps to prevent the disk from slipping off. Approximately ⅛-inch to ¼-inch play was left between the sides

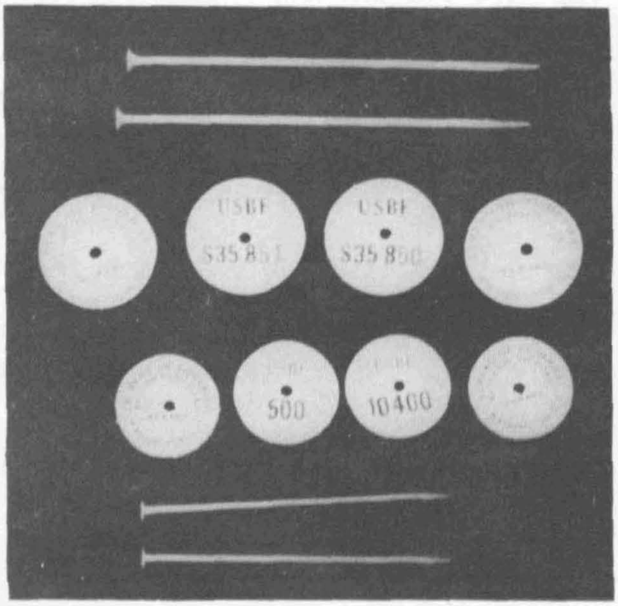

FIGURE 1.—Tags and pins used in marking experiments.

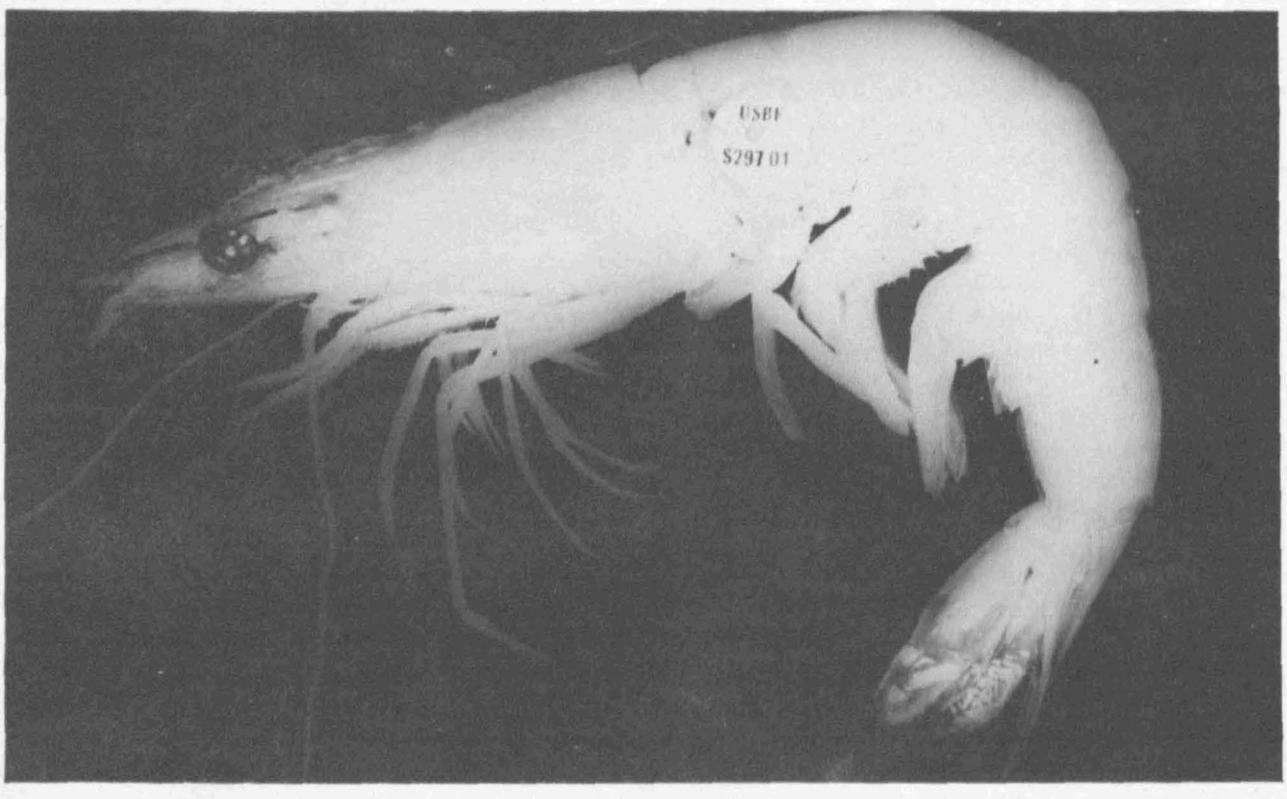

FIGURE 2.—A tagged specimen of the common or white shrimp of the United States, *Penaeus setiferus*.

FIGURE 3.—Tagging shrimp along the east coast of Mexico.

of the shrimp and each disk to allow for growth. The pin traversed the animal through muscle tissue only, and no vital organs were penetrated (fig. 2).

Several methods of capturing shrimp for tagging were tried, such as trapping and seining, and were discarded because they required too much time for the number of shrimp obtained. The commercial shrimp trawl, hauled slowly for a short time (15 to 20 minutes), provided animals in sufficiently good condition for tagging, and this gear was used exclusively.

Wooden or metal tubs were used for holding shrimp aboard the vessel. In addition, a conical net about 3 feet in diameter and 8 feet in length was suspended overboard for holding surplus shrimp not accommodated by the tubs. The live shrimp, as soon as they were hauled aboard, were separated from the fish, dead shrimp, and other organisms and placed in the tubs which had been previously filled with sea water. When this operation was completed, the shrimp that appeared to be in good condition were moved to other tubs of water. The water in the tubs was changed frequently, and dead or dying shrimp were discarded. A small deck pump supplied clean sea water.

Two men did the tagging and a third the recording (fig. 3). The two tubs in which the actual tagging occurred were placed side by side on a table of convenient height. A removable balsa-wood board was fastened to an arm extending vertically between the two tubs. The white, numbered disks were mounted on the pins and stuck on the balsa board in serial order so that either person tagging could remove the tags in sequence. A box of red disks was placed on the table within easy reach of both taggers. A floating measuring board, graduated in half-centimeter units, was placed in each tagging tub. A similar board, as well as the technique of measuring, has been described by Weymouth, Lindner, and Anderson (1933).

So far as possible, measuring and tagging were done under water. As the shrimp were tagged, they were placed in another tub of water, and releases were made in batches of 50. When a batch had been tagged, the shrimp were examined, and substitutions were made for all that appeared to be in poor condition. They were then released by gently emptying the tub overside.

In all experiments a record was maintained of the date, time, and place of capture, the tag number, the sex and length (to the nearest half-centimeter) of each shrimp, and the date, time, and place of release.

Before tagging was begun, it was necessary to acquaint the industry with the work and to make arrangements for handling the returns. Trips were made to all landing ports, and dealers and fishermen were told of the program.

Each shrimp-receiving house was supplied with a jar of formalin for preserving tagged shrimp. Each was also given a book of printed forms on which could be recorded the tag number, the fisherman's name, the boat name, the date of capture, and the place of capture. Posters describing the program and giving instructions on the proper handling of tagged shrimp were placed in strategic places. A reward of 50 cents was given for the return of each whole, marked shrimp accompanied by information on date and place of capture. If the tag was returned without the shrimp, but with the required information, a reward of 25 cents was given. Trips were made at least once each month to collect the tagged shrimp and information, and to pay the rewards.

The success in obtaining tag returns depended on the cooperation of the dealers and fishermen. We were most fortunate in that this cooperation was excellent.

The white disk was always placed on the same side of the shrimp, and the pin from each return was examined carefully to see whether an attempt had been made to substitute another shrimp for one that had been tagged. These checks, together with the known sex of the tagged shrimp, served to prevent our obtaining fraudulent information. Attempts to substitute shrimp were made in very few instances, and these were always during the initial stages of an experiment in a new area. Whenever information was suspect or incomplete, the return was classified as uncertain.

Since it is conceivable that measurements of live shrimp and of those caught by fishermen and preserved in formalin might vary considerably, we ran an experiment to approximate conditions that would occur with marked shrimp caught in the commercial fishery. In this experiment, 300 shrimp were measured alive under water, allowed to die on deck and remain for 1 hour, then were iced down for 24 hours, placed in formalin for another 24 hours, and removed and measured. They were returned to the formalin solution for 1 week, measured again, and returned to the solution for 2 additional weeks, after which they were measured once more. All measurements were of whole shrimp, and to the nearest millimeter (table 1). The means indicate no significant differences between the various measurements. The small differences that occur are obviously the result of observational errors.

EFFECT OF TAGGING

Evidence indicates that some shrimp die as a result of tagging, and that the mortality rate is not uniform with respect to size. In figure 4 and table 2 we show the increasing percentage of recaptures with increasing length (up to about 13.5 cm.). These results we interpret to mean that the smaller the shrimp, the greater the initial tagging mortality.

TABLE 1.—*Effect of preservation in formalin on length of shrimp*

Size group	Number in size group, when measured—			
	Alive	After preservation in formalin for—		
		24 hours	1 week	3 weeks
96–100 mm	12	14	12	14
101–105 mm	28	26	25	24
106–110 mm	29	30	29	33
111–115 mm	23	25	21	24
116–120 mm	30	28	32	29
121–125 mm	29	28	29	26
126–130 mm	19	19	24	23
131–135 mm	28	30	23	22
136–140 mm	26	23	24	25
141–145 mm	27	29	28	30
146–150 mm	21	19	23	22
151–155 mm	15	15	13	14
156–160 mm	7	7	9	7
161–165 mm	5	6	7	6
166–170 mm	1	1	1	1
Total number of shrimp	300	300	300	300
Mean length	126.84	126.82	127.48	126.86

Since the curve levels off at about 13.5 cm., initial tagging mortality apparently is constant in sizes larger than this. It seems entirely logical that initial tagging mortality could be negatively correlated with size up to a certain limit, and be

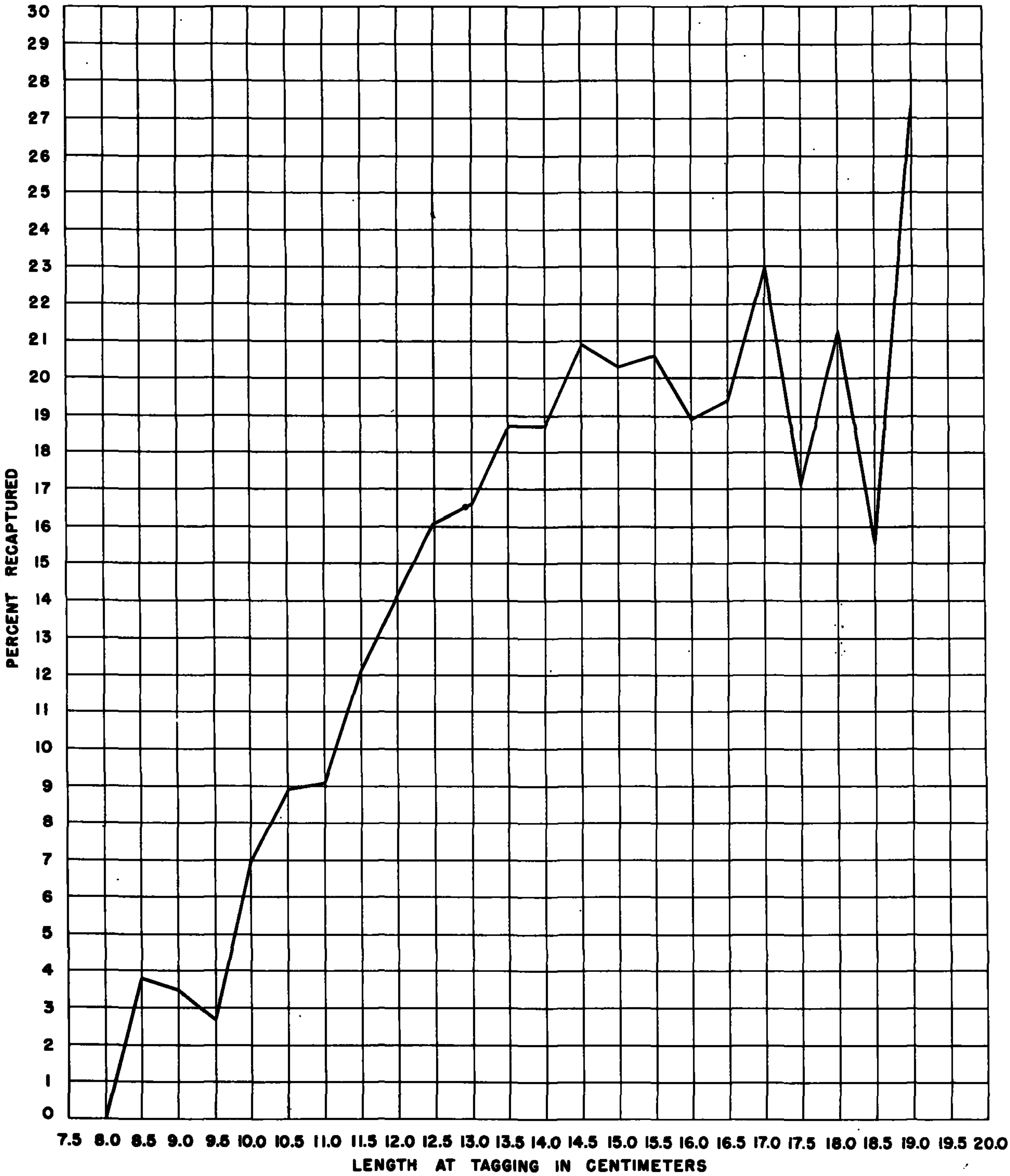

FIGURE 4.—Percentage of shrimp recaptured, according to size at time of tagging.

unaffected by increasing length from this size on. This same type of curve could also result from differential fishing intensity, based on the size of the shrimp, together with a high residual tagging mortality, or a high natural mortality, or both. However, from our experience with the fishery we do not believe that differential fishing appreciably affects the curve.

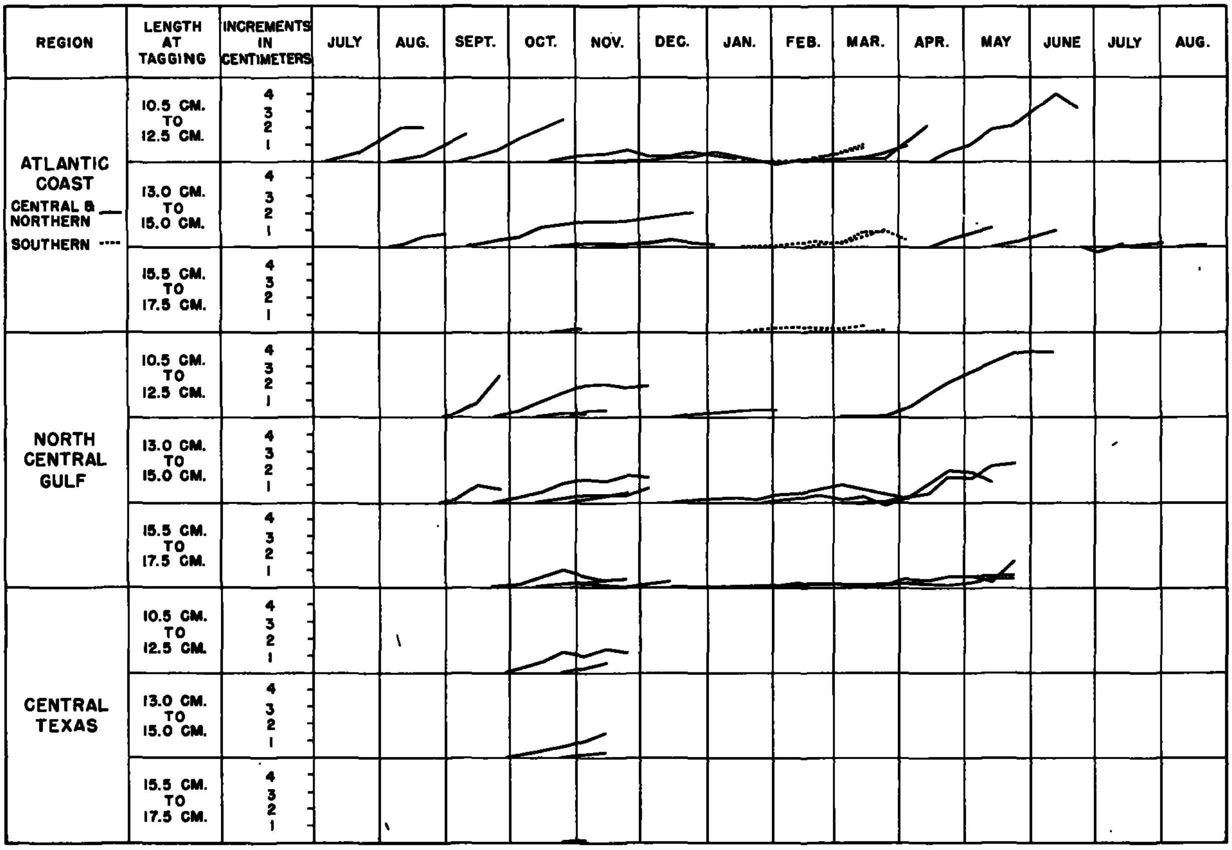

FIGURE 5.—Average growth of marked shrimp throughout the year. The curves begin at the base line on the date of release and follow the average increment, at approximate 10-day intervals, of all recoveries for each experiment. No 10-day interval contains fewer than three recoveries. If more than 1 day of release is included in an experiment, the beginning date is taken as midway between the release dates.

TABLE 2.—*Number of shrimp tagged and number and percentage recovered, according to size when tagged*

[Areas 1 to 38]

Length at tagging	Number released	Number recovered	Percent recovered
7.0 cm	2	----------	0
7.5 cm	80	----------	0
8.0 cm	20	----------	0
8.5 cm	105	4	3.8
9.0 cm	227	8	3.5
9.5 cm	600	16	2.7
10.0 cm	1,372	96	7.0
10.5 cm	2,292	203	8.9
11.0 cm	3,202	292	9.1
11.5 cm	3,903	473	12.1
12.0 cm	4,175	591	14.2
12.5 cm	4,038	652	16.1
13.0 cm	3,665	610	16.6
13.5 cm	3,615	677	18.7
14.0 cm	3,142	588	18.7
14.5 cm	3,147	659	20.9
15.0 cm	3,204	650	20.3
15.5 cm	2,901	599	20.6
16.0 cm	2,246	424	18.9
16.5 cm	1,662	322	19.4
17.0 cm	868	200	23.0
17.5 cm	327	56	17.1
18.0 cm	141	30	21.3
18.5 cm	58	9	15.5
19.0 cm	22	6	27.3
19.5 cm	6	1	16.7
20.0 cm	1	1	100.0
20.5 cm	1	----------	0
Total	45,022	7,167	----------

ANALYSIS OF RESULTS

The seasonal variations in rate of growth of marked shrimp, shown in figure 5,[1] could logically be expected to occur in unmarked individuals, and we therefore assume that the tagged specimens follow rather closely the course of growth of the entire population. It is apparent from figure 5 that growth is rapid during summer, slows down about the end of October, is slight during winter, and accelerates abruptly about the first of March or April, depending on the locality. This suggests that temperature is an important controlling factor, and if this is so we could expect the periods of rapid and slow growth to vary somewhat from year to year and with locality. The influence of locality is evident on the Atlantic coast, where the marked shrimp from the southern portion (Florida) started rapid growth in the

[1] See also tables 3 to 6 showing increments by approximate 10-day intervals of all measurable recoveries.

TABLE 3.—*Distribution by growth increments, of tagged shrimp recovered in northern and central Atlantic fishery*

Date and size when released	Recovered in period—	Number with growth increments, in centimeters, of—														Total number
		−1.0	−0.5	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	
July 6, 1938: [1]																
10.5–12.5 cm	July 6–July 17			1	2											3
	July 18–July 27			3	3	3	1									10
	July 28–Aug. 6					2	1									3
	Aug. 7–Aug. 16						3	4	3							10
	Aug. 17–Aug. 26						2	3	2							7
13.0–15.0 cm	Aug. 7–Aug. 16					1										1
	Aug. 17–Aug. 26						1									1
Aug. 3, 1938: [1]																
10.5–12.5 cm	Aug. 7–Aug. 16				2											2
	Aug. 17–Aug. 26			4	12											16
	Aug. 27–Sept. 5			1	1	4	1	1								8
	Sept. 6–Sept. 15					1	3	1	1							6
	Sept. 16–Sept. 25										1					1
13.0–15.0 cm	Aug. 7–Aug. 16		1	1	3											5
	Aug. 17–Aug. 26				2	1										3
	Aug. 27–Sept. 5				2	3										5
	Sept. 6–Sept. 15						1									1
Sept. 6–11, 1936:																
10.5–12.5 cm	Sept. 6–Sept. 20		3	27	8	3										41
	Sept. 21–Sept. 30			4	8	2	6									20
	Oct. 1–Oct. 10					1	4									5
	Oct. 11–Oct. 20						1									1
	Oct. 21–Oct. 30							2	1	1						4
	Oct. 31–Nov. 9							1		1						2
	Nov. 10–Nov. 19						1	1								2
	Dec. 30–Jan. 8									1						1
13.0–15.0 cm	Sept. 6–Sept. 20		5	39	11	2										57
	Sept 21–Sept. 30		1	8	23	2										34
	Oct. 1–Oct. 10			1	3	3										7
	Oct. 11–Oct. 20					6	2									8
	Oct. 21–Oct. 30					1	2									3
	Oct. 31–Nov. 9					2	1	2								5
	Nov. 10–Nov. 19					2	2	3								7
	Nov. 20–Nov. 29					1	1	1								3
	Dec. 10–Dec. 19							1								1
	Dec. 20–Dec. 29						2			1						3
	Dec. 30–Jan. 8						1									1
	Jan. 9–Jan. 18								1							1
	Jan. 19–Jan. 28						1									1
15.5–17.5 cm	Sept. 6–Sept. 20			2	1											3
	Sept. 21–Sept. 30			2	1											3
	Oct. 1–Oct. 20			1												1
	Oct. 21–Oct. 30						1	1								2
	Oct. 31–Nov. 9					1										1
Oct. 16–21, 1937:																
10.5–12.5 cm	Oct. 16–Oct. 30		9	65	33	6	1									114
	Oct. 31–Nov. 9		1	19	19	7	2	1								49
	Nov. 10–Nov. 19			4	6	4										14
	Nov. 20–Nov. 29			1	1	1	1									4
	Nov. 30–Dec. 9			3	1	1										5
	Dec. 10–Dec. 19		1		1	1										3
	Dec. 20–Dec. 29			1	2	2										5
	Dec. 30–Jan. 8					1										1
	Jan. 19–Jan. 28			3	1											4
	Feb. 18–Feb. 27		1			1										2
	Mar. 10–Mar. 19				1											1
13.0–15.0 cm	Oct. 16–Oct. 30		10	74	40	6										130
	Oct. 31–Nov. 9		9	22	18	5	1									55
	Nov. 10–Nov. 19			6	2	1										9
	Nov. 20–Nov. 29			4	1											5
	Nov. 30–Dec. 9		1													1
	Dec. 10–Dec. 19			3	2	3										8
	Dec. 20–Dec. 29		1	3	3	1										8
	Dec. 30–Jan. 8		1	2	2											5
	Jan. 9–Jan. 18			1	1											2
	Jan. 19–Jan. 28					1										1
	Jan. 29–Feb. 7					1										1
	Feb. 8–Feb. 17				1											1
15.5–17.5 cm	Oct. 16–Oct. 30		1	10	5											16
	Oct. 31–Nov. 9			3	2											5
	Dec. 20–Dec. 29			1												1
	Jan. 19–Jan. 28				1											1
	Jan. 29–Feb. 7			1												1
Nov. 9, 1937:																
10.5–12.5 cm	Nov. 9–Nov. 19		5	27	7											39
	Nov. 20–Nov. 29			2												2
	Nov. 30–Dec. 9		1	10	2											13
	Dec. 10–Dec. 19			7	3	1										11
	Dec. 20–Dec. 29			5	1			1								7
	Dec. 30–Jan. 8			1		2										3
	Jan. 9–Jan. 18			1	1											2
	Jan. 19–Jan. 28			3												3
13.0–15.0 cm	Nov. 9–Nov. 19			7	1											8
	Nov. 30–Dec. 9			3	2											5
	Dec. 20–Dec. 29				1					1						2
	Jan. 19–Jan. 28		1													1
15.5–17.5 cm	Nov. 9–Nov. 19		2													2

[1] Shrimp released on July 6 and Aug. 3, 1938, were immature, whereas those released on July 12 and Aug. 5–11, 1938, were mature.

TABLE 3.—*Distribution by growth increments, of tagged shrimp recovered in northern and central Atlantic fishery*—Continued

Date and size when released	Recovered in period—	Number with growth increments, in centimeters, of— −1.0	−0.5	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	Total number
Jan. 24, 1938:																
10.5–12.5 cm	Jan. 24–Jan. 28			1												1
	Jan. 29–Feb. 7		6	12	1											19
	Feb. 8–Feb. 17		3	31	5	1										40
	Feb. 18–Feb. 27		2	7				1								10
	Feb. 28–Mar. 9			1												1
	Mar. 10–Mar. 19		1	3	3											7
	Mar 20–Mar. 29		1		2											3
	Mar. 30–Apr. 8					2										2
	Apr. 9–Apr. 18						1		2							3
13.0–15.0 cm	Feb. 8–Feb. 17		1													1
	Mar. 10–Mar. 19			1												1
Feb. 23, 1938:																
10.5–12.5 cm	Feb. 23–Feb. 27			1												1
	Feb. 28–Mar. 9			2	1											3
	Mar. 10–Mar. 19		1	11	13	1										26
	Mar. 20–Mar. 29			5	17	5	1									28
	Mar. 30–Apr. 8				3	4		1								8
	Apr. 9–Apr. 18				1				1							2
	Apr. 19–Apr. 28								1		1					2
	Apr. 29–May. 8										1					1
	May 9–May 18							1								1
13.0–15.0 cm	Mar. 10–Mar. 19		1													1
	Mar. 20–Mar. 29				1	1										2
15.5–17.5 cm	Mar. 20–Mar. 29			2												2
Mar. 24, 1938:																
10.5–12.5 cm	Mar. 24–Mar. 29			1	2											3
	Mar. 30–Apr. 8			6	1											7
	Apr. 9–Apr. 18				2											2
	Apr. 19–Apr. 28						1	1								2
	Apr. 29–May 8							2								2
	May 9–May 18							1	1							2
	May 19–May 28								1							1
	June 8–June 17											1				1
13.0–15.0 cm	Mar. 24–Mar. 29			1												1
	Mar. 30–Apr. 8			1												1
	Apr. 9–Apr. 18				1											1
	Apr. 29–May 8									1						1
Apr. 14, 1938:																
10.5–12.5 cm	Apr. 14–Apr. 18		1	3	1	1										6
	Apr. 19–Apr. 28			6	13	16										35
	Apr. 29–May 8			2	9	7	4	3								25
	May 9–May 18					3	9	6	1	3	1					23
	May 19–May 28			1	1	1		1	1	2	2					9
	May 29–June 7											1				1
	June 8–June 17										1	2	1			4
	June 18–June 27								1		2					3
	June 28–July 7									1						1
	July 18–July 27														1	1
13.0–15.0 cm	Apr. 19–Apr. 28			3	3	1										7
	Apr. 29–May 8				2											2
	May 9–May 18				2		1	1								4
	May 19–May 28				1											1
	May 29–June 7					1										1
May 13, 1938:																
13.0–15.0 cm	May 13–May 18		5	14	8	1										28
	May 19–May 28		3	9	10	4										26
	May 29–June 7				1			1								2
	June 8–June 17				5	12	2	2								21
	June 18–June 27				1	1										2
	June 28–July 7						1									1
15.5–17.5 cm	May 13–May 18		1	1	1											3
	May 19–May 28		1		2											3
	June 8–June 17				1											1
June 24, 1938:																
13.0–15.0 cm	June 24–June 27		2	8	3											13
	June 28–July 7		2	2												4
	July 8–July 17			4	2											6
	July 18–July 27			1												1
	July 28–Aug. 6			1												1
15.5–17.5 cm	June 24–June 27		4	7												11
	June 28–July 7		1													1
	July 8–July 17		1	6	2											9
July 12, 1938:[1]																
13.0–15.0 cm	July 12–July 17			13												13
	July 18–July 27		1	5	3											9
	July 28–Aug. 6			3	2											5
	Aug. 7–Aug. 16			1	1											2
15.5–17.5 cm	July 12–July 17		6	11	3											20
	July 18–July 27		6	11	2											19
	July 28–Aug. 6		1	3												4
	Aug. 7–Aug. 16			1												1
Aug. 5–11, 1938:[1]																
13.0–15.0 cm	Aug. 5–Aug. 16		1	4	1											6
	Aug. 17–Aug. 26			5	1											6
	Aug. 27–Sept. 5				1											1
15.5–17.5 cm	Aug. 5–Aug. 16		3	9	1											13

[1] Shrimp released on July 6 and Aug. 3, 1938, were immature, whereas those released on July 12 and Aug. 5–11, 1939, were mature.

spring about one month earlier than in the central portion (Georgia).

A few 13- to 15-cm. shrimp from the central and northern Atlantic coast did not show the characteristic rapid growth during July and August; these are shown in the last two columns of figure 5. These shrimp were mature, whereas those from the same area depicted at the left were immature. The shrimp are not comparable, owing in part to the marked decrease in the rate of growth of the rostrum at maturity. This will be be discussed later.

TABLE 4.—*Distribution by growth increments, of tagged shrimp recovered in southern Atlantic fishery*

Date and size when released	Recovered in period—	Number with growth increments, in centimeters, of—														Total number
		−1.0	−0.5	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	
Jan. 13-19, 1938:																
10.5-12.5 cm	Jan. 19-Jan. 28		3	18	7	1										29
	Feb. 8-Feb. 17		2	6	2											10
	Feb. 18-Feb. 27			1												1
	Feb. 28-Mar. 9		1		1	2										4
	Mar. 10-Mar. 19		1	1	2	1	2	1								8
13.0-15.0 cm	Jan. 19-Jan. 28		32	86	21	3										142
	Jan. 29-Feb. 7		2	8	5											15
	Feb. 8-Feb. 17		2	21	15	1										39
	Feb. 18-Feb. 27		1	11	5	2	1									20
	Feb. 28-Mar. 9		3	10	7	3										23
	Mar. 10-Mar. 19			3	14	6	3									26
	Mar. 20-Mar. 29			2	1	1	2		1							7
	Mar. 30-Apr. 8			1	1	1										3
15.5-17.5 cm	Jan. 19-Jan. 28		6	17	9	1										33
	Jan. 29-Feb. 7			2	2											4
	Feb. 8-Feb. 17			6	5	1										12
	Feb. 18-Feb. 27						1									1
	Feb. 28-Mar. 9		1	1	3											5
	Mar. 10-Mar. 19			2	4											6
	Mar. 20-Mar. 29			1												1
Feb. 13-20, 1938:																
10.5-12.5 cm	Feb. 13-Feb. 27			2	4		1									7
	Feb. 28-Mar. 9				4	1										5
	Mar. 10-Mar. 19			3	2	1	2	2								10
	Mar. 20-Mar. 29		1													1
13.0-15.0 cm	Feb. 13-Feb. 27		2	5	3											10
	Feb. 28-Mar. 9		2	5	5	3										15
	Mar. 10-Mar. 19			4	3	1	3	1	1							13
	Mar. 20-Mar. 29		1		3	1	2	1								8
15.5-17.5 cm	Feb. 13-Feb. 27		3	2	1											6
	Feb. 28-Mar. 9		2	9	4											15
	Mar. 10-Mar. 19		1	4	1											6
	Mar. 20-Mar. 29			3	1											4
	Mar. 30-Apr. 18		1													1

TABLE 5.—*Distribution by growth increments, of tagged shrimp recaptured in north-central Gulf fishery*

Date and size when released	Recovered in period—	Number with growth increments, in centimeters, of—														Total number
		−1.0	−0.5	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	
Aug. 29-30, 1939:																
10.5-12.5 cm	Sept. 1-Sept. 10			3		1										4
	Sept. 11-Sept. 20			1	1		2									4
	Sept 21-Sept. 30							2	1	2						5
	Oct. 1-Oct. 10								1							1
	Oct. 11-Oct. 20										1					1
13.0-15.0 cm	Aug. 29-Aug. 31			1	6											7
	Sept. 1-Sept. 10			14	4	1										19
	Sept. 11-Sept. 20			1	3	7		1	1							13
	Sept. 21-Sept. 30			1		1	1									3
	Oct. 1-Oct. 10					1		1								2
	Oct. 21-Oct. 30							1								1
	Oct. 31-Nov. 9						1									1
	Nov. 10-Nov. 19							1								1
	Dec. 10-Dec. 19					1										1
Sept. 20-25, 1939:																
10.5-12.5 cm	Sept. 20-Sept. 30		5	58	22	4										89
	Oct. 1-Oct. 10			19	18	10	3									50
	Oct. 11-Oct. 20			2	6	8	6	1								23
	Oct. 21-Oct. 30			1	2	2	4	4	2							15
	Oct. 31-Nov. 9				1	1	4	4	2		1					13
	Nov. 10-Nov. 19						2	2	1							5
	Nov. 20-Nov. 29				1	1	4	4	3							13
	Nov. 30-Dec. 9					2	3	4	3							12
	Dec. 10-Dec. 19				1				1							2
	Dec. 30-Jan. 8									1						1
	Jan. 19-Jan. 28								1							1
13.0-15.0 cm	Sept. 20-Sept. 30	1	4	108	34	3										150
	Oct. 1-Oct. 10		2	13	23	3										41
	Oct. 11-Oct. 20			2	8		2									12
	Oct. 21-Oct. 30				2	1	3									6
	Oct. 31-Nov. 9				5	16	11	8	3							43
	Nov. 10-Nov. 19			1	1	5	3			1						11
	Nov. 20-Nov. 29				1	1	2	2	1							7
	Nov. 30-Dec. 9					3	1	2								6
	Dec. 10-Dec. 19						1									1
	Dec. 20-Dec. 29						1									1

TABLE 5.—*Distribution by growth increments, of tagged shrimp recaptured in north-central Gulf fishery*—Continued

Date and size when released	Recovered in period—	Number with growth increments, in centimeters, of—														Total number
		−1.0	−0.5	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	
Sept. 20-25, 1939—Continued																
15.5-17.5 cm	Sept. 20-Sept. 30		4	24	3											31
	Oct. 1-Oct. 10			8	2											10
	Oct. 11-Oct. 20			1	1											2
	Oct. 21-Oct. 30				1	1	1									3
	Oct. 31-Nov. 9			1	9	6										16
	Nov. 10-Nov. 19		1		1	1										3
	Nov. 20-Nov. 29				1											1
	Nov. 30-Dec. 19				1	1										2
Oct. 11-14, 1939:																
10.5-12.5 cm	Oct. 11-Oct. 20			6												6
	Oct. 21-Oct. 30			6	4											10
	Oct. 31-Nov. 9			2	1											3
	Nov. 10-Nov. 19				1											1
	Nov. 20-Nov. 29				1											1
	Nov. 30-Dec. 9					1		1								2
13.0-15.0 cm	Oct. 11-Oct. 20	1	4	21	6											32
	Oct. 21-Oct. 30	1	2	17	14	2	1									37
	Oct. 31-Nov. 9		2	21	31	10	1									65
	Nov. 10-Nov. 19		1	1	5	1										8
	Nov. 20-Nov. 29			3	6	1										10
	Nov. 30-Dec. 9			1	9	5	1		1							17
	Dec. 10-Dec. 19			1												1
	Dec. 30-Jan. 8				1											1
15.5-17.5 cm	Oct. 11-Oct. 20		9	30	4											43
	Oct. 21-Oct. 30		1	7	3											11
	Oct. 31-Nov. 9	1	3	15	17	4										40
	Nov. 10-Nov. 19			3	1	2										6
	Nov. 20-Nov. 29			3	1	3										7
	Nov. 30-Dec. 9			1		1										2
	Dec. 10-Dec. 19					1										1
Oct. 27-28, 1939:																
10.5-12.5 cm	Oct. 27-Oct. 30			3	7											10
	Oct. 31-Nov. 9			14	16	1										31
	Nov. 10-Nov. 19			2	3	1										6
	Apr. 28-May 7						1									1
13.0-15.0 cm	Oct. 27-Oct. 30		1	6	4											11
	Oct. 31-Nov. 9		1	20	12	1										34
	Nov. 10-Nov. 19			1												1
	Nov. 20-Nov. 29			1	1	1										3
	Dec. 10-Dec. 19			1												1
	Dec. 30-Jan. 8			1												1
	Jan. 29-Feb. 7				1											1
	Feb. 8-Feb. 17				1											1
	Feb. 28-Mar. 8				1											1
	Mar. 29-Apr. 7						1									1
15.5-17.5 cm	Oct. 27-Oct. 30			6	2	1										9
	Oct. 31-Nov. 9		1	25	7	3										36
	Nov. 20-Nov. 29		1	4	1											6
	Nov. 30-Dec. 9			2	1											3
	Dec. 10-Dec. 19			3	1	1										5
Nov. 10-15, 1939:																
10.5-12.5 cm	Nov. 20-Nov. 29			1	2											3
	Nov. 30-Dec. 9					1										1
	Dec. 10-Dec. 19			1	1											2
	Jan. 29-Feb. 7				1											1
	Feb. 8-Feb. 17				1											1
	Feb. 28-Mar. 8				1											1
	Mar. 9-Mar. 18				1	1										2
	Mar. 29-Apr. 7				1	1										2
	May 8-May 17										1					1
13.0-15.0 cm	Nov. 30-Dec. 9			3	2											5
	Dec. 10-Dec. 19			1												1
	Feb. 8-Feb. 17			1	1											2
	Feb. 18-Feb. 27					1										1
	Feb. 28-Mar. 8			1		1										2
Nov. 30, 1939:																
10.5-12.5 cm	Nov. 30-Dec. 9			1												1
13.0-15.0 cm	Nov. 30-Dec. 9			17	7											24
	Dec. 10-Dec. 19			2	1											3
	Dec. 30-Jan. 8		1													1
	Jan. 19-Jan. 28			1												1
	Mar. 19-Mar. 28			1												1
	Mar. 29-Apr. 7				1											1
	Apr. 8-Apr. 17				1											1
15.5-17.5 cm	Nov. 30-Dec. 9		2	30	5											37
	Dec. 10-Dec. 19			2	1											3
Dec. 13-16, 1938:																
10.5-12.5 cm	Dec 13-Dec. 19	2	4	49	14	1										70
	Dec. 20-Dec. 29	1		13	6											20
	Dec. 30-Jan. 8			1	1											2
	Jan. 9-Jan. 18				2											2
	Jan. 19-Jan. 28		1	1	5	1										8
	Jan. 29-Feb. 7			1	2											3
	Feb. 8-Feb. 17				1											1
	Apr. 19-Apr. 28							1								1

TABLE 5.—*Distribution by growth increments, of tagged shrimp recaptured in north-central Gulf fishery*—Continued

Date and size when released	Recovered in period—	Number with growth increments, in centimeters, of—														Total number
		−1.0	−0.5	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	
Dec. 13-16, 1938—Continued	Dec. 13-Dec. 19		1	19	9	1										30
	Dec. 20-Dec. 29			4	1											5
	Dec. 30-Jan. 8				1											1
	Jan. 9-Jan. 18			2	2											4
	Jan. 19-Jan. 28			2	1											3
	Jan. 29-Feb. 7			2	2	1										5
13.0-15.0 cm	Feb. 8-Feb. 17			2			1									3
	Feb. 28-Mar. 9					3										3
	Mar. 10-Mar. 19			1												1
	Mar. 30-Apr. 8		1	2		1										4
	Apr. 19-Apr. 28					1										1
	May 19-May 28								1							1
	May 29-June 7				1											1
	Dec. 13-Dec. 19		1	3												4
	Dec. 30-Jan. 8			1	1											2
	Jan. 9-Jan. 18			11												11
	Jan. 19-Jan. 28			1												1
	Jan. 29-Feb. 7		1	6	2											9
	Feb. 8-Feb. 17			10	1											11
	Feb. 18-Feb. 27			1												1
	Feb. 28-Mar. 9		1	8	3											12
	Mar. 10-Mar. 19		1	6	1											8
15.5-17.5 cm	Mar. 20-Mar. 29		1	5	3											9
	Mar. 30-Apr. 8			5	4											9
	Apr. 9-Apr. 18				1											1
	Apr. 19-Apr. 28		1	2	2											5
	Apr. 29-May 8			3		1										4
	May 9-May 18			2	2	2										6
	May 19-May 28			1	2	1										4
	June 8-June 17					1										1
	July 18-July 27						1									1
Jan. 20-26, 1939:																
10.5-12.5 cm	Feb. 28-Mar. 9				1	1										2
	Apr. 19-Apr. 28											1				1
	Jan. 20-Feb. 7			6	2	1										9
	Feb. 8-Feb. 17			4	3											7
	Feb. 18-Feb. 27			2	1	1										4
	Feb. 28-Mar. 9		2	10	5											17
	Mar. 10-Mar. 19			4	7											11
	Mar. 20-Mar. 29		1	5												6
13.0-15.0 cm	Mar. 30-Apr. 8			4	3											7
	Apr. 9-Apr. 18				1	1										2
	Apr. 19-Apr. 28						3	4	1							8
	Apr. 29-May 8				1	1		3		1						6
	May 9-May 18				1	1		1								3
	May 19-May 28					1	1									2
	June 8-June 17								1							1
	Jan. 20-Feb. 7			6	2											8
	Feb. 8-Feb. 17			7	6											13
	Feb. 18-Feb. 27			8	4											12
	Feb. 28-Mar. 9			18	4											22
	Mar. 10-Mar. 19			11	1											12
	Mar. 20-Mar. 29			8	2											10
15.5-17.5 cm	Mar. 30-Apr. 8			5	3	4										12
	Apr. 9-Apr. 18			2		1										3
	Apr. 19-Apr. 28			1	4	1	1									7
	Apr. 29-May 8			2	1	2	1									6
	May 9-May 18			1	2	3										6
	May 19-May 28			1	2	1	1									5
	Jun. 8-Jun. 17			1												1
Feb. 29-Mar. 6, 1940:																
	Feb. 29-Mar. 8		2	22	2											26
	Mar. 9-Mar. 18		14	68	7		1									90
	Mar. 19-Mar. 28	1	4	25	4	1										35
	Mar. 29-Apr. 7		1	1	7	3										12
	Apr. 8-Apr. 17				3	1	2	2	1							9
	Apr. 18-Apr. 27					1	1	1	1	1						5
10.5-12.5 cm	Apr. 28-May 7							3		3		1				7
	May 8-May 17									3	2					5
	May 18-May 27										3	1	1			5
	May 28-Jun. 6								1		1	1	1	1		5
	Jun. 7-Jun. 16									1		1	1			3
	Jun. 17-Jun. 26														2	2
	Jun. 27-Jul. 6											1	1			2
	Feb. 29-Mar. 8		1	1												2
	Mar. 9-Mar. 18		6	27	3											36
	Mar. 19-Mar. 28		2	7	2											11
	Mar. 29-Apr. 7		1	16	9	1										27
	Apr. 8-Apr. 17			1	1	1										3
13.0-15.0 cm	Apr. 18-Apr. 27				1	2	7	3	1							14
	Apr. 28-May 7			1	2	3	6	5		1						18
	May 8-May 17						2	2	1	1						6
	May 18-May 27					2	1	5	2	1	2					13
	May 28-Jun. 6					1			1							2
	Jun. 7-Jun. 16								1							1
	Jun. 17-Jun. 26											1				1
	Feb. 29-Mar. 8			2												2
	Mar. 9-Mar. 18		3	41	10											54
	Mar. 19-Mar. 28			10	2											12
	Mar. 29-Apr. 7		1	17	11											29
	Apr. 8-Apr. 17				5											5
15.5-17.5 cm	Apr. 18-Apr. 27			2	5	5										12
	Apr. 28-May 7			2	8	4	1									15
	May 8-May 17		1	3	8	1										13
	May 18-May 27				1		2	2								5
	Jun. 7-Jun. 16				1											1
	June 17-June 26			1												1

TABLE 6.—*Distribution by growth increments, of tagged shrimp recovered in central Texas fishery*

Date and size when released	Recovered in period—	Number with growth increments, in centimeters, of—														Total number
		−1.0	−0.5	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	
Aug. 27-31, 1937:																
10.5–12.5 cm	Aug. 27–Sept. 20			5	2											7
	Sept. 21–Sept. 30				1											1
	Oct. 1–Oct. 10								1							1
	Oct. 11–Oct. 20					1	1									2
	Oct. 31–Nov. 9								1							1
13.0–15.0 cm	Aug. 27–Sept. 20		5	5	1	1										12
	Sept. 21–Sept. 30				3	1										4
	Oct. 1–Oct. 10						2									2
	Oct. 21–Oct. 30			1												1
15.5–17.5 cm	Aug. 27–Sept. 20			2												2
	Sept. 21–Sept. 30			1												1
	Oct 1–Oct. 10			1												1
Sept. 23-Oct. 23, 1936:																
10.5–12.5 cm	Sept. 23–Oct. 10		11	35	7	1										54
	Oct. 11–Oct. 20			4	13	11										28
	Oct. 21–Oct. 30				1	5	6									12
	Oct. 31–Nov. 9				1	2	1									4
	Nov. 10–Nov. 19				2	3	6	1	1							13
	Nov. 20–Nov. 29				1	1	2									4
	Nov. 30–Dec. 9						1									1
	Dec. 10–Dec. 19							1								1
13.0–15.0 cm	Sept. 23–Oct. 10		9	23												32
	Oct. 10–Oct. 20			8	10	4										22
	Oct. 11–Oct. 30				8	3										11
	Oct. 21–Nov. 9				4	3	2									9
	Nov. 10–Nov. 19					2	1	1								4
	Nov. 20–Nov. 29					1										1
	Nov. 30–Dec. 9			1												1
	Dec. 10–Dec. 19					1										1
15.5–17.5 cm	Sept. 23–Oct. 10		3	3												6
	Oct. 11–Oct. 20		1	2	1											4
	Oct. 21–Oct. 30		1	1												2
	Oct. 31–Nov. 9				1											1
	Nov. 20–Nov. 29					1										1
	Nov. 30–Dec. 9				1											1
	Dec. 10–Dec. 19				1											1
	Dec. 20–Dec. 29				1											1
Oct. 20-28, 1937:																
10.5–12.5 cm	Oct. 20–Oct. 30		1	13	7	1										22
	Oct. 31–Nov. 9		1	12	7	3										23
	Nov. 10–Nov. 19				3	1										4
13.0–15.0 cm	Oct. 20–Oct. 30		9	29	11	1										50
	Oct. 31–Nov. 9		5	50	21	5										81
	Nov. 10–Nov. 19			3	3											6
15.5–17.5 cm	Oct. 20–Oct. 30		2	12	3											17
	Oct. 31–Nov. 9		3	14	4											21

The fact that we found soft-shelled, or recently molted, shrimp during winter indicates that some growth occurs during this season. Figure 6 also demonstrates this fact, but the winter growth is certainly negligible when compared with that of the spring, summer, and early fall. Of the shrimp released during winter (between November 1 and early February), the smallest and generally most rapidly growing group (10.5 to 12.5 cm.) had an average increment of only 5 mm. after 60 to 79 days, whereas during summer the same size group displayed a growth of more than 20 mm. in 40 to 59 days. No shrimp returned after February 28 were included in the calculations of the winter growth.

DESCRIPTION OF GROWTH

Not only does the rate of growth vary during different seasons, it also varies with the size of the shrimp. This is shown in tables 3 to 6. The data for spring and summer growth along the north and central Atlantic coast (typical also of other regions) (fig. 6) show that the smaller shrimp grow much more rapidly than do the larger ones. Walford (1946) described growth of this general type by plotting the length at a given age against the length at that age plus one unit of time, and applied the principle to several species of fishes and other animals. The same description of growth had previously been proposed by Von Bertalanffy (1938). It requires that the ratio of successive pairs of increments in length be constant for all sizes of the animal considered.

In the plot described, the growth data would appear as a straight line. While the straightness of the array of a given set of length measurements so plotted suggests that the animals are conforming to the principles that generate a straight line, this point is not necessarily proved by the plot alone. Such plots provide a convenient tool, however, since growth in this manner is simply described and is easy to illustrate and compute.

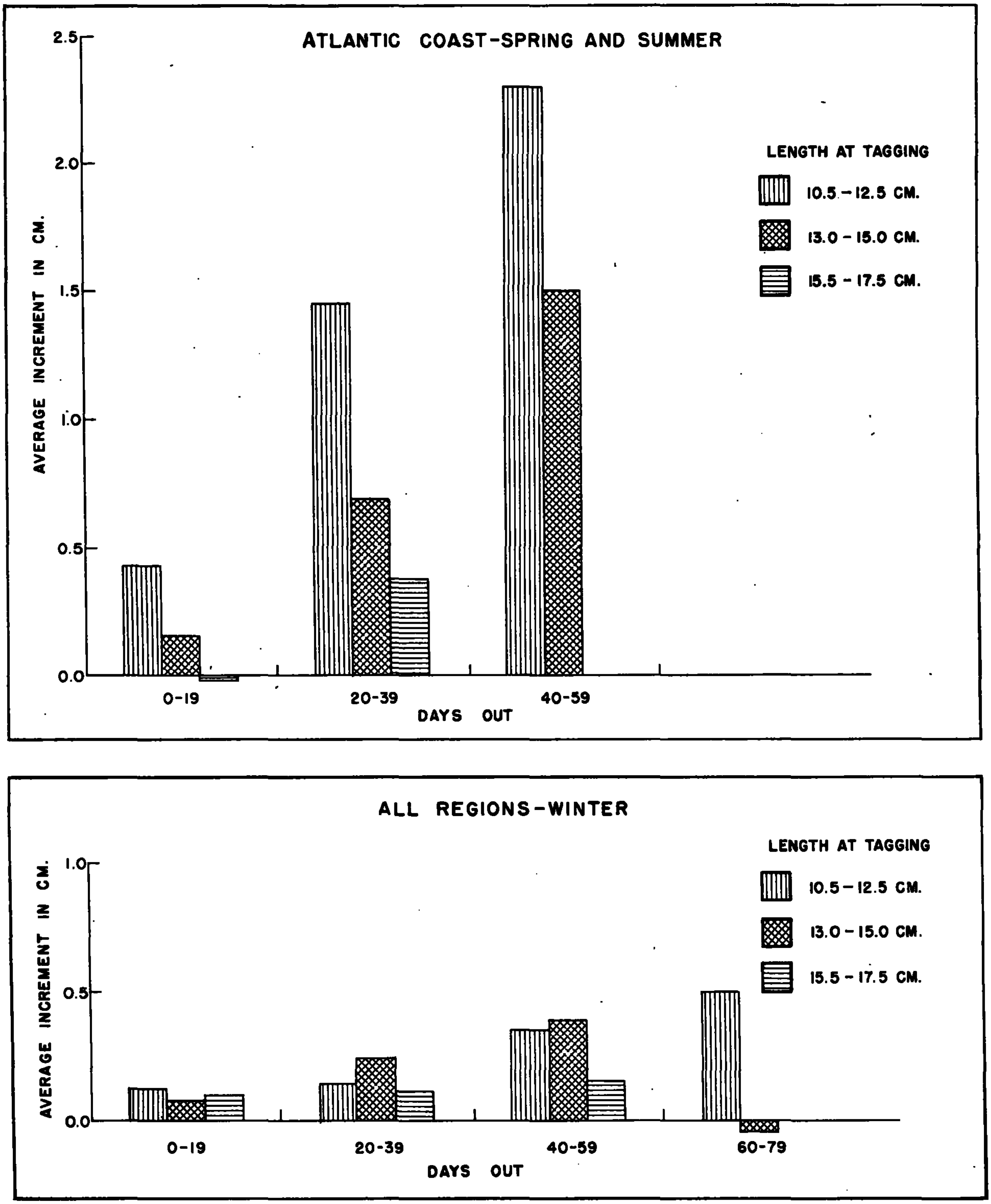

FIGURE 6.—Average growth of tagged shrimp; Atlantic coast, spring and summer, 545 individuals; all regions, winter, 1,183 individuals.

The length of an animal at a given age can be expressed, according to this description, as:

$$L_t = L_\infty (1 - K^t)$$

where L_t is the length at age t
L is a constant, and
K is a constant.

The constant, L_∞ is the average ultimate length of animals growing in this fashion. The expression, $(1-K)$, can be interpreted as the fraction of the length yet to be attained in the animal's life that is attained during one unit of time. The constant, K, is an average ratio of successive pairs of length increments, accrued during constant intervals of time.

The same growth type can also be expressed as:

$$L_{t+1} = L_1 + KL_t$$

where L_{t+1} is the length at age $(t+1)$

L_t is the length at age (t)

and L_1 is a constant, equal to $L_\infty\ (1-K)$

and K is a constant, as before.

This expression is a straight line when L_{t+1} is plotted against L_t. When the available length data are such as can be plotted in this fashion, a straight line fitted to the array describes the growth of the group from which the data were taken according to the principles given above. The slope of the fitted line will be an estimate of the parameter K, and, when $L_t=0$ the value of L_{t+1} will be an estimate of the parameter L_1. The parameter L_∞ can be estimated by dividing L_1 by $(1-K)$.

Having estimated the parameters K and L_∞, one can describe the growth pattern of the average animal with respect to age as given above:

$$L_t = L_\infty (1 - K^t)$$

This would be the growth pattern if the animal grew throughout its life at the rate derived from the data.

Note that the plot, L_{t+1} against L_t, can be made even when the total age of the animals for which one has increments is unknown. Once the parameters K and L_∞ are estimated from such data, the age of the animals can be estimated, under the assumption that they grew at the observed rate throughout their life. For this reason the data here available on the growth increments of shrimp can conveniently be processed according to this growth type, to describe the size attained by the average individual at any given age.

A straight line was fitted to the data after tabulation as L_t (length at tagging) and the corresponding L_{t+r} (length at recovery) for each tagged shrimp. The lines were fitted under the criterion of "least squares." As an example, the data for males of the Atlantic coast, which had been released for a period of 40 to 49 days during summer and fall, are plotted in figure 7.

Since the shrimp were recovered at various time intervals after release, all those recovered after intervals of 0–9 days, 10–19 days, 20–29 days, and so on, were treated separately. The data were further classified by season, spring (March 31 to June 30), summer and fall (July 1 to October 31), and winter (November 1 to March 31), and as belonging to four regions of the coast: (1) Atlantic Coast, (2) Northern Gulf of Mexico east of the Mississippi Delta, (3) Gulf of Mexico west of the Mississippi Delta, and (4) Texas.

The slope (K_r) and L_{t+r} intercept $(L_{1,r})$ of the fitted lines are shown in figure 7. The L_∞ corresponding to the computed L_1 and K is also listed for each line.

TABLE 7.—*Dates of release of shrimp tagged for determining growth*

Atlantic coast: Spring growth	Atlantic coast: Summer and fall growth	North central Gulf, east of Mississippi River: Summer and fall growth	Central Texas: Summer and fall growth
Mar. 24, 1938	Sept. 6, 1936	Sept. 20, 1939	Sept. 23, 1936
Apr. 14, 1938	Sept. 7, 1936	Sept. 21, 1939	Sept. 24, 1936
May 13, 1938	Sept. 8, 1936	Sept. 23, 1939	Sept. 25, 1936
June 24, 1938	Sept. 9, 1936	Sept. 24, 1939	Sept. 28, 1936
	Sept. 10, 1936	Sept. 25, 1939	Sept. 29, 1936
	Sept. 11, 1936	Oct. 11, 1939	Sept. 30, 1936
	Aug. 10, 1937	Oct. 12, 1939	Oct. 3, 1936
	Aug. 11, 1937	Oct. 13, 1939	Aug. 27, 1937
	Aug. 12, 1937	Oct. 14, 1939	Aug. 30, 1937
	Aug. 19, 1937		Aug. 31, 1937
	Sept. 7, 1937		Oct. 20, 1937
	Oct. 11, 1937		Oct. 21, 1937
	Oct. 12, 1937		Sept. 8, 1938
	Oct. 13, 1937		Sept. 14, 1938
	July 6, 1938		Sept. 15, 1938
	July 12, 1938		
	Aug. 3, 1938		
	Aug. 5, 1938		
	Aug. 11, 1938		

While the L_∞'s derived from data of several different time intervals are comparable, the K and L_1's are not. The K_{10} and $L_{1,10}$ given in the right-

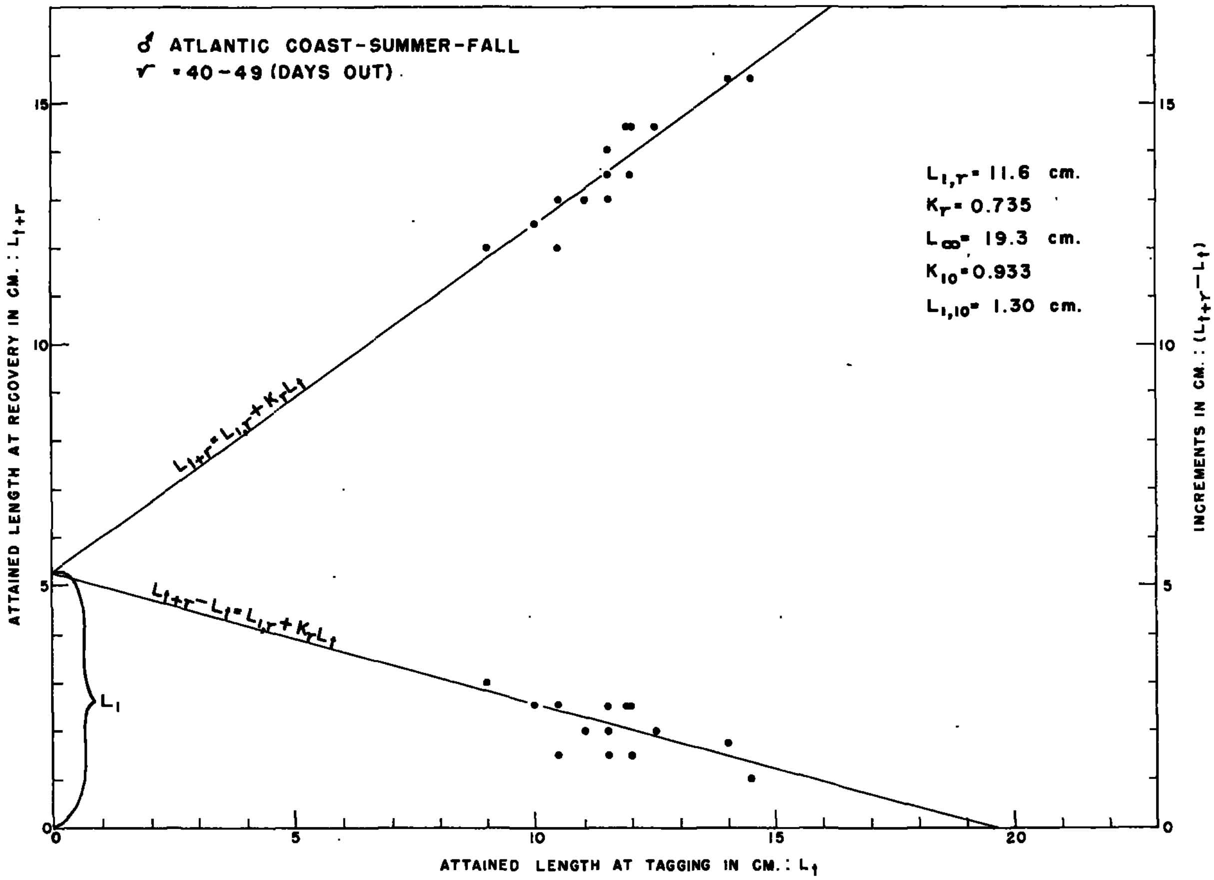

FIGURE 7.—Example of fitting a straight line to growth data from tagged shrimp.

hand columns of table 9 are derived from the K and L_1 of each time interval, from

$$K_r = K_{r'}^{\left(\frac{r}{r'}\right)}$$

where "r" and "r'" are any given intervals of time. The K_r (K for r days) is equivalent to the $K_{r'}$, which refers to a K for r' days. The values for $L_{1,10}$ are derived for each line from

$$L_{1,10}=L_{\infty}(1-K_{10})$$

This relation follows from the original growth-type expression, as does the relation between the value of K for different time intervals given above.

DISCUSSION

Releases in the Northern Gulf of Mexico west of the Mississippi Delta were made only during winter, but some of these shrimp were recovered well into spring. Judging from figure 5, these shrimp grew very slowly until about the end of March, and rapidly thereafter. In table 9 the returns were treated as having been released on March 31, an arbitrarily chosen date. To the degree that these shrimp had grown before that date, the K_{10} and $L_{1,10}$ given for this region are too low and too high, respectively. A somewhat different method of estimating $L_{1,10}$ given by Lindner (1953) yields the following:

Number of days between release and recovery	*Male (length in cm.)*	*Female (length in cm.)*
0–9	3. 20	1. 88
10–19	3. 24	4. 80
20–29	. 42	4. 52
30–39	5. 94	2. 86
40–49	-------------	1. 40
50–59		

376049 O—56——2

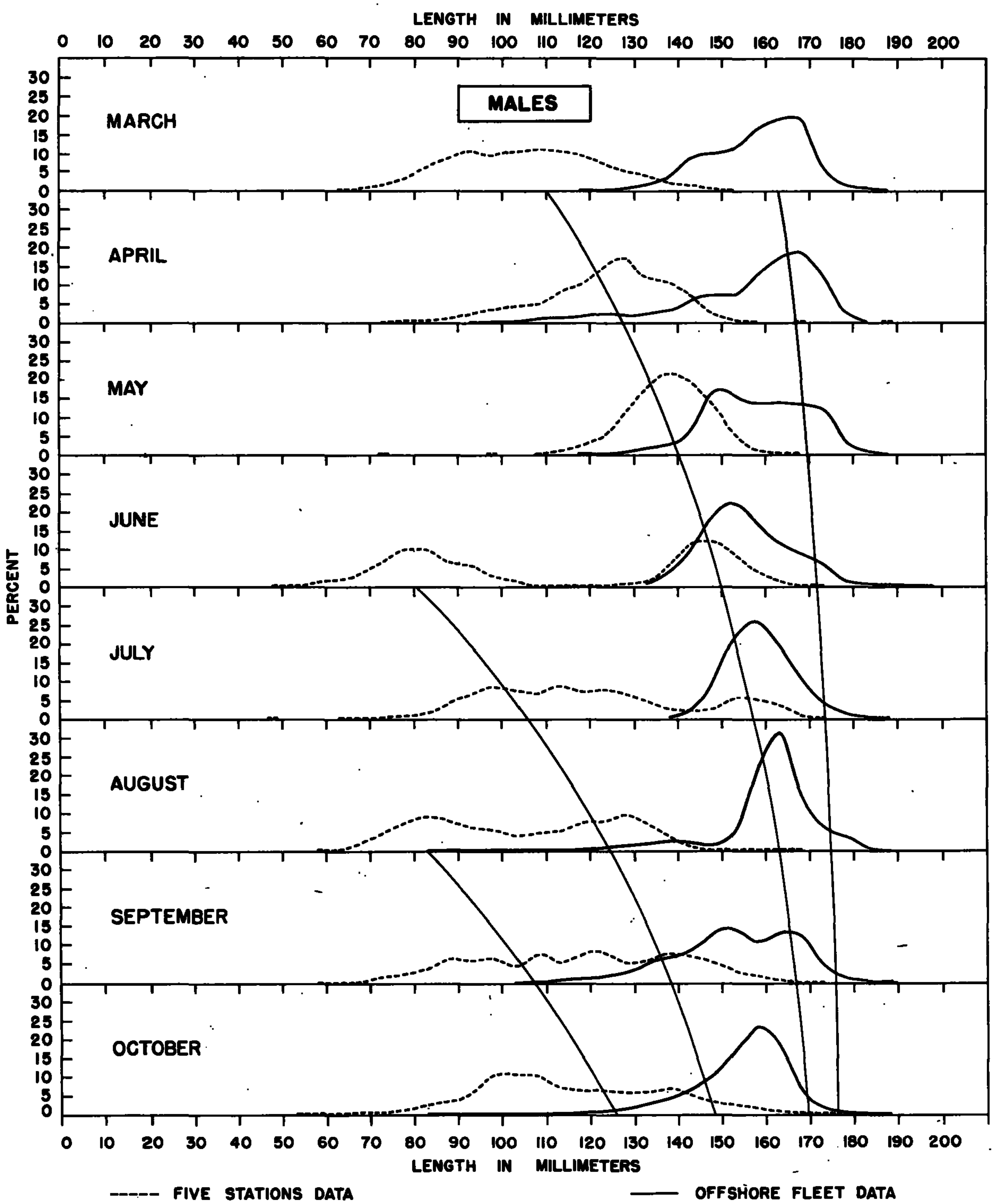

FIGURE 8.—Growth lines applied to Louisiana size distributions for males.

While this treatment does not give biased $L_{1,10}$'s, its results are not as precise as the method used for the other regions. The parameters are not estimated independently of each other, which results in more dispersion in these estimates than in those from data whose time of release occurred during a more uniform growing season. By March 31, these shrimp had grown an average of about one-half centimeter. Lines fitted to the length measurements of these shrimp as they were recovered between March 26 and April 5, irrespective of the time interval out, yielded an L_1 of 1.47, and a K of 0.923. These 61 shrimp were released between October 27 and March 6. Rather than try the several possible ways of correcting these measurements to obtain data comparable to those from other times and areas, the 281 recoveries from west of the Mississippi were not used in describing growth during spring.

The data concerning the release dates of the experiments from which shrimp were taken for determining growth are shown in table 7, while the lengths at release and recovery of all shrimp used for this purpose are presented in table 8.

TABLE 8.—*Lengths of shrimp at tagging and at recovery*

MALES—ATLANTIC COAST—SPRING

0-9 days out			10-19 days out			20-29 days out			30-39 days out		
Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens
Cm.	*Cm.*		*Cm.*	*Cm.*		*Cm.*	*Cm.*		*Cm.*	*Cm.*	
11.0	11.0	2	11.0	11.5	1	10.5	12.5	1	11.5	13.5	1
11.5	12.5	1	11.0	12.0	4	11.5	13.0	2	12.0	13.5	2
12.0	11.5	1	11.5	12.0	4	11.5	13.5	1	12.0	14.0	1
12.0	12.0	1	12.0	12.0	1	11.5	14.0	1	12.0	15.0	1
12.0	12.5	2	12.0	12.5	2	12.0	13.5	3	12.5	13.0	1
12.0	13.0	2	12.0	13.0	4	12.5	13.5	2	12.5	14.0	1
12.5	12.5	3	12.0	13.5	1	12.5	14.0	1	12.5	14.5	1
12.5	13.0	2	12.5	12.5	5	13.0	13.5	3	13.5	14.5	1
13.0	13.0	2	12.5	13.0	2	13.0	14.5	1	14.0	14.5	1
13.0	13.5	1	12.5	13.5	2	13.0	15.0	1	14.5	15.5	1
13.5	13.5	4	12.5	14.5	1	13.5	14.5	5	15.0	15.0	1
13.5	14.0	4	13.5	13.5	3	13.5	15.5	1	16.0	16.5	1
13.5	14.5	1	13.5	14.0	2	14.0	14.5	4			
14.0	13.5	1	13.5	14.5	1	14.0	15.0	3			
14.0	14.0	5	14.0	14.0	1	14.0	15.5	1			
14.0	14.5	3	14.0	14.5	1	14.5	15.0	1			
14.5	14.0	2	14.5	14.0	1	15.0	15.0	2			
14.5	14.5	3	14.5	14.5	2	15.0	15.5	1			
14.5	15.0	2	14.5	15.0	1	15.5	15.0	1			
15.0	14.5	4	15.0	14.5	1	15.5	15.5	1			
15.0	15.0	6	15.0	15.0	1						
15.0	15.5	1	15.5	15.5	4						
15.5	15.0	3									
15.5	15.5	2									
798.5	804.5	58	581.0	601.0	45	478.5	515.0	36	170.0	187.0	13

FEMALES—ATLANTIC COAST—SPRING

0-9 days out			10-19 days out			20-29 days out			30-39 days out		
Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens
11.0	12.0	1	10.0	10.5	1	11.0	12.5	1	11.0	11.0	1
11.5	12.5	1	10.5	11.0	1	11.5	12.5	1	11.5	13.0	1
12.0	12.0	1	11.0	11.0	1	12.0	14.0	3	11.5	14.5	1
12.0	12.5	5	11.5	11.5	1	12.0	15.5	1	11.5	15.0	1
12.5	12.5	1	11.5	12.0	5	12.5	14.5	1	12.0	13.5	1
12.5	13.5	1	11.5	12.5	2	14.5	15.0	1	12.0	14.0	1
13.0	13.0	1	11.5	13.5	1	14.5	16.0	1	12.0	14.5	1
13.0	13.5	1	12.0	12.0	1	14.5	16.5	1	12.0	15.0	1
14.0	14.0	2	12.0	12.5	3	15.0	15.5	1	12.5	15.5	1
14.0	14.5	2	12.0	13.0	3	15.0	16.0	2	13.0	16.0	1
14.0	15.0	1	12.5	12.5	1	16.0	16.5	2	14.0	16.0	1
14.5	14.0	1	12.5	13.0	2						
14.5	14.5	3	12.5	13.5	3						
15.0	14.5	1	12.5	14.0	1						
15.0	15.0	5	13.0	13.0	1						
15.0	15.5	2	13.0	13.5	2						
15.5	15.0	1	13.0	14.0	1						
15.5	15.5	3	13.5	13.5	2						
16.0	16.0	2	14.5	15.0	1						
16.5	16.0	1	14.5	15.5	1						
16.5	16.5	3	15.0	15.0	1						
			15.0	15.5	1						
			15.0	16.0	1						
			15.5	16.5	2						
			16.0	15.5	1						
			17.0	17.0	1						
553.5	560.5	39	523.5	546.5	41	203.5	225.0	15	133.0	158.0	11

Note that the L_∞'s in table 9 are often less than 15 cm. This implies that these tagged shrimp would reach an average maximum length of less than that figure during the course of their life. This may be true, but shrimp of 17.5 cm. were tagged, and lengths up to 20 cm. are not rare in the samples of the commercial catch. It is our opinion that the length-at-recovery measurements are too small. When the tagged shrimp were released only a few days before recovery, some would be recorded as having shrunk. This was particularly true for the large shrimp, whose growth rate is always less than that of the small ones. On preservation in formalin, the tendency of the fleshy part of the shrimp (the tails) to curl under and become stiff, we believe, results in underestimates of their actual length at recovery while alive. Moreover, one effect of tagging shrimp may be to cause them to shrink in length at their next molt. Very few tagged shrimp have been held long enough to molt, and those that did were apparently eaten by others while in the soft condition. The question of shrinkage remains in doubt, but we believe the growth rate of the tagged shrimp as reported here to be minimal in comparison with that of the untagged animals.

TABLE 8.—*Lengths of shrimp at tagging and at recovery*—Continued

MALES—ATLANTIC COAST—SUMMER AND FALL

0-9 days out			10-19 days out			20-29 days out			30-39 days out			40-49 days out		
Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens
Cm.	*Cm.*		*Cm.*	*Cm.*		*Cm.*	*Cm.*		*Cm.*	*Cm.*		*Cm.*	*Cm.*	
10.0	10.0	2	9.5	9.5	1	10.0	11.0	1	9.5	11.0	1	9.0	12.0	1
10.5	10.5	8	9.5	10.0	1	10.5	11.5	1	10.0	11.0	1	10.0	12.5	1
11.0	11.0	9	10.0	11.0	1	11.5	12.5	1	10.0	11.5	1	10.5	12.0	1
11.0	11.5	5	10.5	10.5	1	12.0	12.5	1	10.0	12.5	1	10.5	13.0	1
11.0	12.0	1	10.5	11.0	1	12.0	13.5	1	10.5	12.0	1	11.0	13.0	1
11.5	11.5	14	10.5	12.0	1	12.5	13.0	1	10.5	12.5	1	11.5	13.0	1
11.5	12.0	4	11.0	11.0	2	12.5	13.5	3	10.5	13.0	1	11.5	13.5	1
11.5	12.5	2	11.0	11.5	3	12.5	14.0	1	11.0	12.0	1	11.5	14.0	1
12.0	11.5	2	11.0	12.0	1	13.0	13.0	1	11.0	12.5	1	12.0	13.5	1
12.0	12.0	13	11.0	12.5	1	13.0	13.5	2	11.0	13.0	1	12.0	14.5	2
12.0	12.5	11	11.5	12.0	3	13.5	13.5	1	11.5	13.5	1	12.5	14.5	1
12.0	13.0	1	11.5	12.5	1	13.5	14.0	2	12.0	13.5	1	14.0	15.5	1
12.5	12.5	9	12.0	12.0	1	13.5	14.5	2	12.5	14.0	1	14.5	15.5	1
12.5	13.0	7	12.0	12.5	3	14.0	14.5	1	13.0	14.0	1			
12.5	13.5	1	12.0	13.5	2	14.0	15.0	1	13.5	13.5	2			
13.0	13.0	14	12.5	12.5	1	14.5	14.5	1	14.0	15.0	1			
13.0	13.5	4	12.5	13.0	6	14.5	15.0	1	14.5	15.5	2			
13.0	14.0	1	12.5	13.5	1	14.5	15.5	1						
13.5	13.0	1	12.5	14.0	1	15.0	15.0	2						
13.5	13.5	8	13.0	13.0	2	15.0	15.5	3						
13.5	14.0	6	13.0	13.5	4	15.5	15.5	1						
13.5	14.5	1	13.5	13.5	2									
14.0	14.0	8	13.5	14.0	6									
14.0	14.5	3	14.0	14.0	3									
14.0	15.0	1	14.0	14.5	3									
14.5	14.0	2	14.0	15.0	1									
14.5	14.5	15	14.5	14.5	4									
14.5	15.0	1	14.5	15.0	5									
15.0	14.5	3	15.0	14.5	1									
15.0	15.0	29	15.0	15.0	7									
15.0	15.5	3	15.0	15.5	6									
15.5	15.0	12	15.5	15.0	5									
15.5	15.5	24	16.5	15.5	5									
15.5	16.0	2	16.0	16.0	4									
16.0	15.5	2												
16.0	16.0	9												
16.0	16.5	4												
3,281.5	3,303.5	242	1,211.5	1,241.5	102	387.0	405.5	29	223.0	249.0	19	162.5	191.0	14

TABLE 8.—*Lengths of shrimp at tagging and at recovery*—Continued

FEMALES—ATLANTIC COAST—SUMMER AND FALL

0-9 days out			10-19 days out			20-29 days out			30-39 days out			40-49 days out		
Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens
Cm.	*Cm.*		*Cm.*	*Cm.*		*Cm.*	*Cm.*		*Cm.*	*Cm.*		*Cm.*	*Cm.*	
10.5	10.0	1	10.0	11.5	2	10.5	11.5	1	11.0	12.0	2	10.0	12.5	1
10.5	10.5	3	10.0	11.0	1	11.5	11.5	1	11.0	12.5	1	10.5	12.5	2
10.5	11.0	2	10.5	11.0	4	11.5	12.0	1	11.0	13.5	1	11.0	13.0	1
11.0	10.5	1	10.5	11.5	1	12.0	12.5	2	11.5	13.0	1	11.5	15.0	1
11.0	11.0	4	10.5	12.0	1	12.0	13.0	3	12.0	14.0	1	12.5	14.5	1
11.0	11.5	2	11.0	11.0	2	12.0	13.5	2	12.5	13.0	1	13.0	14.5	1
11.0	12.0	1	11.0	11.5	5	12.5	12.5	1	12.5	14.0	4	14.0	15.5	1
11.5	11.0	3	11.0	12.0	1	12.5	13.5	2	12.5	15.0	1	15.0	16.0	1
11.5	11.5	6	11.5	11.5	7	12.5	14.0	1	13.0	14.0	3	15.5	16.5	1
11.5	12.0	4	11.5	12.0	7	13.0	13.5	1	13.0	14.5	1			
12.0	11.5	2	11.5	12.5	2	13.5	13.5	1	14.0	15.5	2			
12.0	12.0	7	11.5	13.0	1	13.5	14.0	1	15.0	16.0	1			
12.0	12.5	3	12.0	11.5	1	13.5	14.5	1	16.5	17.0	1			
12.0	13.0	1	12.0	12.0	5	14.0	14.5	1						
12.5	12.0	4	12.0	12.5	7	14.0	15.5	1						
12.5	12.5	6	12.0	13.0	1	15.0	15.0	1						
12.5	13.0	6	12.0	13.5	1	15.0	15.5	2						
13.0	13.0	7	12.5	12.0	1	15.5	15.5	1						
13.0	13.5	3	12.5	12.5	8									
13.5	13.0	4	12.5	13.0	10									
13.5	13.5	6	12.5	13.5	3									
13.5	14.0	1	13.0	12.5	1									
14.0	14.0	5	13.0	13.0	3									
14.0	14.5	2	13.0	13.5	17									
14.5	14.0	1	13.0	14.0	1									
14.5	14.5	5	13.5	13.5	5									
15.0	15.0	2	13.5	14.0	10									
15.0	15.5	1	13.5	14.5	3									
15.5	15.5	5	14.0	13.5	1									
16.0	16.0	1	14.0	14.0	3									
16.0	16.5	3	14.0	14.5	7									
16.5	16.0	2	14.5	14.5	8									
16.5	16.5	3	14.5	15.0	5									
17.0	16.5	2	15.0	14.5	1									
17.0	17.0	4	15.0	15.0	2									
			15.0	15.5	2									
			15.5	15.5	3									
			15.5	16.0	2									
			16.0	16.0	2									
			16.0	16.5	2									
			16.5	16.0	1									
			16.5	16.5	2									
			16.5	17.0	1									
			17.0	17.0	3									
			17.0	17.5	2									
			17.5	17.5	1									
1,491.0	1,496.0	113	2,088.0	2,144.0	159	309.5	326.5	24	254.0	281.5	20	123.5	143.5	10

FEMALES—WEST OF MISSISSIPPI RIVER—SPRING

0-9 days out			10-19 days out			20-29 days out			30-39 days out			40-49 days out			50-59 days out		
Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens
Cm.	*Cm.*		*Cm.*	*Cm.*		*Cm.*	*Cm.*		*Cm.*	*Cm.*		*Cm.*	*Cm.*		*Cm.*	*Cm.*	
12.0	12.0	1	10.5	11.0	1	11.5	14.0	1	11.5	14.5	1	12.5	15.5	2	11.0	15.5	1
12.0	12.5	2	12.0	12.5	1	11.5	15.5	1	12.5	15.5	2	12.5	16.0	2	11.5	16.0	1
12.0	13.0	1	12.0	14.5	1	12.0	14.0	1	12.5	16.5	1	13.0	16.0	2	11.5	16.5	1
12.5	13.0	2	12.5	14.0	1	12.5	13.5	1	13.0	15.0	2	13.0	16.5	1	12.0	15.5	1
13.0	13.0	1	13.5	14.5	1	12.5	14.5	1	13.0	15.5	1	13.5	15.5	1	12.0	16.0	1
13.0	13.5	1	15.0	15.5	1	13.5	15.0	1	13.0	16.0	1	14.5	15.5	1	12.5	16.0	1
13.5	13.5	1	16.5	16.5	1	13.5	15.5	1	13.5	15.5	1	14.5	16.0	1	13.0	15.0	1
13.5	14.0	1	16.5	17.0	3	13.5	16.0	1	13.5	16.5	1	15.0	15.5	1	13.0	16.0	1
13.5	14.5	1				14.5	16.0	2	14.0	15.5	1	15.5	16.0	1	13.5	16.0	1
14.0	14.5	1				14.5	16.5	3	14.0	16.0	1	15.5	17.0	1	14.0	16.0	1
14.5	14.5	2				14.5	17.0	1	14.5	16.5	1	15.5	17.5	1	14.0	16.5	1
14.5	15.0	1				15.0	16.0	2	15.0	15.5	1	16.0	17.0	4	14.5	16.5	1
15.0	15.5	3				15.0	16.5	2	15.0	16.0	1	16.0	17.5	1	14.5	17.0	1
15.5	15.5	4				15.0	17.0	1	15.0	17.0	2	16.5	17.0	1	14.5	18.0	1
15.5	16.0	1				15.5	16.5	2	15.5	16.0	1	17.0	17.5	2	15.0	16.0	1
15.5	16.5	1				16.0	16.5	1	15.5	16.5	1				15.0	16.5	1
16.0	16.0	3				16.5	16.5	1	15.5	17.0	1				16.0	16.5	2
16.0	16.5	2				16.5	17.5	5	16.0	16.5	1				16.5	18.0	1
16.0	17.0	1				17.0	17.0	1	17.0	17.5	1				16.5	18.5	1
16.5	16.5	1				17.0	17.5	1	17.0	18.0	1				17.0	17.5	1
16.5	17.0	2				17.0	18.0	2									
17.0	17.0	3				17.5	17.5	1									
17.0	17.5	1				17.5	18.0	1									
17.5	17.5	2															
583.5	596.0	39	141.5	149.5	10	511.5	558.0	34	327.0	370.5	23	323.5	362.0	22	493.5	346.0	21

TABLE 8.—*Lengths of shrimp at tagging and at recovery*—Continued

MALES—WEST OF MISSISSIPPI RIVER—SPRING

0-9 days out			10-19 days out			20-29 days out			30-39 days out			40-49 days out		
Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens
Cm.	*Cm.*		*Cm.*	*Cm.*		*Cm.*	*Cm.*		*Cm.*	*Cm.*		*Cm.*	*Cm.*	
10.5	11.0	1	11.0	13.0	1	10.5	12.0	1	12.5	14.0	1	12.0	15.0	1
11.5	12.5	1	12.0	14.0	1	11.0	14.0	1	12.5	14.5	3	12.0	15.5	1
11.5	13.0	1	12.5	13.5	1	13.0	15.0	1	13.5	15.0	2	13.0	15.0	1
12.0	11.5	1	14.0	14.0	1	13.5	15.5	2	13.5	15.5	1	13.5	15.5	1
12.0	12.5	2	15.0	15.5	1	14.0	15.0	1	14.0	15.5	1	14.5	16.0	1
12.5	13.0	2	15.5	16.0	1	14.0	15.5	1	14.5	15.5	2	15.0	16.0	1
13.5	13.5	2	16.0	16.5	1	14.5	15.0	1	14.5	16.0	1	15.0	17.0	1
13.5	14.0	1	16.0	17.0	1	14.5	16.0	3	15.0	15.5	2	15.5	16.0	1
13.5	14.5	1	16.5	16.5	1	15.0	15.0	1	15.0	16.5	1	15.5	16.5	2
14.0	14.0	1	17.0	17.5	1	15.0	16.0	1	15.5	16.0	2	16.0	16.0	2
14.5	14.5	5				15.0	16.5	1	15.5	16.5	2	16.0	16.5	4
15.0	14.5	2				15.5	15.5	2	15.5	17.0	1	16.5	16.5	1
15.0	15.0	3				15.5	16.0	3	16.0	16.5	1	16.5	17.0	2
15.5	15.5	1				15.5	16.5	2	16.0	17.0	1	17.0	17.0	3
15.5	16.0	2				16.0	16.5	4	16.5	16.0	1	17.0	17.5	1
16.0	16.0	1				16.5	16.0	1	16.5	16.5	3			
16.0	16.5	2				16.5	16.5	1	16.5	17.0	3			
16.0	17.0	1				16.5	17.0	3	17.0	17.0	1			
16.5	16.0	1				17.0	17.0	1						
16.5	16.5	4												
16.5	17.0	1												
17.0	17.0	2												
17.5	17.5	1												
18.0	17.5	1												
588.0	596.5	40	145.5	153.5	10	464.5	491.5	31	435.0	462.0	29	355.0	376.0	23

FEMALES—EAST OF MISSISSIPPI RIVER—SUMMER AND FALL

0-9 days out			10-19 days out			20-29 days out			30-39 days out		
Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens
Cm.	*Cm.*		*Cm.*	*Cm.*		*Cm.*	*Cm.*		*Cm.*	*Cm.*	
8.5	9.0	1	10.0	11.5	1	11.0	13.0	1	11.0	13.5	1
10.0	10.0	1	10.5	11.0	1	11.5	12.5	3	11.5	13.5	3
10.5	11.0	1	11.5	12.5	1	11.5	13.0	2	12.0	13.0	1
11.0	11.0	2	12.0	12.0	2	12.0	12.0	1	12.5	13.5	1
11.0	11.5	2	12.0	12.5	4	12.0	13.0	1	12.5	14.0	1
11.5	11.0	2	12.0	13.0	3	12.0	13.5	1	13.0	14.0	1
11.5	11.5	5	12.0	13.5	1	13.0	14.5	1	13.5	15.0	1
11.5	12.0	3	12.5	12.5	6	13.5	14.0	2	14.0	15.5	1
11.5	12.5	1	12.5	13.5	1	13.5	15.0	1	14.5	15.5	1
12.0	12.0	11	13.0	13.0	3	14.0	14.5	3	15.0	16.0	2
12.0	12.5	4	13.0	13.5	2	15.5	16.0	1	15.5	16.0	1
12.5	12.0	1	13.0	14.0	1				15.5	16.5	2
12.5	12.5	17	13.5	13.5	1				15.5	17.0	1
12.5	13.0	7	13.5	14.0	4						
13.0	12.0	1	14.0	13.5	1						
13.0	12.5	2	14.0	14.0	4						
13.0	13.0	11	14.0	14.5	1						
13.0	13.5	8	14.5	14.5	3						
13.0	14.0	1	14.5	15.0	3						
13.5	13.0	2	14.5	15.5	1						
13.5	13.5	18	15.0	15.0	4						
13.5	14.0	8	15.0	15.5	2						
14.0	14.0	12	15.5	15.5	3						
14.0	14.5	2	15.5	16.0	1						
14.5	14.0	2	16.0	16.0	3						
14.5	14.5	10	16.5	16.5	2						
14.5	15.0	9									
15.0	15.0	11									
15.0	15.5	3									
15.5	15.0	2									
15.5	15.5	19									
15.5	16.0	4									
16.0	15.5	2									
16.0	16.0	11									
16.5	16.0	3									
16.5	16.5	7									
16.5	17.0	4									
17.0	16.5	1									
17.0	17.0	4									
17.0	17.5	1									
17.5	17.5	1									
3,025.5	3,046.5	217	803.5	822.0	59	215.5	232.0	17	275.5	252.5	17

TABLE 8.—*Lengths of shrimp at tagging and at recovery*—Continued

MALES—EAST OF MISSISSIPPI RIVER—SUMMER AND FALL

0-9 days out			10-19 days out			20-29 days out			30-39 days out		
Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens
Cm.	*Cm.*		*Cm.*	*Cm.*		*Cm.*	*Cm.*		*Cm.*	*Cm.*	
8.5	8.5	2	10.0	10.0	1	10.0	11.5	1	10.5	12.0	1
9.5	9.5	1	10.0	10.5	1	11.5	12.0	1	11.0	13.5	1
10.0	10.0	1	10.5	11.0	1	12.0	12.5	3	11.5	12.0	1
10.5	10.5	3	11.0	11.5	1	12.0	13.0	2	11.5	13.0	1
11.0	10.5	1	11.5	12.0	1	12.0	13.5	1	11.5	13.5	1
11.0	11.0	2	11.5	12.5	2	12.5	13.5	2	12.0	12.5	1
11.0	11.5	1	12.0	12.5	2	13.0	13.0	1	12.0	13.0	1
11.5	11.5	4	12.0	13.0	3	13.0	13.5	1	12.0	13.5	1
11.5	12.0	1	12.0	13.5	1	13.5	13.5	1	12.5	13.0	1
11.5	12.5	1	12.5	12.5	7				12.5	13.5	1
12.0	12.0	6	12.5	13.0	4				13.0	15.5	1
12.0	12.5	7	13.0	13.0	2				13.5	15.0	1
12.5	12.5	25	13.0	13.5	3				14.5	15.0	1
12.5	13.0	5	13.5	13.0	1				14.5	16.0	1
12.5	13.5	2	13.5	13.5	1				15.0	15.5	1
13.0	12.5	2	13.5	14.0	5				15.5	16.0	2
13.0	13.0	24	13.5	15.0	1				15.5	16.5	1
13.0	13.5	5	14.0	13.0	1						
13.5	13.5	18	14.0	14.5	3						
13.5	14.0	3	14.5	14.5	4						
13.5	14.5	2	14.5	15.0	2						
14.0	13.5	2	15.0	15.5	4						
14.0	14.0	10	15.0	16.0	1						
14.0	14.5	8	15.5	15.5	1						
14.0	15.0	2	15.5	16.0	1						
14.5	14.5	11	16.0	16.0	1						
14.5	15.0	2	16.0	16.5	1						
15.0	14.0	1	16.5	16.5	1						
15.0	14.5	2	17.0	16.5	1						
15.0	15.0	11									
15.0	15.5	6									
15.0	16.0	1									
15.5	15.0	1									
15.5	15.5	12									
16.0	15.0	3									
16.0	16.0	2									
16.0	16.5	1									
16.5	16.0	1									
16.5	16.5	3									
2,625.5	2,646.0	195	773.0	794.5	58	158.0	167.5	13	234.0	255.0	18

FEMALES—TEXAS—SUMMER AND FALL

0-9 days out			10-19 days out			20-29 days out			0-9 days out			10-19 days out			20-29 days out		
Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens	Tagging length	Recovery length	Number of specimens
Cm.	*Cm.*		*Cm.*	*Cm.*		*Cm.*	*Cm.*		*Cm.*	*Cm.*		*Cm.*	*Cm.*		*Cm.*	*Cm.*	
10.5	10.0	1	11.0	11.5	1	11.5	12.0	1	13.5	14.0	2	15.0	14.5	1			
10.5	10.5	1	11.0	12.0	1	11.5	12.5	1	13.5	14.5	1	15.0	15.0	1			
10.5	11.0	1	11.5	11.5	3	11.5	13.0	2	14.0	13.5	1	15.5	15.0	1			
11.0	10.5	1	11.5	12.0	1	12.0	12.5	1	14.0	14.0	4	15.5	15.5	2			
11.0	11.0	2	11.5	12.5	1	12.0	13.0	3	14.0	14.5	1						
11.0	11.5	3	12.0	12.5	1	12.0	13.5	2	14.5	14.0	2						
11.5	11.5	6	12.0	13.0	1	12.5	13.5	3	14.5	14.5	4						
11.5	12.0	1	12.5	12.5	1	13.5	14.0	1	15.0	14.5	1						
12.0	11.5	2	12.5	13.0	1	14.0	14.5	2	15.0	15.0	8						
12.0	12.0	9	12.5	13.5	1	14.0	15.0	1	15.5	15.0	2						
12.0	12.5	2	13.0	13.0	2	15.0	16.0	1	15.5	15.5	3						
12.5	12.0	1	13.0	13.5	2	16.0	16.0	1	16.0	16.0	1						
12.5	12.5	5	13.0	14.0	1	16.5	16.5	1	16.5	16.0	1						
12.5	13.0	3	13.5	13.5	1	18.0	18.0	1	16.5	16.5	2						
13.0	12.5	2	13.5	14.0	3				16.5	17.0	1						
13.0	13.0	3	14.0	14.5	1				17.5	17.5	1						
13.0	13.5	1	14.0	15.0	2												
13.5	13.0	3	14.5	14.5	1												
13.5	13.5	2	14.5	15.5	2				1,115.5	1,115.5	84	422.0	435.0	32	276.5	294.0	21

MALES—TEXAS—SUMMER AND FALL

10.0	9.5	1	10.5	11.5	1	11.5	12.0	1	13.0	13.0	4	15.5	16.0	1			
10.0	10.0	1	11.5	11.0	1	12.5	13.0	1	13.5	13.0	2						
10.0	10.5	1	11.5	12.0	1	12.5	13.5	1	13.5	13.5	3						
10.5	10.0	1	11.5	12.5	1	12.5	14.0	1	13.5	14.0	2						
10.5	10.5	3	12.0	12.5	5	13.0	14.0	1	14.0	13.5	2						
11.0	10.5	1	12.0	13.0	1	13.5	14.0	1	14.0	14.0	7						
11.0	11.0	3	12.5	12.5	3	14.5	15.0	4	14.5	14.0	1						
11.5	11.0	1	12.5	13.0	1	15.0	15.5	2	14.5	14.5	3						
11.5	11.5	6	12.5	13.5	2	16.0	15.5	1	15.0	14.5	1						
11.5	12.0	1	13.0	13.0	1	16.0	16.0	1	15.5	15.0	1						
11.5	12.5	1	13.0	13.5	1				15.5	15.5	1						
12.0	12.0	5	13.5	13.5	3				15.5	16.0	1						
12.0	12.5	2	13.5	14.0	3				16.0	15.5	1						
12.5	12.0	2	13.5	14.5	1				16.0	16.0	2						
12.5	12.5	4	14.0	14.5	2												
12.5	13.0	2	14.5	14.5	1												
13.0	12.5	2	15.0	15.0	2				869.5	867.0	68	400.5	413.0	31	195.5	203.0	14

TABLE 9.—*Growth characteristics derived from tagged shrimp: single experiments*

Time out (in days)	L_1	K	L_∞	K_{10}	$L_{1,10}$	n
MALES						
Atlantic coast:						
Spring:	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	
0–9	2.25	0.8440	14.40	0.686	4.52	58
10–19	3.30	.7788	14.90	.842	2.36	45
20–29	6.78	.5661	15.65	.792	3.26	36
30–39	7.06	.5599	16.05	.845	2.49	13
Total			61.00	3.165	12.62	152
Mean			15.25	.791	3.16	
Summer and fall:						
0–9	.85	.9437	15.2	.874	1.91	242
10–19	2.19	.8623	15.9	.903	1.54	90
20–29	3.04	.8202	16.9	.922	1.32	29
30–39	4.39	.7427	17.0	.806	3.31	19
40–49	5.11	.7352	19.3	.933	1.29	14
Total			84.3	4.438	9.38	394
Mean			16.8	.888	1.88	
East Mississippi: Summer and fall:						
0–9	.47	.9728	17.4	.940	1.04	195
10–19	1.40	.9224	18.1	.946	.98	58
20–29	5.22	.6304	14.1	.828	2.42	13
30–39	3.54	.8177	19.4	.943	1.10	18
Total			69.0	3.657	5.54	284
Mean			17.2	.914	1.38	
Texas: Summer and fall:						
0–9	.36	.9693	11.6	.933	.78	68
10–19	1.76	.8954	16.8	.926	1.24	31
20–29	3.71	.7728	16.4	.900	1.64	14
Total			44.8	2.759	3.66	113
Mean			14.9	.920	1.22	
West of river: Spring: [1]						
0–9	1.90	.8853	16.9	.762	4.02	40
10–19	4.62	.7379	17.6	.811	3.32	10
20–29	6.99	.5917	16.1	.807	3.30	31
30–39	7.37	.5708	17.2	.850	2.58	29
40–49	10.44	.3831	16.9	.805	3.30	23
Total			85.6	4.035	16.52	133
Mean			17.2	.807	3.30	
FEMALES						
Atlantic coast: Spring:						
0–9	2.54	.8337	15.2	.667	5.08	39
10–19	1.60	.9187	19.7	.943	1.12	41
20–29	5.64	.6893	18.2	.859	2.06	15
30–39	−1.62	[2] 1.3224	0			11
Total			53.1	2.469	8.76	106
Mean			17.7	.823	2.92	
Summer and fall:						
0–9	.38	.9745	15.0	.944	.84	113
10–19	1.26	.9305	18.2	.952	.88	159
20–29	2.50	.8612	18.0	.941	1.06	24
30–39	3.34	.8454	21.6	.952	1.04	20
40–49	4.20	.8216	23.6	.957	1.02	10
Total			96.3	4.746	4.82	326
Mean			19.2	.949	.96	
East Mississippi: Summer and fall:						
0–9	.55	.9677	17.0	.929	1.21	217
10–19	2.14	.8660	16.0	.906	1.50	59
20–29	3.92	.7673	16.8	.898	1.72	17
30–39	4.39	.7753	19.6	.929	1.39	17
Total			69.4	3.662	5.82	310
Mean			17.4	.916	1.46	
Texas: Summer and fall:						
0–9	.44	.9669	13.3	.927	.97	84
10–19	1.75	.8981	17.2	.928	1.24	32
20–29	3.58	.7910	17.2	.908	1.58	21
Total			47.6	2.763	3.78	137
Mean			15.8	.921	1.26	

TABLE 9.—*Growth characteristics derived from tagged shrimp: single experiments*—Continued

Time out (in days)	L_1	K	L_∞	K_{10}	$L_{1,10}$	n
West of river (not corrected): Spring: [1]	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*
0–9	1.26	.9371	20.0	.865	2.70	39
10–19	2.97	.8465	19.4	.892	2.09	10
20–29	7.18	.6130	18.6	.819	3.36	34
30–39	10.10	.4230	17.5	.779	3.87	23
40–49	11.10	.3644	17.4	.796	3.56	22
50–59	11.70	.3413	17.8	.821	3.18	21
Total			110.6	4.972	18.76	149
Mean			18.4	.829	3.12	

[1] Shrimp from this locality, although tagged at various times during the winter, were treated as if released on March 31, the approximate date of resumption of growth in the spring.

[2] One shrimp, 11.5 cm when tagged, was recorded as having not grown in more than 30 days out.

RESULTS

The data from which table 9 was prepared have been pooled, and the results of the growth description of all of these animals, 1,822 individuals, are contained in table 10. The data from west of the Mississippi have been omitted, for reasons previously given. The K_{10} and $L_{1,10}$ from the several regions and from the different "time-out" intervals are quite similar. Variances of the several individual parameter estimates were not computed, but in combining the several K_{10}, $L_{1,10}$, and L_∞'s, two schemes of weighting were employed: (1) The several parameter estimates were given equal weight for each "time-out" period, and (2) they were weighted according to the square root of the size of the sample from which they came. The latter procedure is equivalent to weighting inversely as their standard errors, if the standard deviation of their original distributions in the regressions were all equal. Since there was little difference among the several parameters, these two schemes of weighting produce very similar averages. For convenience in comparing monthly modes in the length frequency distribution with the growth pattern here derived for tagged shrimp, the K_{10} and $L_{1,10}$ were converted to K_{30} and $L_{1,30}$. This is accomplished, as given above, by cubing the K_{10}'s to get K_{30}'s and by using K_{30} and L_∞ to get $L_{1,30}$, as described.

	K_{30}	$L_{1,30}$	L_∞
Females:			
Weighted equally	0.817	3.5	19.0
Weighted to $\sqrt{n}$	.810	3.3	17.6
Males:			
Weighted equally	.761	4.0	17.0
Weighted to $\sqrt{n}$	.756	4.0	16.3

The growth lines shown in figures 8 and 9 were calculated from the formulas: [2]

		L_∞
Males	$Y=4.58+0.7427\ X$,	17.80
Females	$Y=5.64+\ .7225\ X$,	20.30

We chose the initial points to approximate the modes of the distributions. The remaining points were then determined by calculation (table 11).

Judging from the modes, there is some indication that the young shrimp appearing in June increase more rapidly in total length than do those resuming rapid growth at the beginning of March. This difference may well be actual, since the March shrimp are approaching maturity more rapidly than are those which appear in June, and as the shrimp approach maturity various morphological changes occur. The result of one of these changes is that mature shrimp have a shorter rostrum in comparison with immature shrimp of the same total length.

TABLE 10.—*Growth characteristics derived from tagged shrimp: Combined single experiments*

[All localities except West of the Mississippi River and all seasons pooled, sexes separated]

Time out and sex	a	b	L_∞	K_{10}	$L_{1,10}$	$\sqrt{n}$	n
0–9 days:							
Females	0.52	0.967	15.8	0.928	1.1	21.3	453
Males	.58	.963	15.6	.920	1.2	23.7	563
10–19 days:							
Females	1.65	.910	17.4	.937	1.1	17.1	291
Males	2.15	.866	16.0	.905	1.5	15.0	224
20–29 days:							
Females	3.35	.815	18.1	.920	1.4	8.8	77
Males	4.28	.736	16.2	.882	1.9	9.6	92
30–39 days:							
Females	4.23	.793	20.4	.935	1.3	6.9	48
Males	4.30	.759	17.8	.923	1.3	7.1	50
40–49 days:							
Females	4.20	.822	23.5	.957	1.0	3.2	10
Males	5.11	.735	19.3	.933	1.3	3.7	14
Averages:							
Females:							
Unweighted			19.1	.935	1.2		
Weighted			17.6	.932	1.2		
Males:							
Unweighted			17.0	.913	1.4		
Weighted			16.3	.911	1.4		
Totals:							
Females							879
Males							943

Figure 10, showing the 30-day growth line for males and females combined, has been drawn so that the solid part represents the range covered by our data (100 to 180 mm.), and the broken parts are extensions beyond this range. The

[2] These lines, very similar to those represented by the parameter estimates given, were those included in the first draft of this manuscript. Although a reexamination of the original data yielded slightly different results, the original growth lines were not changed. These results are used primarily for checking the advance in length of modes in monthly length frequencies, for which they are adequate, in the opinion of the authors.

TABLE 11.—*Calculated growth of shrimp, derived from single experiment*

Sex and month	Length, in millimeters					
Males:						
March	105.0	110.0	163.0			
April	123.8	127.5	166.9			
May	137.7	140.5	169.8			
June	148.1	150.1	171.9	81.0		
July	155.8	157.3	173.5	106.0	113.0	
August	161.5	162.6	174.7	124.5	129.7	83.0
September	165.7	166.6	175.5	138.3	142.1	107.4
October	168.9	169.5	176.1	148.5	151.3	125.6
Females:						
March	105.0	168.0				
April	132.2	177.7	128.0			
May	151.9	184.7	148.8			
June	166.1	189.8	163.9	78.0		
July	176.4	193.5	174.8	112.7		
August	183.8	196.2	182.6	137.8	83.0	128.0
September	189.1	198.1	188.3	155.9	116.3	148.8
October	193.0	199.5	192.4	169.0	140.4	163.9

equation of this line is noted on the figure. We realize that it is not sound to extend the line to L_o, but we have done so because the growth of the shrimp seems to approximate that represented by this line. In other words, we believe that shrimp reach about 80 mm. in length approximately 2 months after spawning. Perhaps this is fortuitous, since it indicates a growth considerably more rapid than that obtained by Pearson (1939) with shrimp in aquariums. However, his aquarium conditions did not duplicate the natural environment, nor was the food the same as that found naturally.

To use this line we proceed thus: Choose the size of shrimp we wish to follow, say 100 mm., on the X axis and continue vertically until the growth line is intersected. This gives us about 125 mm. Hence, a shrimp 100 mm. long (from tip of rostrum to end of telson) will in 1 month have grown to about 125 mm. Following the same procedure with 125 mm. on the X axis, we find that at the end of 2 months the shrimp will have grown from 100 mm. to about 141 mm. This line, of course, can be used only for the rapid growing season, from about March until the end of October.

MIGRATIONS

In any tagging experiment one must assume, unless there is evidence to the contrary, that the unmarked individuals follow a pattern similar to that of the marked individuals. Since the size distributions (treated in a later section) suggest no difference in the movements of the two groups, and since we have encountered no evidence which would lead us to suspect any abnormal behavior of the tagged shrimp, we make this assumption.

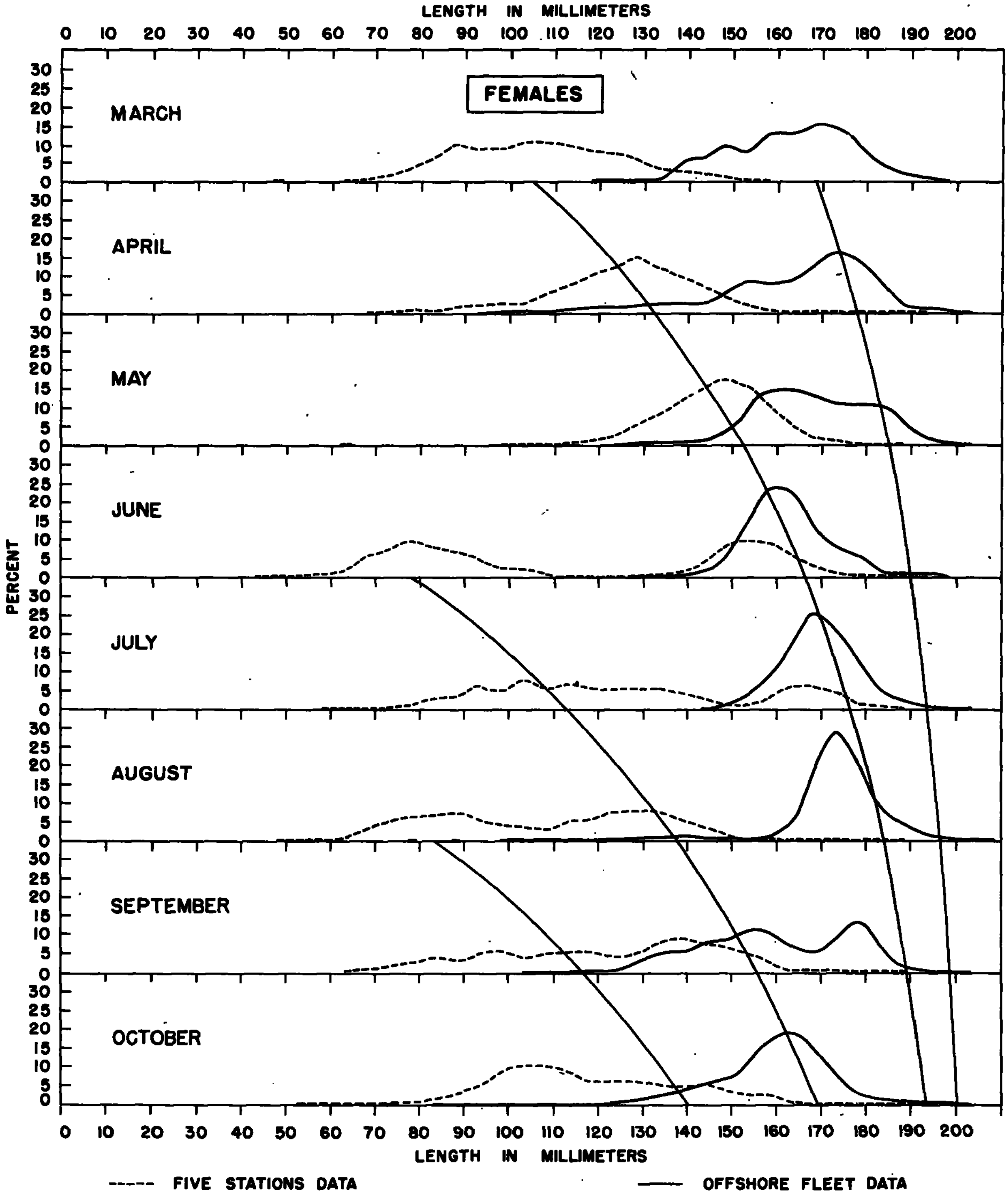

FIGURE 9.—Growth lines applied to Louisiana size distributions for females.

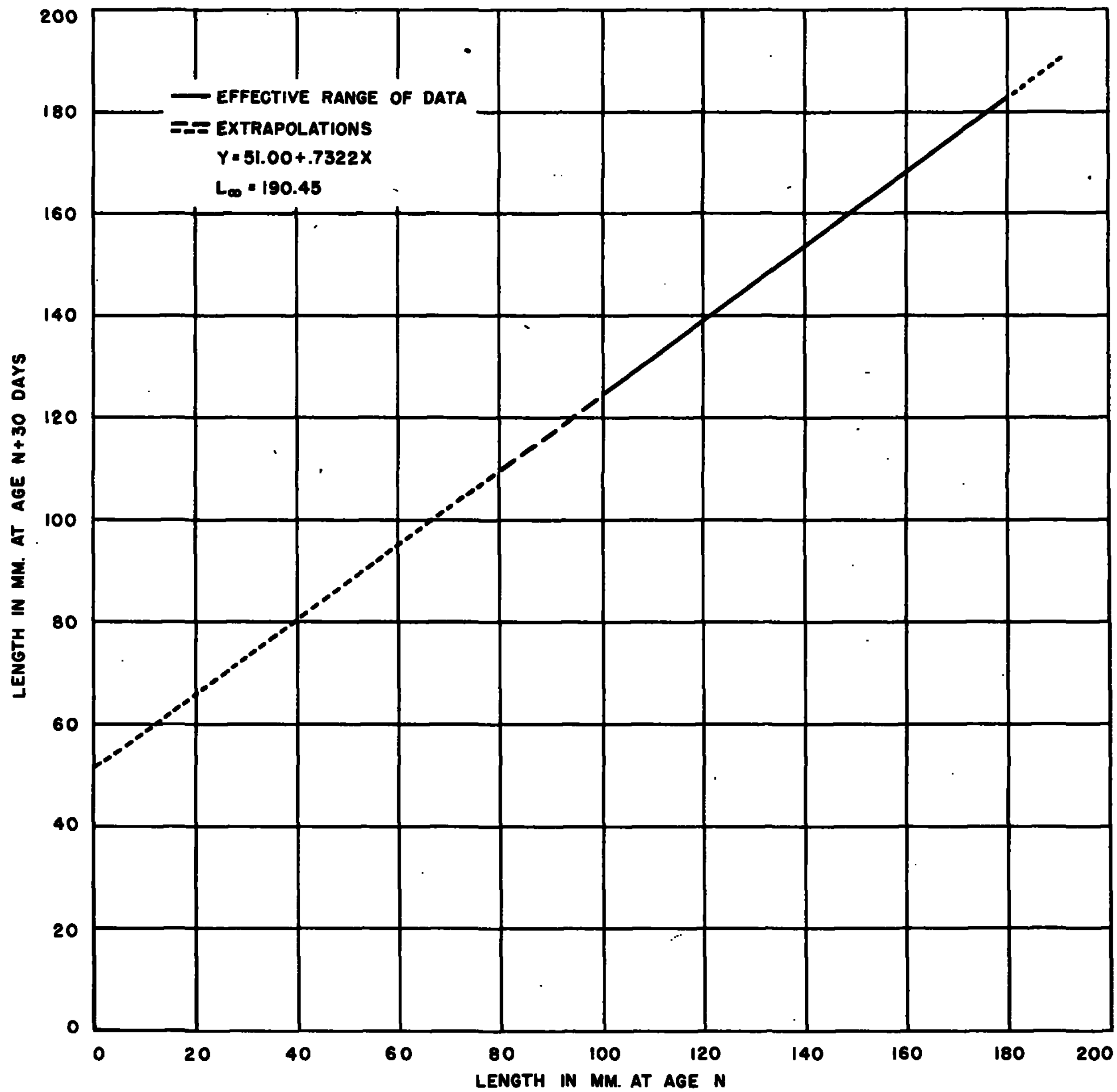

FIGURE 10.—Transformed growth line in 30-day intervals, calculated from marked shrimp.

With few exceptions, we always marked random samples of shrimp as we found them on the fishing grounds. The exceptions occurred now and then when small individuals were abundant. On these occasions we would not mark shrimp less than about 9 cm. in length, since we had found that our technique failed on small shrimp (see table 2 and fig. 4).

For convenience in analysis and interpretation of our data, we divided the coast into sections about 50 miles long. Our divisions are shown in figures 11 and 12. The extent of the present-day fishery for white shrimp off the coast of the United States is shown in these figures by stippling.[3]

We marked 46,532 shrimp. Our conclusions are based on 7,055 returns for which we know the date and locality of recapture. The longest time between release and recapture was that of a shrimp marked at Cape Canaveral in January and recaptured off the Georgia coast 257 days later.

[3] A description of the boats, gear, fishing methods, and localities can be found in Anderson, Lindner, and King (1949).

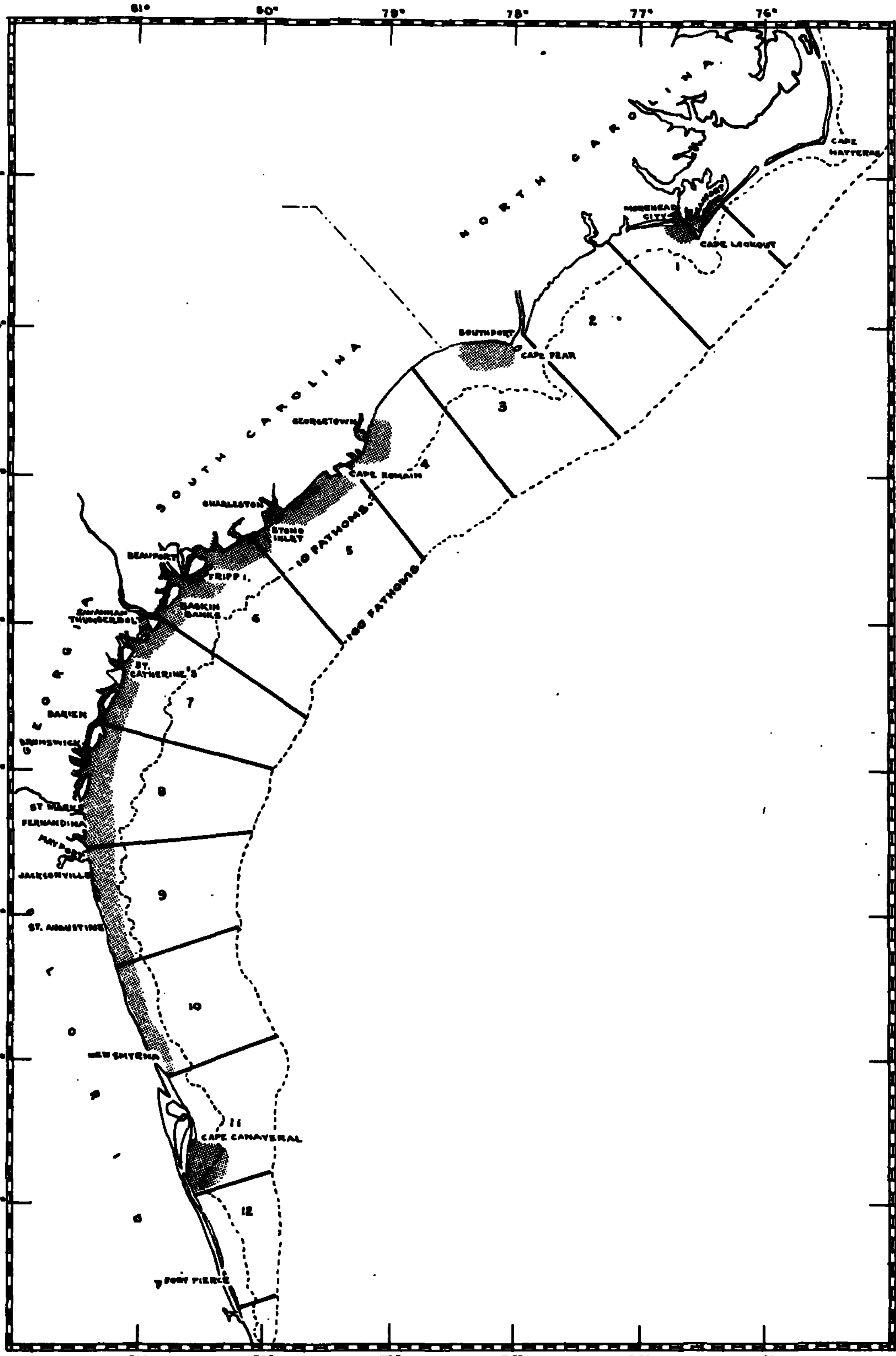

FIGURE 11.—Shrimp-fishing grounds and reference areas for tagging analyses along the Atlantic coast. Fishing grounds are shown by stippling.

FIGURE 12.—Shrimp-fishing grounds and reference areas for tagging analyses along the coast of the Gulf of Mexico. Fishing grounds are shown by stippling.

In table 12 we give for each experiment, the date and locality of release and the number of returns for all our marking experiments.

MIGRATIONS FROM INSIDE WATERS TO OUTSIDE WATERS

The common or white shrimp has very definite patterns of movement, but these vary in different areas. However, in one respect the movements of marked shrimp were similar in all localities studied between North Carolina and Texas, that is, after the young shrimp first made their appearance on the inland fishing grounds they gradually worked their way towards the sea.

If the shrimp move from inside waters (those landward of the outer beach line, the marshes, bays, sounds, rivers, creeks, and bayous) to outside waters (the littoral waters beyond the outer beach line) and remain subject to recapture, we should expect that with the passage of time increasing proportions of inside releases would be encountered in outside waters. Eventually, we should expect to find the recaptures coming only from outside waters. We found this to happen along the Atlantic coast and in the north-central Gulf of Mexico. However, if the marked shrimp moved from inside waters to outside waters and then beyond the range of the fishing fleet we should expect relatively poor returns from outside waters, although the recaptures from inside waters should decline progressively at a rate greater than could be explained on the basis of mortality alone. We found that our central-Texas recaptures of inside releases behaved in this fashion. They were soon lost to the fishery once they moved to outside waters. They obviously moved beyond the range of the fishery.

The data substantiating these statements are contained in table 13 and are arranged so that the months after release represent calendar months, with 0 month the month of release. For instance,

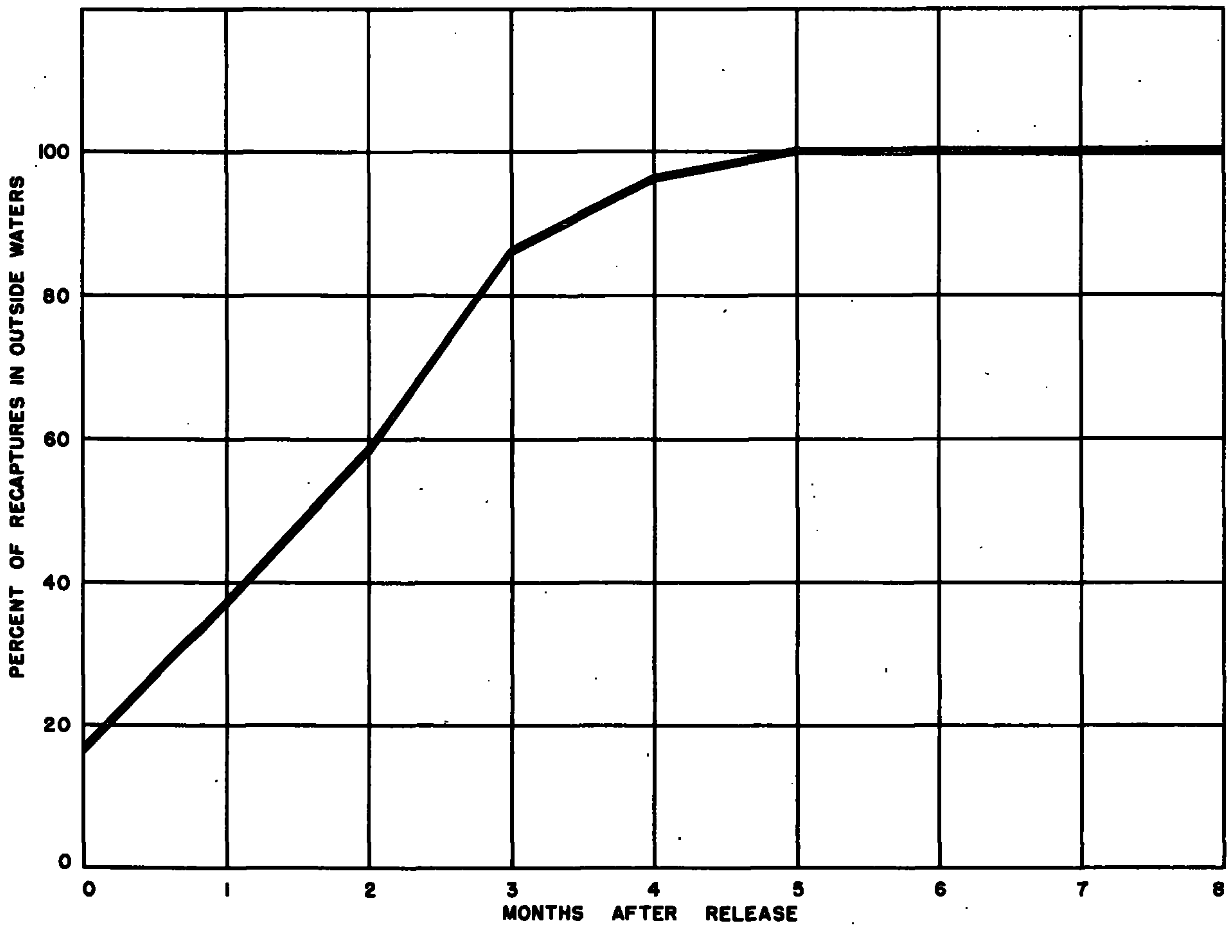

FIGURE 13.—Movement of marked shrimp from inside to outside waters.

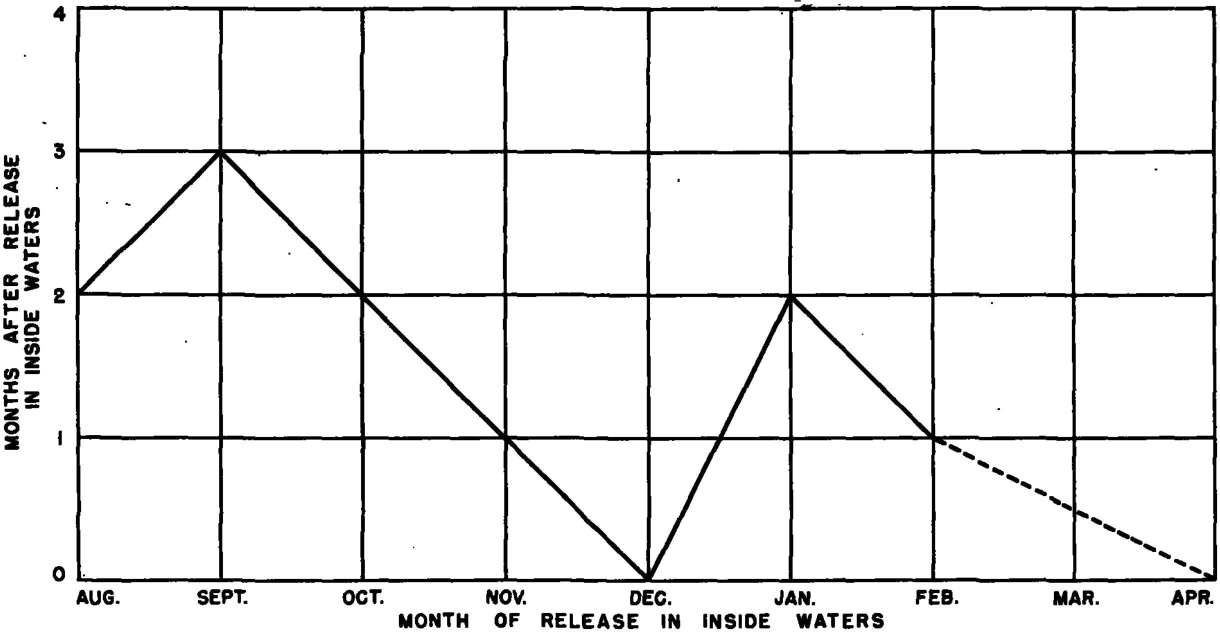

FIGURE 14.—Seasonal changes in length of time required for 60 percent of the marked shrimp to move from inside to outside waters.

recaptures any time during September of shrimp released any time in September were recorded as month 0 returns. Recaptures any time in October from September releases were recorded as month 1 returns.

Figure 13 (based on the data for all areas except Texas) shows the monthly percentage of marked shrimp, recaptured in outside waters, which originally were caught, marked, and released in inside waters. During 0 month, 16.5 percent of all recaptures were in outside waters. The month following the release month, 37.2 percent of all recaptures were taken in outside waters. After the fourth month none of these shrimp was recaptured in inside waters.

The movement of marked shrimp from inside to outside waters is not uniform throughout the year. We can obtain a rough estimate of the seasonal changes in the rapidity of this migration by noting the number of months required for outside recaptures of shrimp tagged in inside waters to reach, or to exceed and maintain, a level of 60 percent of the total recaptures for each month. The data on this point are given in tables 14 and 15, from which we have omitted Texas data for reasons previously given. We have depicted the data graphically in figure 14. The September releases in inside waters required 3 months before 60 percent or more of the recaptures were found in outside waters. In December and April, more than 60 percent were caught in outside waters during the same month in which they were released. We made no releases in inside waters during March, May, or June. July is not included in figure 14 since all of the recaptures from releases made during this month were caught in July or August, and in neither month did the returns from outside waters equal 60 percent.

It is obvious that the movement from inside waters to outside waters speeds up during two periods of the year, at the onset of winter and in the spring. As we shall demonstrate later, these two periods seem to be associated with two groups of shrimp, one an early-spawned group, and the second a later-spawned group. The first group spawned apparently was almost completely in outside waters by December, and the second was rapidly moving out in April.

Of course these data are only rough approximations, but they do corroborate (as will be demonstrated in the section on size distribution) conclusions reached by other means. These conclusions are as follows:

1. After the young shrimp appear on the inside fishing grounds they move toward the sea.

2. This movement becomes more rapid during two seasons, with the approach of winter and during spring.

TABLE 12.—*Releases and recoveries of tagged shrimp*

Area No.	Experiment No.	Date released	Released in locality of—	Number released	Total (each experiment)	Number recovered
		Oct. 11, 1937	Beaufort Fisheries Station, N. C.	197		
		Oct. 12, 1937	Off Beaufort Bar, N. C.	149		
1	1	do	Near Gallant Point, N. C.	34	834	60
		do	Gallant Point, N. C.	248		
		Oct. 13, 1937	Off Beaufort Bar, N. C.	206		
3	1	Oct. 16, 1937	Off Oak Island, N. C.	442	935	388
		do	Inside Southport Entrance, N. C.	493		
		Oct. 6, 1936	Mouth of Key Creek, S. C.	178		
		do	Mouth of Bull Creek, S. C.	214		
	1	do	Bull Creek, S. C.	174	941	35
5		Oct. 7, 1936	Mouth of Bull Creek, S. C.	375		
	2	Oct. 18, 1937	Mouth of Warf Creek, S. C.	97		
		Oct. 18–19, 1937	Warf Creek, S. C.	841	938	37
		Sept. 8, 1936	Off Sandy Point, S. C.	399		
6	1	do	Off Trenchard Inlet, S. C.	289		
		Sept. 9, 1936	Mouth of Trenchard Inlet, S. C.	108	1,188	107
		do	Off Point of Hilton Head, S. C.	392		
		Oct. 1, 1935	Sapelo Sound, Ga.	236		
	1	Oct. 2, 1935	Off south end of St. Catherines Island, Ga.	59		
		do	Julienton River, Ga.	142	603	163
		do	Mud River, Ga.	166		
7		Oct. 23, 1935	Off south end of Sapelo Island, Ga.	499		
	2	Oct. 24, 1935	Off south end St. Catherines Island, Ga.	390	1,185	345
		do	Near mouth of Sapelo Sound, Ga.	296		
	3	Sept. 10, 1936	South end of Ossabaw Island, Ga.	396	396	105
	4	Oct. 21, 1937	Sapelo Sound, Ga.	398	398	125
	1	Sept. 10, 1935	North end Cumberland River, Ga.	7	7	5
		Sept. 20, 1935	Off south end St. Simon's Island, Ga.	118		
	2	do	Jekyll Creek, Ga.	25	210	33
		Sept. 23, 1935	St. Simons Sound, Ga.	67		
	3	Oct. 16, 1935	St. Simons Sound, Ga.	23	23	7
		Oct. 21, 1935	Off St. Simons sea buoy, Ga.	370		
	4	do	Off north end Jekyll Island, Ga.	280	1,143	299
		Oct. 22, 1935	Near mouth St. Andrew's Sound, Ga.	493		
	5	Sept. 11, 1936	St. Simons Sound Entrance, Ga.	495	495	78
		Aug. 10, 1937	Umbrella Creek, Ga.	389		
	6	Aug. 11, 1937	St. Simons Sound, Ga.	294	733	129
		Aug. 12, 1937	St. Simons Sound Entrance, Ga.	50		
	7	Aug. 19, 1937	Off south end of St. Simon's Island, Ga.	423	423	16
8	8	Sept. 7, 1937	St. Simons Sound Entrance, Ga.	397	472	59
		do	St. Simons Sound, Ga.	75		
	9	Nov. 9, 1937	do	398	398	109
	10	Jan. 24, 1938	do	543	543	128
	11	Feb. 23, 1938	do	395	395	83
	12	Mar. 24, 1938	Off St. Simons Island bar, Ga.	396	396	26
	13	April 14, 1938	St. Simons Sound, Ga.	397	397	136
	14	May 13, 1938	Off St. Simons Island bar, Ga.	393	393	92
	15	June 24, 1938	do	260	260	51
	16	July 6, 1938	Jekyll Jetties, St. Simons Sound, Ga.	426	895	124
		July 12, 1938	Off south end Jekyll Island, Ga.	469		
		Aug. 3, 1938	Jekyll Jetties, St. Simons Sound, Ga.	200		
	17	do	Eastfield River, near St. Simons Sound, Ga.	197	592	76
		Aug. 5, 1938	Off St. Simons bar, Ga.	165		
		Aug. 11, 1938	do	30		
		Nov. 12, 1935	Off Mayport Jetties, Fla.	136		
	1	do	Off Mayport can buoy, Fla.	262	598	79
9		Nov. 13, 1935	Off St. Augustine sea buoy, Fla.	200		
	2	Jan. 19, 1938	St. Augustine Entrance, Fla.	772	772	211
	3	Feb. 13, 1938	Off St. Augustine Inlet, Fla.	99	99	25
	4	Mar. 18, 1938	St. Augustine Inlet, Fla.	198	198	7
	1	Jan. 17, 1936	Off New Smyrna bar, Fla.	300	300	18
10	2	Jan. 17, 1938	do	507	656	142
		do	Inside New Smyrna Entrance, Fla.	149		
	3	Feb. 20, 1938	Off New Smyrna bar, Fla.	196	393	58
		do	Inside New Smyrna bar, Fla.	197		
	1	Jan. 16, 1936	Cape Canaveral, Fla.	399	399	168
	2	Feb. 15, 1936	do	55	55	13
11	3	Jan. 13, 1938	do	348	582	132
		Jan. 14, 1938	do	234		
	4	Feb. 15, 1938	do	392	491	35
		Feb. 16, 1938	do	99		
	1	Sept. 20, 1939	Bon Secours Bay in Mobile Bay, Ala.	493	493	89
27	2	Sept. 21, 1939	Mobile Bay, upper portion, Ala.	489	489	96
	3	Oct. 11, 1939	Bayou La Batre, outer beacon, Ala.	324	324	103
	4	Oct. 12, 1939	Grants Pass, Ala.	363	363	34
	1	Sept. 23, 1939	Three miles off Gulfport, Miss.	298		
		Sept. 24, 1939	East Beach, Gulfport, Miss.	596	894	259
	2	Sept. 25, 1939	Vicinity of Grand Island, Mississippi Sound, Miss.	922	922	303
28	3	Oct. 12, 1939	Off Belle Fontaine Point, Miss.	392	392	36
	4	Oct. 13, 1939	Near Gulfport, Mississippi Sound, Miss.	378	378	83
	5	Oct. 14, 1939	Sundown Island, near Isle au Pitre, Miss.	479	479	109
	6	Dec. 1, 1939	Mitchell Keys Light, Chandeleur Sound, La.	247	247	1
29	1	Nov. 30, 1939	Breton Sound near Breton Island, La.	688	688	84
	1	Dec. 13, 1938	Four Bayou Pass, La. (inside)	495	495	26
	2	Dec. 14, 1938	Shell Island, La.	771	771	164
	3	Jan. 19, 1939	Four miles W. of Caminada Pass, La.	169	169	0
	4	Aug. 29–30, 1939	Barataria Bay, La. (inside)	978	978	88
30	5	Oct. 27, 1939	Two miles north of Shell Reef Light, Barataria Bay, La. (inside)	970	970	102
	6	Oct. 28, 1939	Seven miles off Caminada Pass, La.	189	770	124
		do	Caminada Pass, La.	581		
	7	Nov. 10, 1939	Four Bayou Pass (inside), La.	50	50	3
	8	Nov. 11, 1939	Three miles off Four Bayou Pass, La.	444	444	9

TABLE 12.—*Releases and recoveries of tagged shrimp*—Continued

Area No.	Experiment No.	Date released	Released in locality of—	Number released	Total (each experiment)	Number recovered
31	1	Dec. 16, 1938	Eleven miles southwest of Ship Shoal Light, La	957	957	17
	2	Jan. 20, 1939	Whiskey Pass, La	806	806	4
	3	Nov. 12–15, 1939	Inside Wine Island, near Pt. Mast, La	928	928	27
	4	Jan. 17, 1940	One mile off Whiskey Pass, La	348	348	4
	5	Feb. 29, 1940	Ten miles south-southeast of Ship Shoal Light, La	589	589	65
	6	Mar. 1, 1940	Northeast of Ship Shoal Light, La	1190	1190	194
	7	do	Eight miles northwest of Ship Shoal Light, La	199	199	42
	8	Mar. 6, 1940	Eight miles west-northwest of Ship Shoal buoy, La	589	589	107
32	1	Jan. 25, 1939	Thirty miles south of Atchafalaya beacon, La	394		
		Jan. 26, 1939	Twenty-five miles south of Atchafalaya beacon, La	344	738	64
	2	Dec. 15–16, 1939	Thirty miles south of Marsh Island, La	1, 133	1, 133	128
	3	Jan. 30, 1940	Ten miles southeast of Trinity Shoal buoy, La	1, 241	1, 241	194
	4	Feb. 29, 1940	Ship Shoal Light, La	593	593	73
	5	Mar. 5, 1940	South-southwest of Atchafalaya Beacon, La	793	793	195
37	1	Oct. 2, 1936	Two miles east of Signal Island, San Antonio Bay, Tex	200	200	0
	2	Oct. 3, 1936	One mile east of Sand Point Beacon and 2 miles west of Gallinipper Pt. Beacon, Mategorda and Lavaca Bays, Tex	380	380	5
38	1	Sept. 23, 1936	One mile S. of Half Moon Reef, Aransas Bay, Tex	98	490	34
		Sept. 24, 1936	Ship Island, Aransas Bay, Tex	296		
		do	Cool Coast Camp, Tex	96		
	2	Sept. 25, 1936	Copano Bay, Tex	296	296	5
	3	Sept. 28, 1936	Mud Island, Aransas Bay, Tex	199	298	21
		do	Harbor Island Light, Aransas Bay, Tex	99		
	4	Sept. 29, 1936	Shamrock Cove, Corpus Christi Bay, Tex	490	882	206
		Sept. 30, 1936	Off Ingleside, Corpus Christi Bay, Tex	392		
	5	Aug. 27, 1937	Mouth Allen's Bight, Aransas Bay, Tex	99	391	18
		Aug. 30, 1937	Allen's Bight, Aransas Bay, Tex	196		
		do	Off Ranch House, Mud Island, Aransas Bay, Tex	96		
	6	Aug. 31, 1937	Shamrock Point, Corpus Christi Bay, Tex	189	283	21
			Ingleside Beacon, Corpus Christi Bay, Tex	94		
	7	Oct. 20, 1937	Rockport Basin, Aransas Bay, Tex	404	701	157
		Oct. 21, 1937	Three-quarter mile E. of Mud Island Point, Aransas Bay, Tex	100		
		Oct. 26, 1937	Rockport Basin, Aransas Bay, Tex	197		
	8	Oct. 27, 1937	Inside south jetty, Aransas Pass, Tex	249	793	78
		Oct. 28, 1937	Four miles off, 3 miles S. of jetties, Aransas Pass, Tex	544		
	9	do	Docks at Port Aransas, Tex	195	195	31
	10	Sept. 8, 1938	Just west of drawbridge, Copano Causeway, Tex	177	472	10
		Sept. 14, 1938	Two miles SW. of Jordan Pass, Copano Bay, Tex	100		
		Sept. 15, 1938	One mile N. of Port Bay Channel, Copano Bay, Tex	195		
41	1	Mar. 17–22, 1947	Fifteen to 35 miles S. of Rio Grande River, Mexico	616	616	118
42	1	Mar. 17, 1947	Off Huts Bayou, Mexico	379	379	19
1	All		North Carolina		834	60
3	do		do		935	388
5	do		South Carolina		1, 879	72
6	do		do		1, 188	107
7	do		Georgia		2, 582	738
8	do		do		7, 775	1, 451
9	do		Florida		1, 667	322
10	do		do		1, 349	218
11	do		do		1, 527	348
27	do		Alabama		1, 669	322
28	do		Mississippi and Louisiana		3, 312	791
29	do		Louisiana		688	84
30	do		Inside waters, Louisiana	2, 493	4, 647	516
			Offshore, Louisiana	2, 154		
31	do		Inside waters, Louisiana	928	5, 606	460
			Offshore, Louisiana	4, 678		
32	do		Offshore, Louisiana		4, 498	654
37	do		Central Texas		580	5
38	do		do		4, 801	581
41	do		Northern Mexico		616	118
42	do		do		379	19
1–11	do		Atlantic coast	19, 736		3, 704
27–29	do		Northern Gulf, east of Mississippi River	5, 669		1, 197
30–32	do		Northern Gulf, west of Mississippi River (inside)	3, 421		246
			Northern Gulf, west of Mississippi River (offshore)	11, 330		1, 384
37–38	do		Central Texas	5, 381		586
41–42	do		Off Mexico, south of Rio Grande	995		137
All	do		North Carolina to northern Mexico	46, 532		7, 254

Apparently, once the shrimp reach outside waters they tend to remain there unless driven out before their normal time by sudden environmental changes. Of those shrimp we tagged in outside waters along the Atlantic coast, only two were recaptured in the inside waters of another area. Along the Louisiana coast, 118 of our marked shrimp released in outside waters were later recaptured in inside waters. However, all but nine of these were small shrimp from late February and early March releases following an unusual cold spell. These shrimp had sought refuge in deeper water, but later when the inland waters became warmer they returned there, probably almost immediately to move offshore to spawn.

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TABLE 13.—*Movement of tagged shrimp from inside waters to outside waters*

Locality of recapture	Number recaptured in month								
	0	1	2	3	4	5	6	7	8
Atlantic Coast:									
Inside waters	334	185	12		1				
Outside waters	139	263	94	33	11	1		2	
Northern Gulf east of Mississippi River:									
Inside waters	518	386	100	8					
Outside waters	2	90	58	10	5	2			
Northern Gulf west of Mississippi River:									
Inside waters	16	101	2						
Outside waters	30	45	7	7	10	3	2	1	1
Texas:									
Inside waters	83	221	48	7					
Outside waters	49	94	1	1					
Total all localities except Texas:									
Inside waters	868	672	114	8	1				
Outside waters	171	398	159	50	26	6	2	3	1
Total (excluding Texas)	1,039	1,070	273	58	27	6	2	3	1
Percent outside (excluding Texas)	16.5	37.2	58.2	86.2	96.3	100.0	100.0	100.0	100.0

TABLE 14.—*Numbers of tagged shrimp released in inside waters, arranged according to locality and time of recapture*

[Atlantic coast and northern Gulf of Mexico; Texas omitted]

Locality of recapture and month of release	Number recaptured in month								
	0	1	2	3	4	5	6	7	8
Inside waters:									
January	3	71	4						
February		16	1						
April	11	10	2						
July	8	18							
August	106	80	1						
September	358	230	102	8					
October	331	232	3		1				
November	49	15	1						
December	2								
Outside waters:									
January	6	23	12	7	2				
February		55	8	3					
April	49	52	8	1	1				
July	11	12							
August	34	23	8	3	1				1
September	2	20	39	15	8				
October	39	100	71	17	4	3	1	3	
November	10	112	13	4	10	3	1		
December	20	1							
Total inside	868	672	114	8	1				
Total outside	171	398	159	50	26	6	2	3	1

TABLE 15.—*Monthly percentages of recaptures of inside releases recaptured in inside and outside waters*

[Data from table 17]

Month and locality of release	Percent recaptured in month								
	0	1	2	3	4	5	6	7	8
January:									
Inside waters	33.3	75.5	25.0						
Outside waters	66.7	24.5	75.0	100.0	100.0				
February:									
Inside waters		22.5	11.1						
Outside waters		77.5	88.9	100.0					
April:									
Inside waters	18.3	16.1	20.0						
Outside waters	81.7	83.9	80.0	100.0	100.0				
July:									
Inside waters	42.1	60.0							
Outside waters	57.9	40.0							
August:									
Inside waters	75.6	77.7	11.1						
Outside waters	24.4	22.3	88.9	100.0	100.0				100.0
September:									
Inside waters	99.4	92.0	72.3	34.8					
Outside waters	.6	8.0	27.7	65.2	100.0				
October:									
Inside waters	89.5	69.9	4.1		20.0				
Outside waters	10.5	30.1	95.9	100.0	80.0	100.0	100.0	100.0	
November:									
Inside waters	83.1	11.8	7.1						
Outside waters	16.2	88.2	92.9	100.0	100.0	100.0	100.0		
December:									
Inside waters	9.1								
Outside waters	90.9	100.0							

TABLE 16.—*Months in which tagged shrimp were released along the Atlantic coast*

Released in month of —	Released in area No.—								
	1	3	5	6	7	8	9	10	11
January	------	------	------	------	------	x	x	x	x
February	------	------	------	------	------	x	x	x	x
March	------	------	------	------	------	x	x	------	------
April	------	------	------	------	------	x	------	------	------
May	------	------	------	------	------	x	------	------	------
June	------	------	------	------	------	x	------	------	------
July	------	------	------	------	------	x	------	------	------
August	------	------	------	------	------	x	------	------	------
September	------	------	x	x	x	x	------	------	------
October	x	x	x	------	x	x	------	------	------
November	------	------	------	------	------	x	x	------	------

Once the shrimp reached the outside waters their movements varied with the size of the shrimp and the locality, and apparently also the time of the year.

The small shrimp, 13 cm. or less in total length, did not make any extensive movements. Once they reached the outside waters they remained there, almost immediately adjacent to their inland nursery grounds. The large shrimp, more than 13 cm. in total length, showed distinct behavior patterns which, since they varied with locality, must be discussed on a geographical basis.

ATLANTIC COAST

Weymouth, Lindner, and Anderson (1933) demonstrated that the larger shrimp disappeared from the Georgia coast during fall and winter. We later found that a decrease in abundance of large shrimp also occurred at about the same time along the North and South Carolina coasts. Concomitant with the decline in catch and the disappearance of larger shrimp from the northern and central sections, we found that in the southern section (Florida) the catches increased (fig. 15),[4] and that the shrimp caught were comparable in length to those missing from the north. These facts suggest the possibility of a southward migration during fall.

Throughout the winter, small shrimp remained in varying numbers from North Carolina to northern Florida. They were most abundant in southern Georgia and northern Florida. In Georgia and the Carolinas, after the winter low, the catches increased during April, May, and June, before the appearance of the new spring-spawned shrimp on the fishing grounds. This was primarily due to the growth and entrance into the fishery of small shrimp that wintered in these areas.

[4] The data for this figure are from Anderson, Lindner, and King (1949).

The catch records for the various States, mostly based on tax receipts, cannot be considered entirely accurate. However, from intimate association with the fishery, we believe that figure 15 roughly represents both relative seasonal abundance and relative fishing effort. In general, there was more effort expended when and where the shrimp were abundant than when and where they were not.

At the time we ran our marking experiments (1935–38), part of the fishing fleet would move along the coast in accordance with the shifting abundance of shrimp and operate in South Carolina and Georgia during late summer and fall and along the Florida coast during winter. Many of the boats would return to Georgia and South Carolina for the spring run of shrimp. North Carolina did not permit fishing by boats from other States. In all the States, there were fleets of small boats that fished the entire year from their home ports, but the majority of these were in Georgia and northern Florida.

Except in area 3, North Carolina boats would fish only occasionally in outside waters during winter and early spring. There was no fishing in area 2 at any time. Winter and early spring fishing in outside waters of South Carolina (areas 4, 5, and 6) was more frequent than in areas to the north, but it still was casual. It was only along the coasts of Georgia and northern Florida (areas 7, 8, and 9) that fishing occurred with a fair degree of intensity throughout the year. Fishing in central Florida (areas 10 and 11) was limited almost exclusively to late fall, winter, and spring.

Because of these conditions, and also because of our facilities, we concentrated our efforts on the one area (area 8) where throughout the year fairly intensive fishing occurred both to the north and to the south; here we tagged shrimp each month of the year, except December. In the other areas, we tagged only when the shrimp were most abundant. Table 16 shows the months in which we released marked shrimp in each area.

In figure 16 (based on data presented in table 17) we show graphically, by months, the percentage of total recaptures for each month taken in areas north or south of the areas of release. In this figure the lines begin with the month in which the

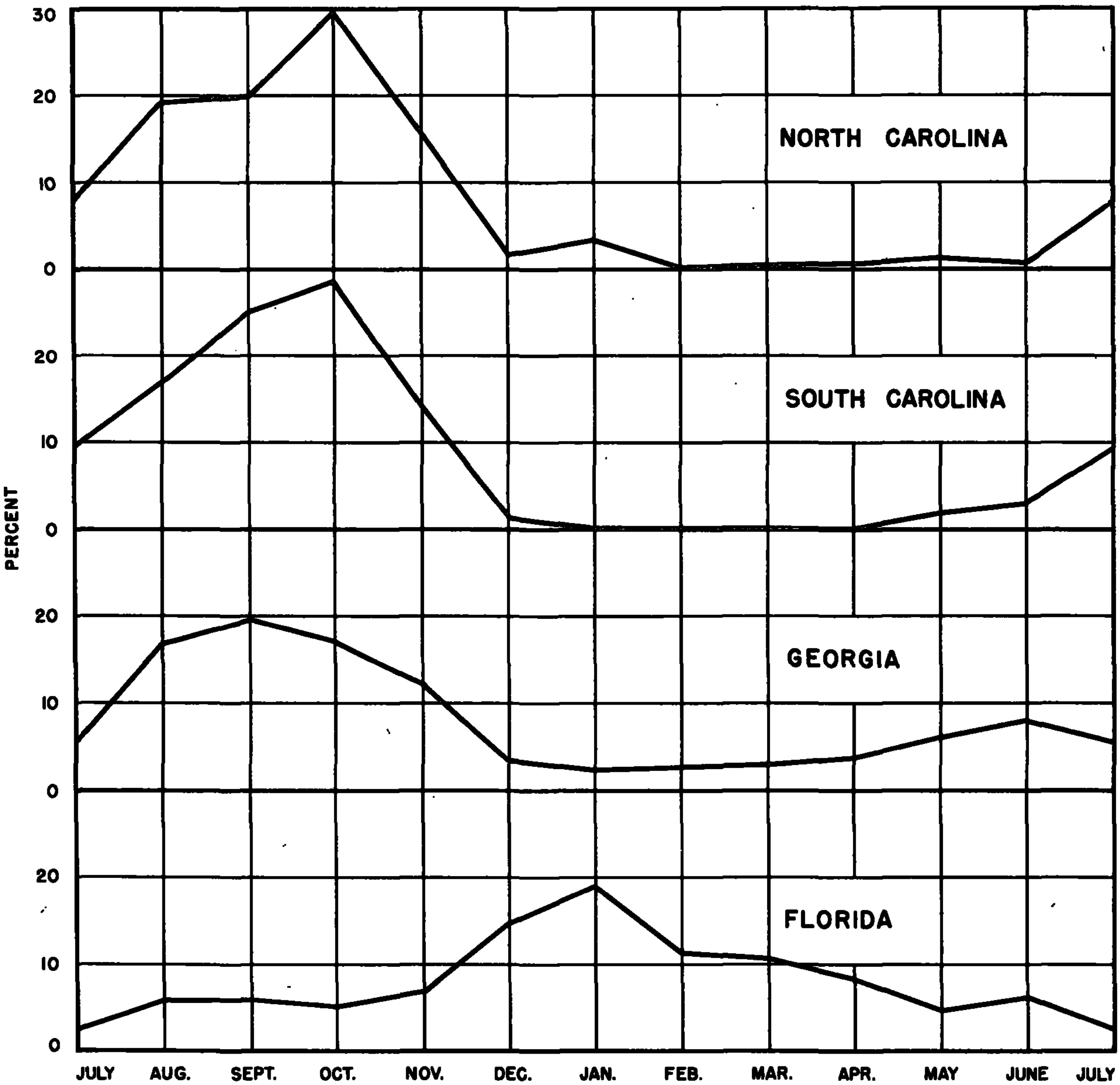

FIGURE 15.—Average monthly percentage of annual shrimp catch for the Atlantic coast, by States.

shrimp were released and follow (from top to bottom) the recaptures from the releases of this month until fewer than eight of these shrimp were recaptured in any following month. The points falling within the 0–0 section of this graph indicate that no recaptures were made in areas other than the release area. For example, from releases made during May all recoveries during both May and June were from the area of release. However, we find that about 12 percent of all October releases that were recaptured during the same month were taken south of the release areas. Following these October releases month by month, we see that each month the percentage of recoveries in areas south of the release areas increased until, in February, all recaptures were to the southward. When recaptures were made in the same month both north and south of the release area, the line shows only the direction in which the predominant recaptures were made. We believe that this figure tells the general story of shrimp movements along the Atlantic coast: a southward movement

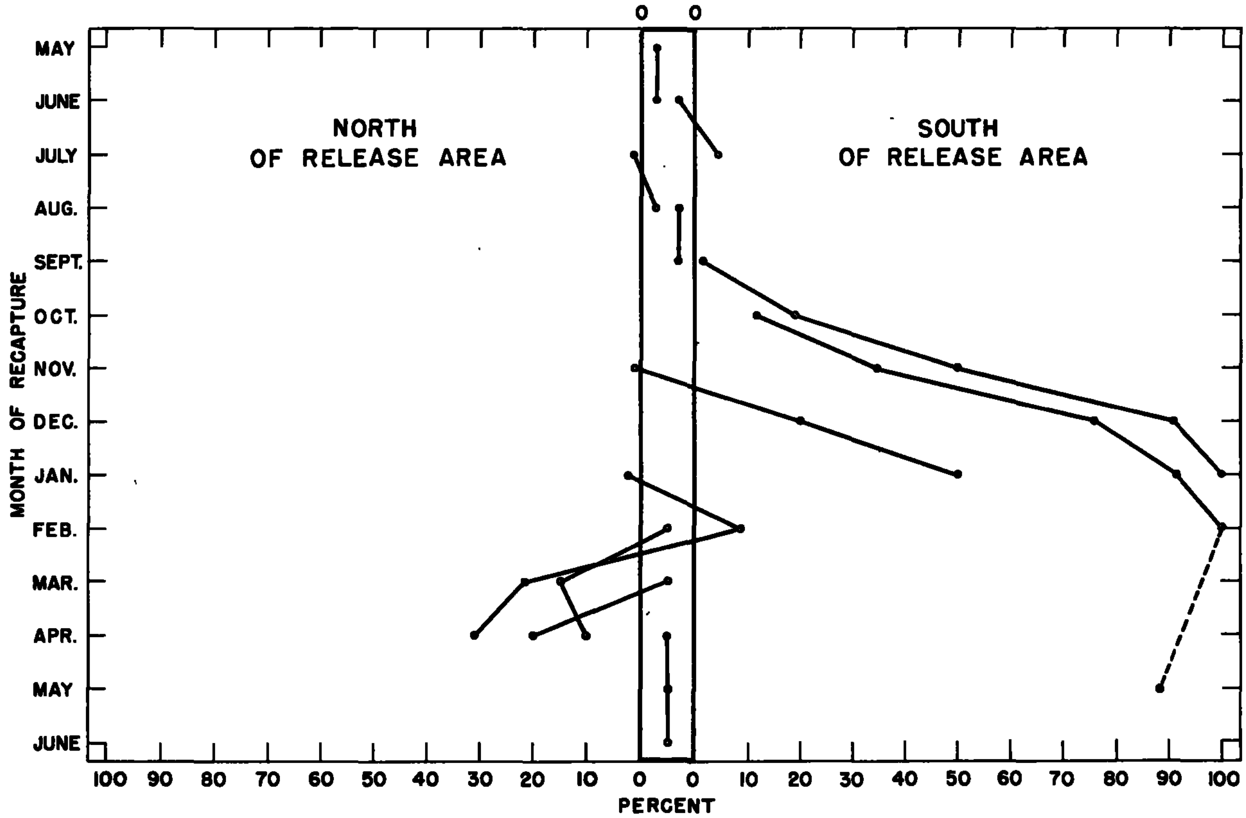

FIGURE 16.—Monthly percentage of total monthly recaptures of marked shrimp recovered in areas north and south of release area.

during fall and early winter, a return northward in late winter and early spring, and no coastwise movement during late spring and summer.

Of the 10 shrimp recaptured between July and December (of releases made during these same months) in areas north of the release area, only one was retaken as far as 35 miles from the place of release. These certainly cannot be considered to indicate a migration pattern. During the same period, 425 shrimp were recaptured south of the release areas. Some of these shrimp had migrated more than 200 miles, and one was recaptured 290 miles from where it had been released.

The movements can be followed in greater detail in tables 17 and 18 and are diagramed in figures 17 to 19. In table 17 we interpret the apparent shaped pattern of recoveries from the October markings to indicate a southward movement and then a later northward return.

Our January to March releases of tagged shrimp, in contrast to the fall releases, show a definite northward trend. In discussing this matter, we can eliminate from consideration releases made in area 11, since recoveries from outside this area could only be from the north. If we then follow through April, the January and February releases made in the other areas (after April there was little fishing in areas 10 and 11), we find that in February about 37 percent and in March about 78 percent of those shrimp recaptured outside the release area were taken in areas to the north of that in which they were liberated (table 19).

Similarly, when we consider the releases from area 8, to the north and south of which relatively equally intensive fishing occurred throughout the year, we find (table 20) that the recaptures to the south and to the north of this area follow the same general pattern as already described. They show that the shrimp move south during fall and early winter, north during late winter and early spring, and remain relatively stationary from mid-spring until fall.

None of the shrimp marked in area 8 were recaptured north of area 7. It should be noted, however, that shrimp released in area 8 during the period January to March, when the northern

TABLE 17.—*Monthly recaptures of Atlantic-coast tagged shrimp, arranged according to month of release and distance (in areas) shrimp were recaptured north and south of release area*

[Areas are 50 miles wide]

Released in month of—	Recaptured in month of—	Number recaptured in areas north or south of release area in geographical sequence													
		North					Area of release	South							Total
		5	4	3	2	1	0	1	2	3	4	5	6	7	
May	May						62								92
	June						29								
	July						1								
June	June						26								49
	July						21	1							
	August						1								
July	July					1	84								123
	August						38								
August	August						179								220
	September						36								
	October						2	1							
	November							1							
	January							1							
September	September					2	282	3	1						412
	October					3	53	12			1				
	November						18	13	2	1	2				
	December						1	3		2	4	1			
	January							2		3	3				
October	October					2	578	73	3						1366
	November						326	158	13	1					
	December						38	69	30	12	6	2			
	January						3	3	7	11	6	1	2	1	
	February								3	3	2	1			
	March								3					1	
	May						1	7							
November	November					1	95								180
	December					1	52	9	2	2					
	January						8	6	2						
	February							1							
	March								1						
January	January				5	5	420		1						785
	February				5	11	180	19							
	March				3	22	84	8							
	April				1	3	8	1							
	May						2	1							
	July	1			2	1									
	August					1									
	September			1											
February	February						36								210
	March				1	22	136	1							
	April					1	9								
	May				1	1	2								
March	March						11								31
	April					3	11	1							
	May					1	3								
	June						1								
April	April						60								134
	May						62								
	June						10								
	July						1								
	August						1								

migration is at its height, were mostly small shrimp which normally do not migrate far.

Since some of our releases from areas 5 and 6 were recaptured in September in areas south of the release area, and none from areas 7 and 8 were recaptured in more southerly regions until October, it is probable that the fall migration begins earlier in South Carolina than it does in Georgia.

The shrimp have completed their southern migration by January or February. The northward return appears to begin at the southern extremity (area 11) as early as January, but not until February in areas 8 to 10. Our data do not indicate precisely when the northward migration terminates, but apparently there is little or no coastwise movement of shrimp between April and August. Since temperature is probably one of the principal factors influencing these coastal movements, we may expect some changes in their timing from year to year. The longest southward migration was by a shrimp released near Beaufort, N. C., in October, and recaptured 95 days later off the east coast of Florida, about 360 miles south of where we released it. The greatest northward migration was recorded for a specimen released at Cape Canaveral, Fla., in January, and recaptured 168 days later off the coast of South Carolina. It had traveled about 260 miles.

TABLE 18.—*Recaptures, by area, month, and size, of tagged shrimp released along the Atlantic coast from 1935 to 1938, inclusive*

Area, and month of release, and size [1] when released	Recaptured in month of—	Number recaptured in area— 1	2	3	4	5	6	7	8	9	10	11	All areas	Total
Area 1:														
October:														
Small	October	45											45	45
Large	October	9		1									10	14
	November	1		2									3	
	January								1				1	
Area 3:														
October:														
Small	October			98									98	146
	November			46									46	
	December			1									1	
	February								1				1	
Large	October			167									167	240
	November			60									60	
	December			4					2				6	
	January			2					1	2			5	
	February							1					1	
	March										1		1	
Area 5:														
September:														
Small	October					2							2	4
	December									1			1	
	January								1				1	
Large	September					7		1					8	29
	October				3	1				1			5	
	November					4	2	1	1				8	
	December								1	3	1		5	
	January									3			3	
October:														
Small	December								3	1			4	10
	January								5				5	
	February							1					1	
Large	November					2	3		1				6	24
	December							1	7	5			13	
	January								2	2			4	
	February								1				1	
Area 6:														
September:														
Small	September						26	1					27	33
	October						1	3					4	
	November							1			1		2	
Large	September						51	2					53	71
	October						6	5					11	
	November						2	3			1		6	
	December									1			1	
Area 7:														
September:														
Small	September						1	54					55	58
	October							2					2	
	November								1				1	
Large	September							41					41	46
	October							2	2				4	
	November								1				1	
October:														
Small	October							55					55	105
	November							32	4				36	
	December							1	7	3			11	
	March									1			1	
	May								2				2	
Large	October							98	69	2			169	508
	November							124	110	11			245	
	December							19	26	25	2		72	
	January								1	6	2	4	13	
	February									1	2	1	4	
	May								5				5	
Area 8:														
January:														
Small	January								9				9	125
	February							1	91				92	
	March								15				15	
	April							1	6				7	
	May								2				2	
Large	February								2				2	3
	March								1				1	
February:														
Small	March							1	65				66	78
	April							1	8				9	
	May							1	2				3	
Large	March							1	4				5	5
March:														
Small	March								6				6	21
	April							2	8				10	
	May							1	3				4	
	June								1				1	
Large	March								1				1	4
	April							1	1	1			3	

[1] Small shrimp are those less than 13 cm.; large shrimp are those 13 cm. and longer.

TABLE 18.—*Recaptures, by area, month, and size, of tagged shrimp released along the Atlantic coast from 1935 to 1938, inclusive*—Continued

Area, and month of release, and size [1] when released	Recaptured in month of—	Number recaptured in area— 1	2	3	4	5	6	7	8	9	10	11	All areas	Total
Area 8—Continued														
April:														
Small	April								51				51	118
	May								56				56	
	June								9				9	
	July								1				1	
	August								1				1	
Large	April								9				9	16
	May								6				6	
	June								1				1	
May: Large	May								62				62	92
	June								29				29	
	July								1				1	
June: Large	June								26				26	49
	July								21	1			22	
	August								1				1	
July:														
Small	July								19				19	48
	August								29				29	
Large	July							1	65				66	75
	August								9				9	
August:														
Small	August								103				103	129
	September								24				24	
	October									1			1	
	November									1			1	
Large	August								76				76	91
	September								12				12	
	October								2				2	
	January									1			1	
September:														
Small	September								40				40	54
	October								10				10	
	November								2				2	
	January									1		1	2	
Large	September							1	63				64	117
	October								29	2			31	
	November								10	5	1		16	
	December								1	3			4	
	January									1		1	2	
October:														
Small	December									2			2	2
Large	October							2	106	4			112	272
	November								61	41			102	
	December								13	34	1		48	
	January								1	2	1	2	6	
	February										1		1	
	March										2		2	
	May								1				1	
November:														
Small	November								41				41	85
	December								29	3	1		33	
	January								7	3			10	
	March										1		1	
Large	November								12				12	23
	December								4	2	1	2	9	
	January									2			2	
Area 9:														
January:														
Small	January									20			20	30
	February									2	1		3	
	March									5	2		7	
Large	January									105		1	106	178
	February								2	16	16		34	
	March								1	30	4		35	
	April								1	1			2	
	July								1				1	
February:														
Small	February									1			1	15
	March									13	1		14	
Large	February									2			2	9
	March									7			7	
March:														
Small	March									1			1	2
	April									1			1	
Large	March									3			3	4
	April									1			1	
November: Large	November								1	42			43	72
	December								1	19	4		24	
	January									1	1	2	4	
	February										1		1	

[1] Small shrimp are those less than 13 cm.; large shrimp are those 13 cm. and longer.

TABLE 18.—*Recaptures, by area, month, and size, of tagged shrimp released along the Atlantic coast from 1935 to 1938, inclusive*—Continued

Area, and month of release, and size [1] when released	Recaptured in month of—	Number recaptured in area—												Total
		1	2	3	4	5	6	7	8	9	10	11	All areas	
Area 10:														
January:														
Small	January										8		8	18
	February										6		6	
	March									1	3		4	
Large	January										58		58	142
	February								2	6	33	2	43	
	March									16	17	2	35	
	April									1		1	2	
	May											1	1	
	July								2				2	
	August									1			1	
February:														
Small	February										1		1	1
Large	February										18		18	57
	March									12	27		39	
Area 11:														
January:														
Small	January											11	11	18
	February											3	3	
	March									2	1	1	4	
Large	January									5	5	209	219	271
	February									3	2	27	32	
	March									1	3	12	16	
	April									1		1	2	
	July						1						1	
	September								1				1	
February:														
Small	February											8	8	18
	March										3	7	10	
Large	February											6	6	27
	March									1	5	13	19	
	April											1	1	
	May									1			1	

[1] Small shrimp are those less than 13 cm.; large shrimp are those 13 cm. and longer.

TABLE 19.—*Recaptures north and south of release area, of shrimp tagged in areas 8, 9, and 10 during January and February*

[Small and large shrimp combined]

Recaptured in month of—	Number recaptured in areas—	
	North of release area	South of release area
January		1
February	11	19
March	31	9
April	4	1

TABLE 20.—*Recaptures, other than in area 8, of tagged shrimp released in area 8*

[Small and large shrimp combined]

Recaptured in month of—	Number recaptured in—		
	Area 7	Area 9	Areas south of 9
August			
September	1		
October	2	7	
November		47	1
December		44	5
January		10	5
February	1		1
March	2		3
April	5	1	
May	2		
June			
July	1	1	

TABLE 21.—*Tagged small shrimp (less than 13 cm.) recaptured along southern Atlantic coast*

[Both sexes included, 1935–38 experiments]

Distance captured from point of release	Direction	Number recaptured, of shrimp released in area—									
		1	3	5	6	7	8	9	10	11	All areas
335–360 miles	South										
305–330 miles	do										
275–300 miles	do		1								1
245–270 miles	do										
215–240 miles	do			1							1
185–210 miles	do			1	1						2
155–180 miles	do			7			1				8
125–150 miles	do			3			1				4
95–120 miles	do						1				1
65–90 miles	do					4	3				7
35–60 miles	do				1	10	11				22
0–30 miles	Local	45	145	2	31	149	643	47	18	26	1,106
35–60 miles	North								1	3	4
65–90 miles	do									2	2
95–120 miles	do									1	1
125–150 miles	do										
155–180 miles	do										
185–210 miles	do										
215–240 miles	do										
245–270 miles	do										
Total		45	146	14	33	163	660	47	19	32	1,159

The proportion of large shrimp that move is much greater than that of the small ones. In tables 18, 21, and 22, we have divided the marked shrimp into two size groups, small and large, with 13 cm. as the arbitrarily selected dividing line between them. The different behavior of the two size groups may be ascertained from table

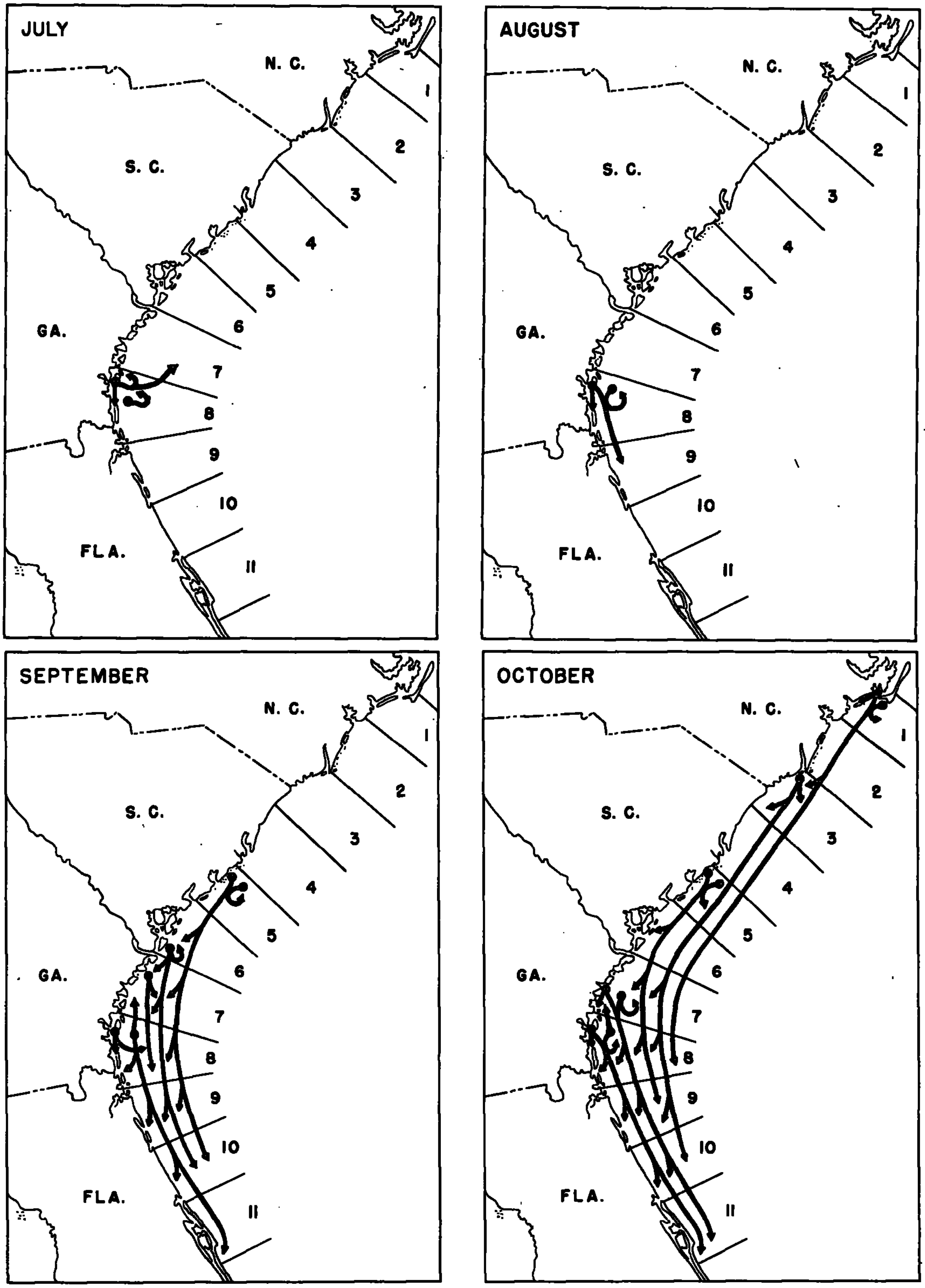

FIGURE 17.—Movements of marked shrimp released along the Atlantic coast during July, August, September, and October. These diagrams (also figs. 18–26) show where marked shrimp were recovered. They do not indicate quantity, or length of time between release and recovery, but merely where the shrimp went. The dot at the beginning of each arrow indicates locality of release.

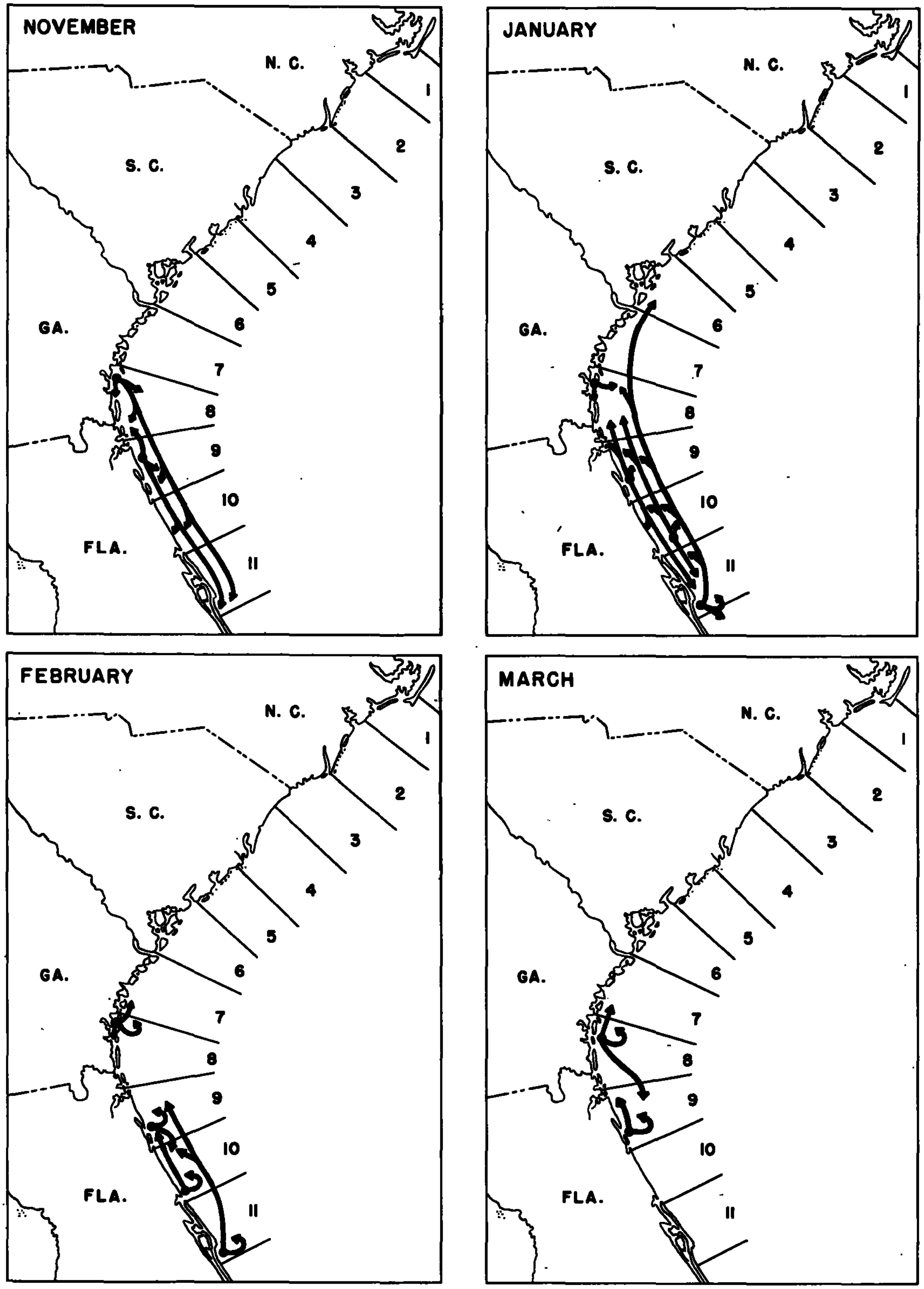

FIGURE 18.—Movements of marked shrimp released along the Atlantic coast during November, January, February, and March. See figure 17 for further explanation.

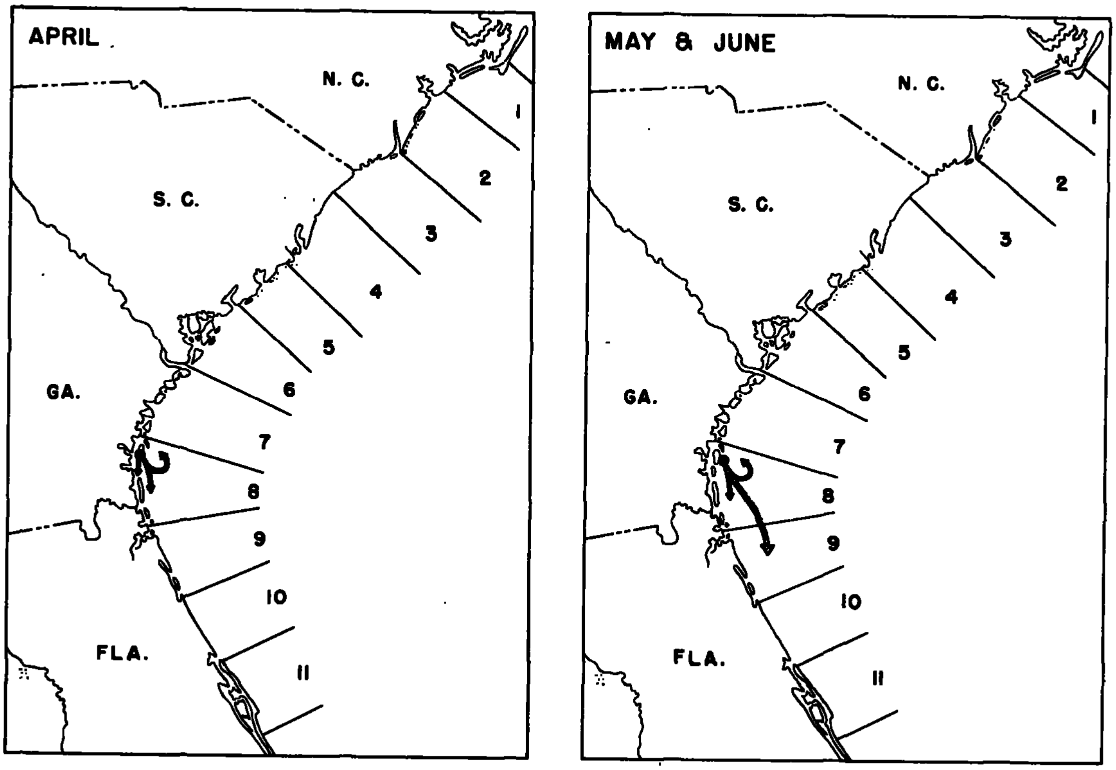

FIGURE 19.—Movements of marked shrimp released along the Atlantic coast during April, May, and June. See figure 17 for further explanation.

18, and a comparison of table 21 with 22, but the very definite correlation between migratory tendency and size is most clearly displayed in table 23.

With respect to the southward migrations along the Atlantic coast during fall and early winter, we do not claim that all the large shrimp move south, but we think the vast majority do. Our data cannot be considered conclusive for the most northern section because in this region we tagged shrimp only during 1 year (there was almost no winter fishing north of area 3), and our returns from this section were few.

If the shrimp are affected by temperature, it is possible, because of the effects of the Gulf Stream on this stretch of the coast (Parr 1933), that both a northward and a southward winter migration might occur, with southern South Carolina or northern Georgia as the center from which the dispersion takes place. Apparently, to a limited and variable extent, there is a northward movement along the Carolina coasts during winter, but the numbers of shrimp involved are few, since the bulk of the population of large shrimp has migrated to the Florida coast. Our tagging would not show such a northward movement, since we did not tag in South Carolina during midwinter. (See p. 621 for additional discussion.)

We believe the migrations of the common shrimp, as presented here, represent the pattern followed by the bulk of the shrimp along the Atlantic coast.

Before we began our marking experiments along the Atlantic coast, the information we had available (length-distribution records and production figures), although highly indicative, was not conclusive evidence of coastwise migration. The decline in abundance and decrease in length of the shrimp in the central and northern sections of the fishery during late fall and early winter might be caused by factors other than a southward migration. Similar symptoms could be caused by the large shrimp burying in the mud and hibernating, or by an offshore migration.

We believe that the evidence we have presented here effectively disposes of these other possibilities. However, we do have additional information.

Shrimp which we kept in aquariums would bury themselves on occasion but never for long periods—a few days at the most, never for weeks or months.

Table 22.—*Tagged large shrimp (13 cm. and longer) recaptured along southern Atlantic coast*

[Both sexes included, 1935–38 experiments]

Distance captured from point of release	Direction	Number recaptured, of shrimp released in area—									
		1	3	5	6	7	8	9	10	11	All areas
335–360 miles	South	1	1								2
305–330 miles	do										
275–300 miles	do		4								4
245–270 miles	do		1								1
215–240 miles	do		1	5							6
185–210 miles	do			10	1	5					16
155–180 miles	do			5			5				10
125–150 miles	do			8	1	5	2	1			17
95–120 miles	do			3		10	4	2			19
65–90 miles	do	3		2		34	46	4			89
35–60 miles	do			5	6	67	58	9	6		151
0–30 miles	Local	10	233	15	63	432	632	242	153	274	2,054
35–60 miles	North					1		4	32	11	48
65–90 miles	do							1	6	6	13
95–120 miles	do								2	7	9
125–150 miles	do									2	2
155–180 miles	do									1	1
185–210 miles	do										
215–240 miles	do										
245–270 miles	do									1	1
Total		14	240	53	71	554	747	263	199	302	2,443

Table 23.—*Effect of length on migratory tendencies of shrimp from Atlantic coast*

[Migratory shrimp are those recaptured 35 or more miles from release point]

Length	Number recaptured	Number migratory	Percent migratory
10.5 cm. and smaller	199	4	2.0
11 to 12.5 cm.	960	49	5.1
13 cm. and larger	2,443	389	15.9

We have considerably more information, all negative, on the subject of large shrimp moving offshore. During the winter and early spring of 1940 we explored the area from Cape Hatteras to Cape Canaveral in depths between 5 and 100 fathoms and, although we caught other species of shrimp, we did not find a single specimen of *P. setiferus* more than about 8 miles from the coast. Furthermore, despite the intensive commercial fishing, our own exploratory fishing, and that of Springer and Bullis (1952) in the Gulf of Mexico out to 100 fathoms, the greatest known depth in which *P. setiferus* has been taken is 43 fathoms. This record was reported by Springer and Bullis. The white shrimp is usually taken by the commercial fishery in the Gulf of Mexico in depths of less than 20 fathoms, and these shallow waters seem to be its normal habitat. On the Atlantic coast this species does not appear to frequent the depths attained by it in the Gulf. The probable explanation for this is the lack of suitable feeding grounds in the deeper waters along the Atlantic coast.

Our findings lead us to conclude that the bulk of the shrimp of the Atlantic coast, after migrating from inshore to offshore waters, do not move into very deep water far from the coast. Instead, they execute seasonal migrations parallel to the shoreline, moving southward during the fall and early winter, and northward in late winter and early spring. During late spring and summer, their movements are limited and random, so that they remain relatively stationary. The larger specimens are much more prone to move considerable distances than are the smaller ones.

NORTHERN GULF EAST OF THE MISSISSIPPI RIVER

In areas 27 to 29, between Mobile Bay and the mouth of the Mississippi River (fig. 20), we released marked shrimp only during September, October, November, and December; consequently our remarks refer only to the fall and winter movements of the shrimp in these areas. Only one shrimp from the December releases was recaptured, and this in zone *c* in December.[5] Hence, the remaining recaptures during December and later were from September, October, and November releases. All of our releases were in inside waters.

In 1939, when we carried out our tagging program in this area, fishing occurred throughout the year, but the intensity shifted towards the mouth of the Mississippi River during winter, as the shrimp were more abundant there at that time. Our exploratory fishing did not reveal concentrations of white shrimp in depths greater than those covered by the commercial fishery.

Most of the ocean bottoms of the outside littoral waters off the Alabama and Mississippi coasts (other than those immediately adjacent to the outlying islands, and principally the passes between the islands) are barren wastes of sand and shell. There probably is little or no food

[5] In our discussion of movements in the northern Gulf of Mexico and in Texas we have subdivided each area into depth zones. Zone *a* represents inside waters as we have already defined them; zones *b* to *f* are outside waters with depths as follows: *b*, 0 to 4½ fathoms; *c*, 5 to 8½ fathoms; *d*, 9 to 12½ fathoms; *e*, 13 to 16½ fathoms; *f*, 17 fathoms and deeper.

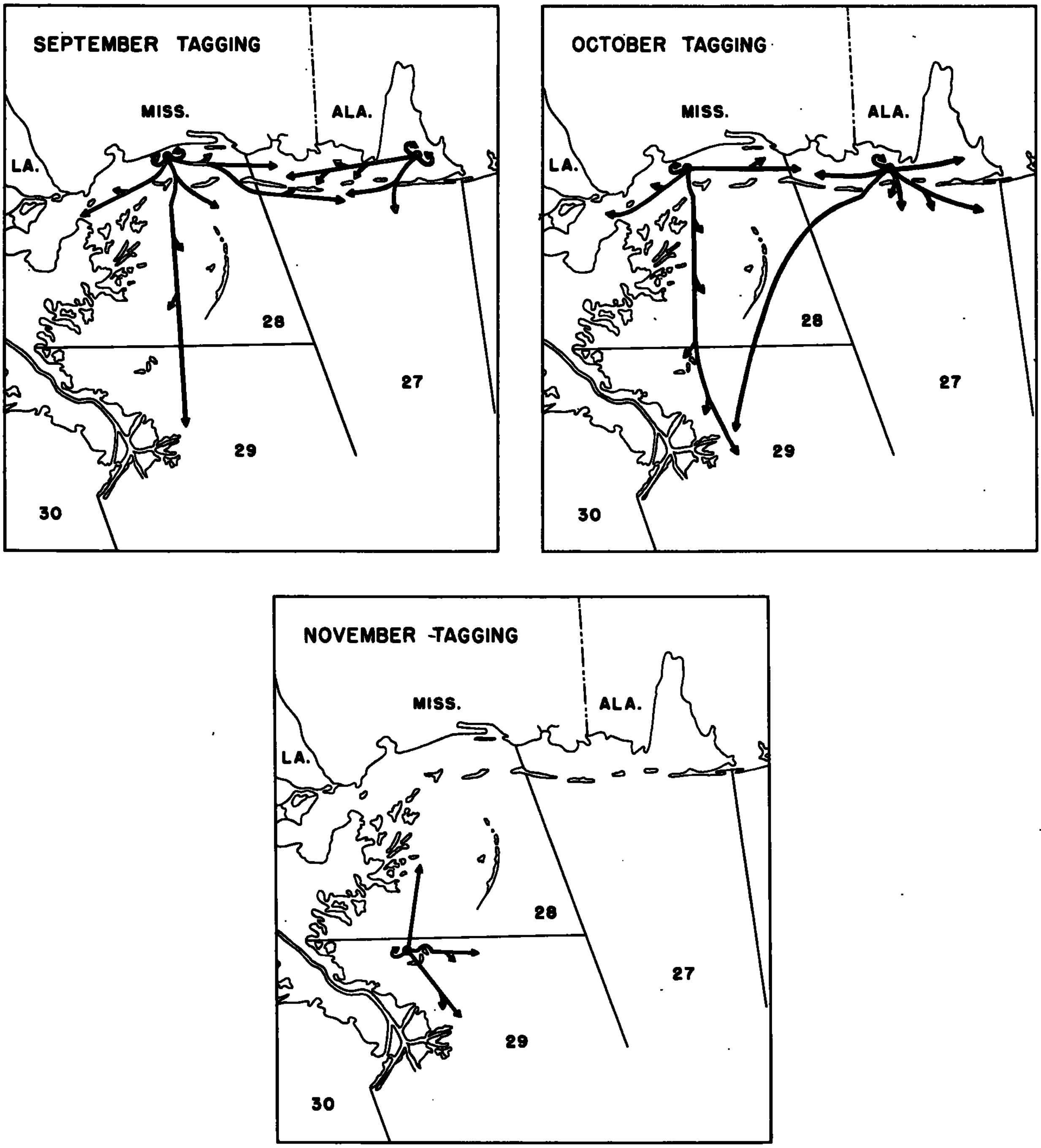

FIGURE 20.—Movements of marked shrimp released in the northern Gulf of Mexico east of the Mississippi River during September, October, and November. See figure 17 for further explanation.

for large shrimp in these areas. Near the delta of the Mississippi River, the bottom, although it shelves off rapidly, consists mostly of mud with an abundance of food. Probably because of this, the large shrimp in this region tend to seek the deeper waters near the mouth of the Mississippi River as winter progresses. Tables 24 and 25 indicate this tendency of the large shrimp, and some of the small ones, to invade area 29. The data presented in tables 26 and

TABLE 24.—*Recaptures of small shrimp (less than 13 cm.) released in Gulf of Mexico, by area of release and by month and area of recapture*

Released in—	Recaptured in month—	Number recaptured in area—														Total
		27	28	29	30	31	32	33	34	35	36	37	38	Unknown	All areas	
Area 27	September	43													43	141
	October	54													54	
	November	31													31	
	December	10													10	
	January	3													3	
Area 28	September		92												92	200
	October		86												86	
	November		16	3											19	
	December		1	2											3	
Area 30	September				16										16	215
	October				13	1									14	
	November				42	6									48	
	December				117										117	
	January				12										12	
	February				2									2	4	
	March					1									1	
	April					1	1								2	
	May					1									1	
Area 31	November					4									4	278
	December					2									2	
	January						2								2	
	February						3								3	
	March					199	4	1							204	
	April					30	4								34	
	May					12	11								23	
	June					5	1								6	
Area 32	March					32	3								35	45
	April					3	1							1	5	
	May					1	3								4	
	June							1							1	
Area 37	November											4			4	4
Area 38	August												3		3	211
	September												29		29	
	October												127		127	
	November												50		50	
	December												2		2	

TABLE 25.—*Recaptures of large shrimp (13 cm. and longer) released in Gulf of Mexico, by area of release and by month and area of recapture*

Released in—	Recaptured in month—	Number recaptured in area—																	Total
		27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	All areas	
Area 27	September	22																22	179
	October	71																71	
	November	72																72	
	December	12		2														14	
Area 28	September		197															197	576
	October	4	181	1														186	
	November	34	129	9														172	
	December	1		20														21	
Area 29	December			78														78	83
	January		1															1	
	March			2														2	
	April			2														2	
Area 30	August				2													2	271
	September				57													57	
	October				38	6												44	
	November				82	11												93	
	December				54	1												55	
	January				10													10	
	February				3	2	1											6	
	March					2	1											3	
	April						1											1	
Area 31	December					5												5	159
	January					2	2	1										5	
	February					3	2											5	
	March				1	44	15											60	
	April					21	19	2										42	
	May					25	13											38	
	June					1	2	1										4	
Area 32	December						3											3	588
	January					3	24	2										29	
	February					21	54											75	
	March				1	72	174	12										259	
	April					46	71	7										124	
	May				1	29	50	8										88	
	June					1	5	2										8	
	July						1											1	
	August						1											1	

TABLE 25.—*Recaptures of large shrimp (13 cm. and longer) released in Gulf of Mexico, by area of release and by month and area of recapture*—Continued

Released in—	Recaptured in month—	Number recaptured in area— 27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	All areas	Total
Area 37	November											1						1	1
Area 38	August												3					3	365
	September												36					36	
	October												186					186	
	November												134					134	
	December												6					6	
Area 41	March														26			26	118
	April														63	3		66	
	May													7	16			23	
	June												1	1	1			3	
Area 42	March														2			2	19
	April														4	1		5	
	May												1		2			3	
	June													3	1		1	5	
	July														2	2		4	

27 demonstrate quite clearly the movement from zone *a* to offshore zones during fall and early winter.

No tagged shrimp from areas 27 to 29 were recaptured west of the mouth of the Mississippi River.

At present, all that can be said about the movements of the shrimp in this region is that during the fall and winter they tend to move into deeper water and toward the mouth of the Mississippi River.

NORTHERN GULF WEST OF THE MISSISSIPPI RIVER

Between the mouth of the Mississippi River and western Louisiana (areas 30 to 32), we released marked shrimp from the latter part of August until March (table 28). In this region, therefore, our remarks pertain only to the fall, winter, and spring movements of shrimp (figs. 21–24).

During the years we tagged, the inside waters were closed to fishing from about mid-June until mid-August, but during the rest of the year they were subjected to relatively heavy fishing. In the outside waters, fishing occurred throughout the year, although it was probably most intense during winter and spring, when a part of the inshore fleet moved into outside waters. Fishermen in this region (judged by the depths to which the fleet fished and the maximum depths at which we caught white shrimp in our exploratory fishing), fished the entire population of adult and subadult shrimp.

The specimens we marked in inside waters displayed the typical movement to outside waters (tables 26 and 27). Once the shrimp reached outside waters they tended to move offshore and then mill about. Tables 29 and 30 demonstrate this behavior of the shrimp for August, October, and November releases.

TABLE 26.—*Recaptures of small shrimp (less than 13 cm.) released in Gulf of Mexico, by depth of release and by month and depth of recapture*

[Depth zones are as follows: *a*, inside waters, *b* outside waters, 0–4½ fathoms; *c*, outside waters, 5–8½ fathoms; *d*, outside waters, 9–12½ fathoms; *e*, outside waters, 13–16½ fathoms; and *f*, outside waters, 17 fathoms and deeper]

Area and depth of release	Recaptured in month—	Number recaptured in depth zone— *a*	*b*	*c*	*d*	*e*	*f*	All depths	Total
Areas 27–29: Depth zone *a*	September	135						135	343
	October	140						140	
	November	44	4	4				52	
	December	6	1	5	1			13	
	January		3					3	
Areas 30–32: Depth zone *a*	September	16						16	109
	October	7	3					10	
	November	19	18	10				47	
	December	2	18	4				24	
	January		1					1	
	February					2		2	
	March		5		1			6	
	April		1					1	
	May			1	1			2	
Depth zone *b*	November		1					1	193
	December		93	3				96	
	January		8	3				11	
	February			2				2	
	March	24	46					70	
	April	3	2					5	
	May		2	4	1			7	
	June				1			1	
Depth zone *c*	October		3	2				5	234
	November	4	1					5	
	January		2					2	
	February		1					1	
	March	53	103	4	1			161	
	April	16	18		1			35	
	May	2	4	8	5			19	
	June			4	2			6	
Depth zone *d*	March			1	1			2	2
Areas 37–38: Depth zone *a*	August	3						3	202
	September	29						29	
	October	96		24	1			121	
	November	39		8				47	
	December	2						2	
Depth zone *b*	October			2				2	7
	November			5				5	
Depth zone *d*	October			4				4	6
	November			2				2	

Our tables also show an inshore movement during March and April, and a tendency for the shrimp to move offshore again in May and June. We think that the return to shallower waters during spring is an anomaly which is emphasized in the data by the fact that many of our releases were made during the winter of 1939–40, in which an unusual cold wave occurred in January. After the cold wave, the fishermen reported many dead shrimp in inside waters and small shrimp much further offshore than usual for that time of year.

The observations of the fishermen were corroborated by our own investigations when, on the last day of February and early in March 1940, we marked random samples consisting of 3,160 of these small shrimp in depths *b* and *c*. According to random samples of shrimp from the commercial fishery, in this region we should normally expect to find, in depth *c*, less than 1 percent of the shrimp to be smaller than 13 cm. in total length in February; in March the normal value is about 2 percent. In depth *b* we should expect about 2.5 percent of the shrimp to be less than 13 cm.

TABLE 27.—*Recaptures of large shrimp (13 cm. and longer) released in Gulf of Mexico, by depth of release and by month and depth of recapture*

[Depth zones are as follows: *a*, inside waters; *b*, outside waters, 0–4½ fathoms; *c*, outside waters, 5–8½ fathoms; *d*, outside waters, 9–12½ fathoms; *e*, outside waters, 13–16½ fathoms; and *f*, outside waters, 17 fathoms and over]

Area and depth of release	Recaptured in month—	Number recaptured in depth zone—							Total
		a	*b*	*c*	*d*	*e*	*f*	All depths	
Areas 27–29:									
Depth zone *a*.	September	219						219	836
	October	251	5					256	
	November	202	9	30	2			243	
	December	14	19	78	2			113	
	January	1						1	
	March		1	1				2	
	April				2			2	
Areas 30–32:									
Depth zone *a*.	August	1	1					2	117
	September	56	1					57	
	October	6	3	2	1	1		13	
	November	11	10	4				25	
	December	1	8					9	
	January		2		1			3	
	February				2	1		3	
	March		3					3	
	April		1		1			2	
Depth zone *b*.	October		16	8	1			25	180
	November		50	7	3	1		61	
	December		41	2	3			46	
	January		7	2				9	
	February			3				3	
	March	2	19	2	1			24	
	April		6					6	
	May		2	1	1			4	
	June		1		1			2	
Depth zone *c*.	October		3	1				4	182
	November	1	3	3				7	
	December		5					5	
	January		2	1	1			4	
	February			1	7	2	3	13	
	March	5	43	4	13	1		66	
	April	4	17	8	12			41	
	May	2	7	19	11			39	
	June			1	2			3	
Depth zone *d*.	December				3			3	537
	January		2	5	12	10		29	
	February		1	17	40	8		66	
	March	1	73	79	74	5		232	
	April		43	31	39	2		115	
	May	1	22	42	17	2		84	
	June			1	5			6	
	July				1			1	
	August				1			1	
Areas 37–38:									
Depth zone *a*.	August	3						3	272
	September	36						36	
	October	109		47				156	
	November	36		35				71	
	December	5		1				6	
Depth zone *b*.	October			20				20	76
	November	3		53				56	
Depth zone *d*.	October			11				11	18
	November			7				7	

TABLE 28.—*Depths and dates of release of tagged shrimp in areas 30 to 32*

[Depth zones are as follows: *a*, inside waters; *b*, outside waters, 0–4½ fathoms; *c*, outside waters, 5–8½ fathoms; *d*, outside waters, 9–12½ fathoms]

Released in month of—	Years in which releases were made in depth zone—			
	a	*b*	*c*	*d*
August	1939			
October	1939	1939	1939	
November	1939		1939	
December	1938	1938	1938	1939
January		1939, 1940	1939	1939, 1940
February		1940	1940	
March		1940	1940	1940

TABLE 29.—*Monthly recaptures of tagged shrimp, arranged according to month of release and number of depth zone shrimp were recaptured inshore and offshore from release depth*

[Release depth is zero. Releases in depth zones *a* (inside waters) and *b* (outside waters, 0–4½ fathoms) only. Areas 30–32]

Released in month of—	Recaptured in month of—	Depth zones from release zone						Total
		Inshore	Release depth	Offshore				
		1	0	1	2	3	4	
August	August		1	1				85
	September		72	1				
	October		1	3		1	1	
	November			2				
	December			1				
	April			1				
October and November	October		28	11	3			214
	November		81	33	17	1		
	December		5	10	3			
	January			2		1		
	February					2	3	
	March			8	1	1		
	April			1		1		
	May				1	1		
December and January	December		131	20	4			188
	January		15	6				
	February			5				
	March		4					
	April	1	1					
	June		1					
February and March	March	26	61	2				112
	April	2	7					
	May		4	5	2			
	June		1		2			

TABLE 30.—*Monthly recaptures of tagged shrimp, arranged according to month of release, and number of depth zones shrimp were recaptured inshore and offshore from release depth*

[Release depth is zero. Releases in depth zones *c* (outside waters, 5-8½ fathoms) and *d* (outside waters, 9-12½ fathoms) only. Areas 30-32]

Released in month of—	Recaptured in month of—	Depth zones from release zone: Inshore 3	Inshore 2	Inshore 1	Release depth 0	Offshore 1	Offshore 2	Offshore 3	Total
October and November.	October	----	----	6	3	----	----	----	29
	November	----	5	4	3	----	----	----	
	December	----	----	5	------	----	----	----	
	February	----	----	----	------	1	----	----	
	March	----	----	----	------	1	----	----	
	April	----	1	----	------	----	----	----	
December and January.	December	----	----	----	3	----	----	----	391
	January	----	2	9	13	11	----	----	
	February	----	1	18	41	14	2	3	
	March	1	40	37	45	15	1	----	
	April	----	26	21	22	6	----	----	
	May	1	13	26	11	2	----	----	
	June and August.	----	----	1	6	----	----	----	
February and March.	March	----	91	190	37	3	----	----	535
	April	----	36	45	25	9	----	----	
	May	----	13	27	33	16	----	----	
	June	----	----	----	6	4	----	----	

long in March (we have no data for February). In February of 1940, however, 81 percent of our marked shrimp taken in depth *c* were less than 13 cm. in length, while in March 94 percent were of this small size. In depth *b*, these small specimens constituted 62 percent of the catch in February and 23 percent in March.

The migrations of these small shrimp are clearly shown by our tagging results. From the data presented in table 31 it is evident that the small shrimp were the ones that went towards the shore after release. They had evidently been driven offshore by the excessively low temperatures of the inshore waters during the cold wave, but they returned to their usual habitat when the temperatures became normal in March (fig. 37). Then in May and June they made the typical spawning movement and reentered the deeper waters (table 32).

Probably a more nearly typical spring distribution is demonstrated by shrimp marked in offshore waters before January (table 33). In the outside waters, though the shrimp move about in all depths (mostly between depths *b* and *d*), there is a tendency for the largest shrimp to seek the deepest waters. During fall, winter, and spring, only occasionally will shrimp less than 13 cm. in length be found in depths greater than 5 fathoms (table 34).

TABLE 31.—*Recaptures by depth and by size of shrimp released in depths* b *and* c *during February and March 1940*

[Areas 30-32. Depth zones are as follows: *a*, inside waters; *b*, outside waters, 0-4½ fathoms; *c*, outside waters, 5-8½ fathoms; *d*, outside waters, 9-12½ fathoms]

Recaptured in depth zone—	Number recaptured, of shrimp whose lengths at tagging were—: 10 cm. and less	10.5-12.5 cm.	13-15 cm.	15.5 cm. and more	Percentage recaptured, shrimp whose lengths at tagging were—: 10.5-12.5 cm.	13-15 cm.	15.5 cm. and more
a	2	94	13	------	32.1	10.1	------
b	2	170	74	19	58.0	57.4	57.6
c	1	19	22	9	6.5	17.1	27.3
d	------	10	20	5	3.4	15.5	15.2
Total	5	293	129	33	100.0	100.1	100.1

TABLE 32.—*Recaptures, by depth and month, of tagged shrimp released in depths* b *and* c *during February and March 1940*

[Areas 30-32. Depth zones are as follows: *a*, inside waters; *b*, outside waters, 0-4½ fathoms; *c*, outside waters, 5-8½ fathoms; *d*, outside waters, 9-12½ fathoms]

	Number recaptured in month of—: March	April	May	June
Released in depth zone *b* and recaptured in depth zone—				
a	26	2	------	------
b	61	7	4	1
c	2	------	5	------
d	------	------	2	2
Total	89	9	11	3
Released in depth zone *c* and recaptured in depth zone—				
a	58	19	4	------
b	146	35	11	------
c	5	8	26	5
d	3	8	16	4
Total	212	70	57	9

TABLE 33.—*Recaptures, by depth of release and by month and depth of recapture, of shrimp tagged before January*

[Areas 30-32. Depth zones are as follows: *a*, inside waters; *b*, outside waters, 0-4½ fathoms; *c*, outside waters, 5-8½ fathoms; *d*, outside waters, 9-12½ fathoms; *e*, outside waters, 13-16½ fathoms; *f*, outside waters, 17 fathoms and deeper]

	Number recaptured in depth zone—: *a*	*b*	*c*	*d*	*e*	*f*	Total recaptured
Released in depth zones *a*, *b*, and *c* and recaptured in month of—							
December	3	165	9	3	------	------	180
January	------	22	6	2	------	------	30
February	------	1	5	4	4	1	15
March	------	8	1	6	------	------	15
April	1	2	------	2	------	------	5
May	------	------	2	1	------	------	3
Released in depth zone *d* and recaptured in month of—							
December	------	------	------	3	------	------	3
January	------	2	4	12	1	------	19
February	------	------	11	12	1	------	24
March	------	6	17	10	4	------	37
April	------	5	9	8	------	------	22
May	------	2	11	3	1	------	17
June	------	------	------	1	------	------	1
July	------	------	------	1	------	------	1

TABLE 34.—*Recaptures, by depth and by size, of shrimp for three different release depths*

Areas 30–32. Depth zones are as follows: *a*, inside waters; *b*, outside waters, 0–4½ fathoms; *c*, outside waters, 5–8½ fathoms; *d*, outside waters, 9–12½ fathoms]

Released in depth zone—	Released in *month of*—	Recaptured in depth zone—	Number recaptured, of shrimp whose lengths at tagging were—				Percent recaptured, of shrimp whose lengths at tagging were—			
			10 cm. and less	10.5–12.5 cm.	13–15 cm.	15.5 cm. and more	10 cm. and less	10.5–12.5 cm.	13–15 cm.	15.5 cm. and more
b	October, December, and January	*a*		1				1.0		
		b	13	92	69	48	100.0	91.1	85.2	71.6
		c		8	10	12		7.9	12.3	17.9
		d and deeper			2	7			2.5	10.4
		All	13	101	81	67	100.0	100.0	100.0	99.9
c	October, November, December, and January	*a*		5	1			38.5	4.2	
		b		6	6	8		46.2	25.0	25.8
		c		1	5	5		7.7	20.8	16.1
		d and deeper		1	12	18		7.7	50.0	58.1
		All		13	24	31		100.1	100.0	100.0
d	December, January, and March	*a*			1	1			0.6	0.3
		b			64	77			37.9	21.0
		c		1	46	128		50.0	27.2	34.9
		d and deeper		1	58	161		50.0	34.3	43.9
		All		2	169	367		100.0	100.0	100.1

No shrimp marked in areas 30 to 32 were recaptured east of the mouth of the Mississippi River, or in Texas waters. They concentrated mostly in areas 31 and 32 and the eastern part of 33 (tables 24 and 25). This section between Ship and Trinity Shoals probably provides the most favorable outside feeding grounds for shrimp in this region. We believe the more or less aimless wanderings of the shrimp (but not the offshore and onshore movements) represent a search for food.

In brief, along the Louisiana coast west of the Mississippi River the large shrimp move offshore and scatter during fall and winter. At all times they appear to be drifting about, like cattle on open rangeland. The only definite patterns were those of the offshore and onshore movements, which evidently were associated with temperature changes and spawning, and a tendency to concentrate between Ship and Trinity Shoals, probably because of better feeding conditions.

There appeared to be a natural barrier at the Mississippi River, for we found neither east-west nor west-east crossings.

CENTRAL TEXAS

At the time we ran our tagging experiments in central Texas there was no fishing along the Mexican coast and no outside fishing during winter near the mouth of the Rio Grande, and the outside fishing near Port Aransas was limited to an area of narrow radius near the pass. There was no more or less continuous coastwise fishing along the entire coast, as there has been in recent years. Consequently, all of our recaptures were made close to the points of release (fig. 25, tables 24–27) and once our marked shrimp left the restricted area covered by the fishing fleet we could no longer follow them. As a matter of fact, for this very reason we discontinued tagging in Texas, once we had established that the shrimp were moving from inside waters to outside waters in accordance with the evidence we had obtained from the size-distribution pattern.

The fact that the larger of our marked specimens disappeared soon after reaching outside waters off Port Aransas, indicates only that they left this area; they could have gone farther offshore or to the north or south beyond the range of the fishing fleet. We believe it most likely that they went south, because in winter the waters are warmer to the south and because there appears to be a northward return of the shrimp in spring, as is suggested by a tagging experiment along the coast of Tamaulipas, Mexico, to be discussed in the next section.

Probably the migration pattern, for at least part of the western Gulf, is comparable to that along the southern Atlantic coast. We also think it probable that the shrimp reared in the vicinity of Galveston, Tex., move as do those in areas 30–32.

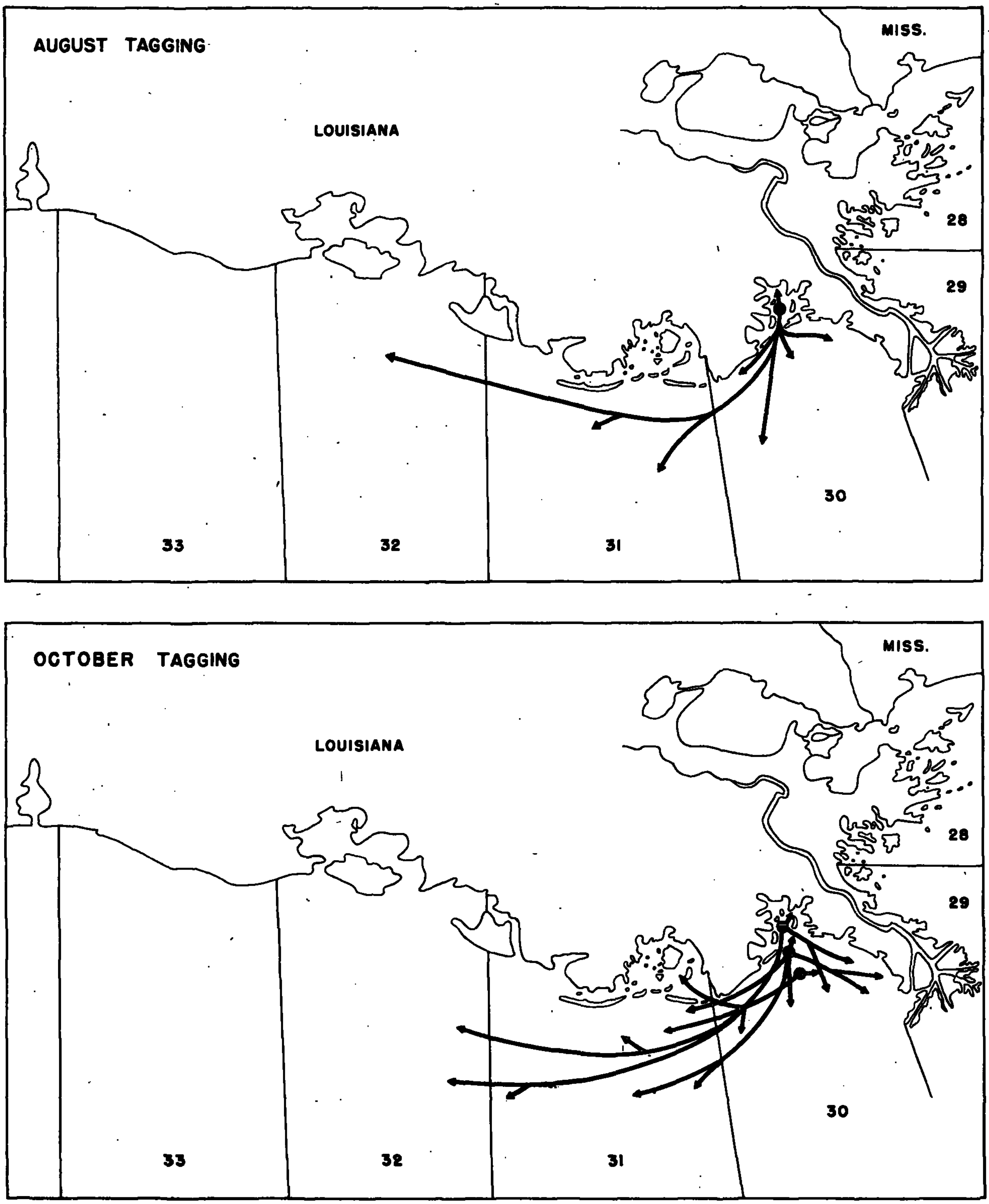

FIGURE 21.—Movements of marked shrimp released in the northern Gulf of Mexico west of the Mississippi River during August and October. See figure 17 for further explanation.

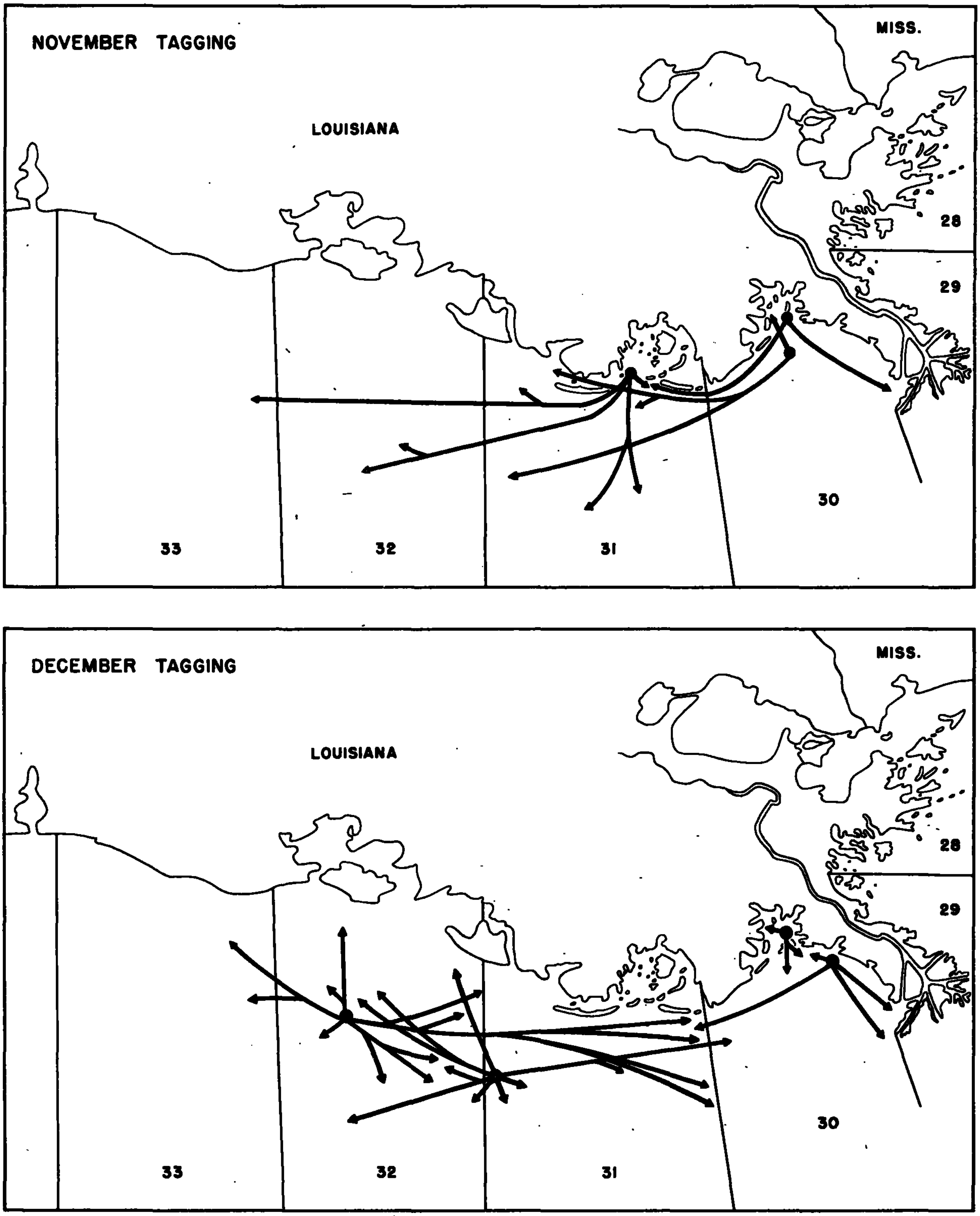

FIGURE 22.—Movements of marked shrimp released in the northern Gulf of Mexico west of the Mississippi River during November and December. See figure 17 for further explanation.

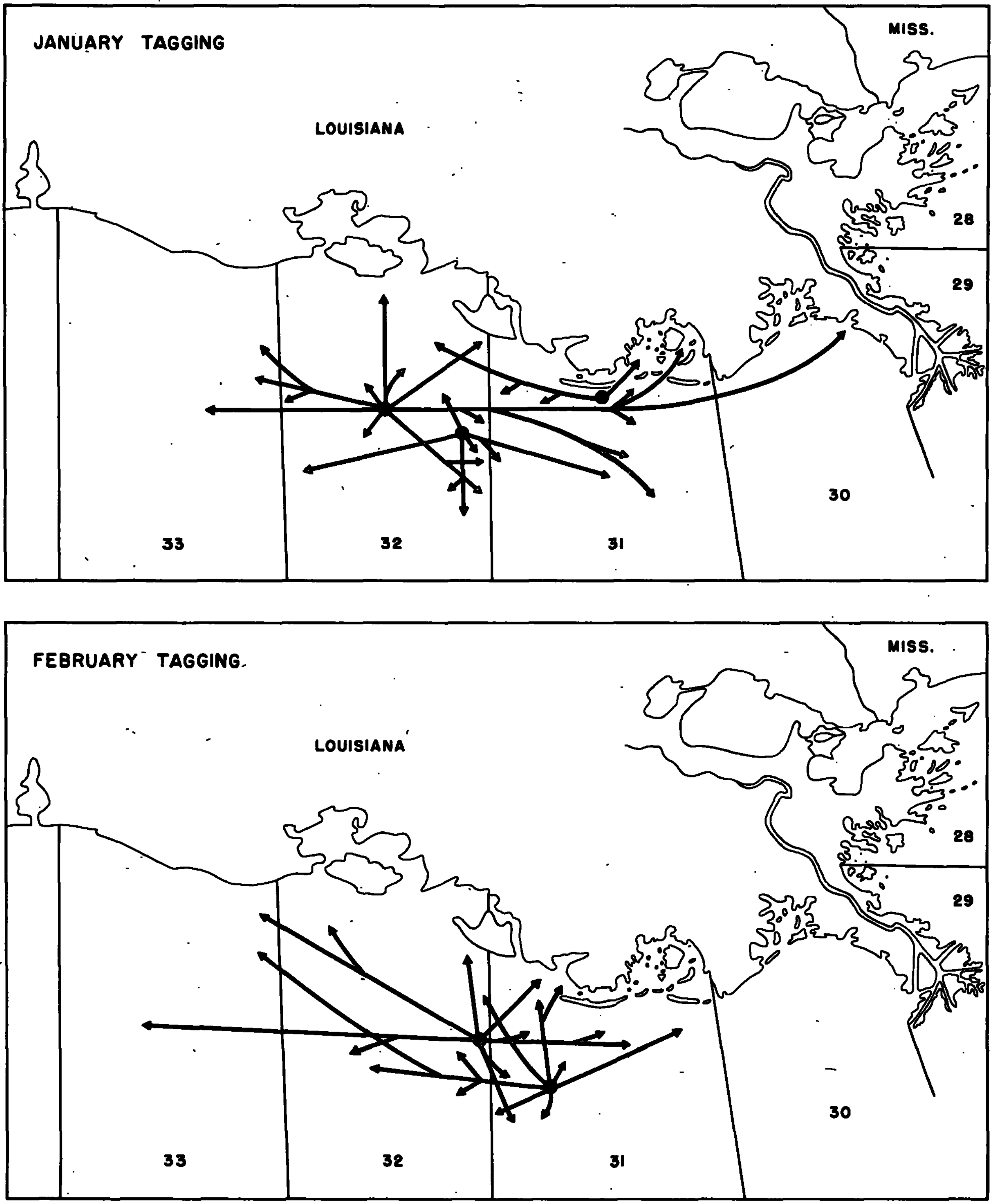

FIGURE 23.—Movements of marked shrimp released in the northern Gulf of Mexico west of the Mississippi River during January and February. See figure 17 for further explanation.

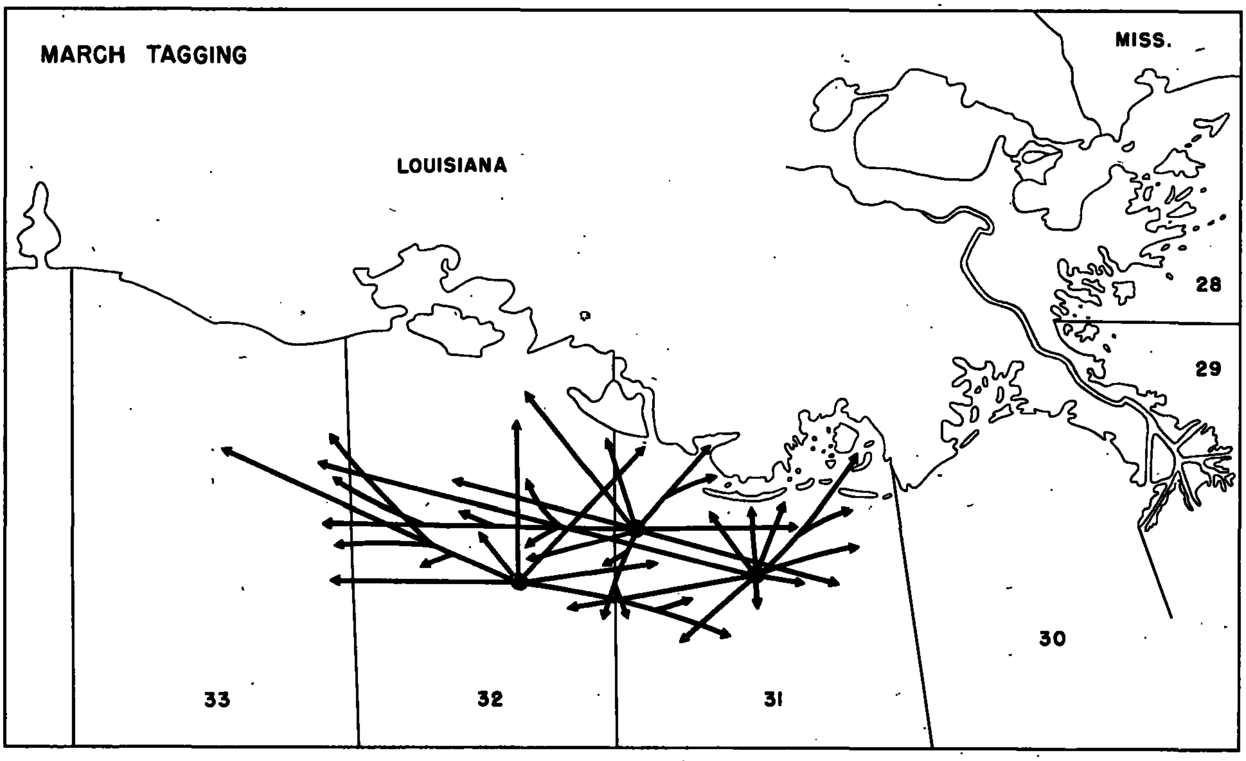

FIGURE 24.—Movements of marked shrimp released in the northern Gulf of Mexico west of the Mississippi River in March. See figure 17 for further explanation.

NORTHERN MEXICO

At the time we tagged shrimp along the coast of Tamaulipas, Mexico (March 1947), there was a large fleet of shrimp boats operating out of Brownsville, Tex. Fishing was intense near the mouth of the Rio Grande. For this reason our returns were mostly from near the mouth of this river (area 40). Perhaps more returns are shown as coming from near the mouth of the Rio Grande than actually occurred, as it is probable that some shrimp caught in Mexican waters were reported as having been captured north of the border.

Inasmuch as there was no fishing (or very little) to the south of area 40, returns would have to come from area 40 and to the north. Consequently, the movements of the shrimp released in areas 41 and 42 (table 25 and fig. 26) might be merely normal feeding movements. Area 41 is closer to the region of heavy fishing than is area 42; this would account for the difference in the percentage of returns from the releases in area 42 (5 percent) and those from area 41 (19.2 percent). Although the large majority of recaptures from these areas had moved considerable distances and appear to indicate a migratory population, it must be remembered that they represent a small percentage of the releases.

Therefore, the majority of the shrimp tagged in March could have been local or nonmigratory shrimp reared in Laguna Madre, Tamaulipas, which were not recaptured because of the total lack of fishing in these areas. Yet (1) in recent years there has been a spring run of shrimp striking first (about March) near the Rio Grande and later (about May) near Aransas Pass, Tex. (2) Of the recaptured shrimp marked in areas 30 to 32 (Louisiana) less than 1 percent moved more than 75 miles, whereas about 17 percent of those recaptured after tagging in Mexico moved more than this distance; the greatest distance between release and recapture along the Louisiana coast was about 110 miles, whereas 5 of the recoveries from our Mexican releases were taken at distances greater than this (the greatest distance, about 175 miles). (3) The water temperatures during winter off the coast of Mexico are warmer than they are

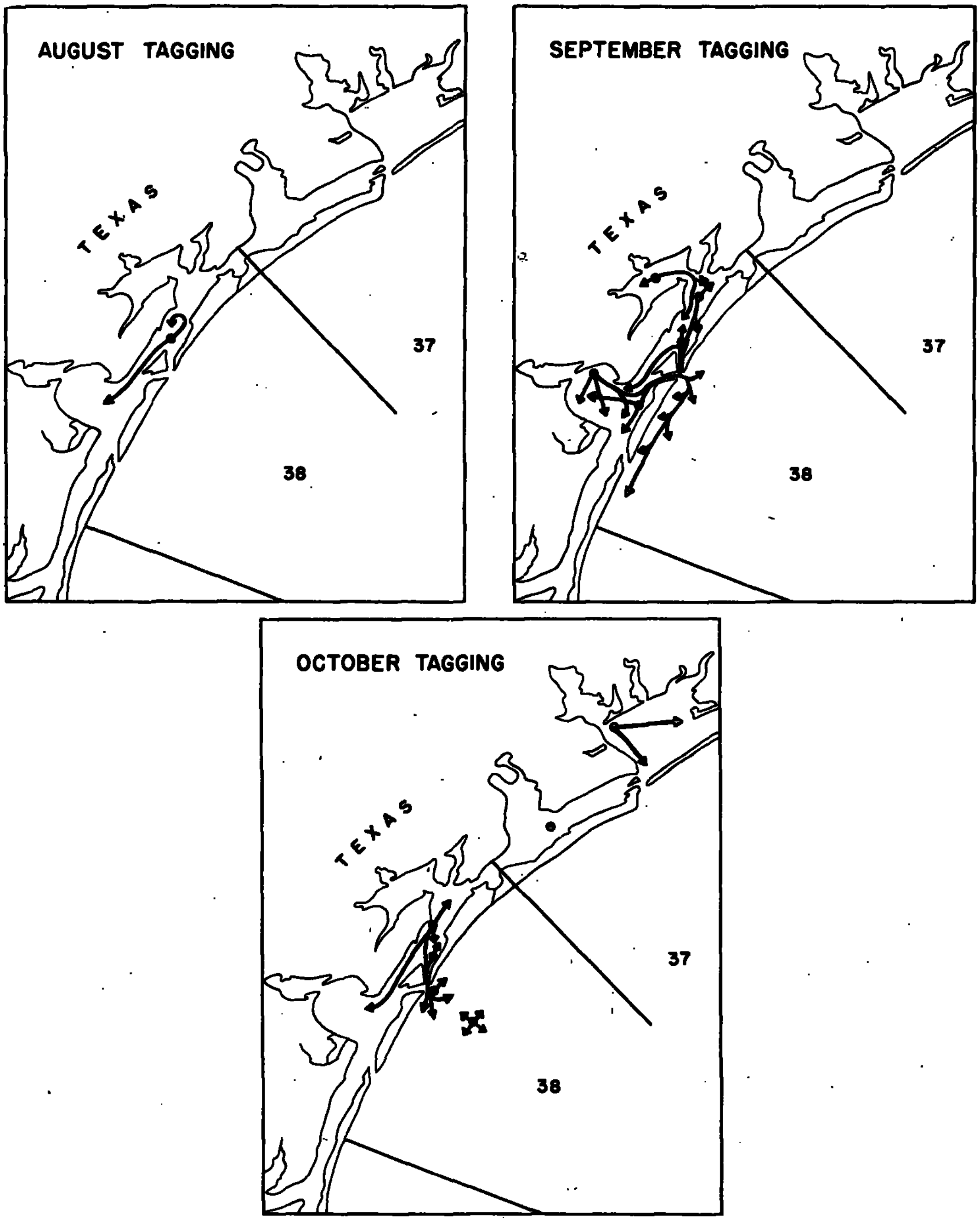

FIGURE 25.—Movements of marked shrimp released in central Texas during August, September, and October. See figure 17 for further explanation.

in Texas. The evidence, therefore, seems to favor a springtime south-to-north migration.

Our data are not adequate to establish this point, but if such a spring migration occurs it is also likely that during the fall and winter there is a reciprocal southward movement of larger shrimp from central and southern Texas into northern Mexico.

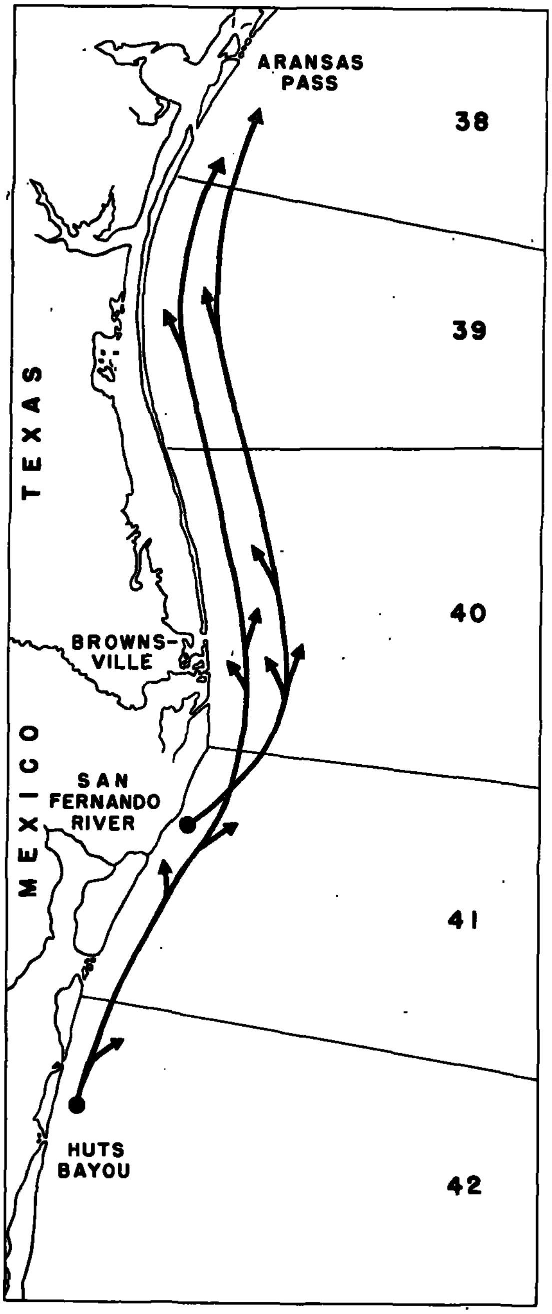

FIGURE 26.—Movements of marked shrimp released along the northern coast of Mexico during March. See figure 17 for further explanation.

SPAWNING AND LONGEVITY

Weymouth, Lindner, and Anderson (1933) have shown that when the young (spring-spawned) shrimp first appear on the inside fishing grounds (in June or July, depending on the locality) they can readily be distinguished from the spawning population both by size and by sexual development. By September, the largest of the spring-spawned shrimp have attained the length of the smallest of the mature shrimp spawned the previous summer, and the two groups overlap in total length. At the same time, many of the mature females have completed spawning and are beginning to enter a stage in which it is impossible, by ovarian examination alone, to distinguish them from the larger spring-spawned females. With the approach of maturity, various morphological changes took place in the shrimp, which made it possible to separate immature spring-spawned individuals from spent mature shrimp until December, but by January the spring-spawned specimens began assuming the adult characteristics and we could no longer distinguish them.

SPAWNING

In the field we recognized five successive stages of ovarian development: Undeveloped; developing; yellow; ripe; and spent.[6] Unfortunately, most of our field records of ovarian development are incomplete, as we were unable to work out a satisfactory technique for field determination of spent shrimp until late in 1941. Before December 1941, recently spent shrimp, during and immediately following the spawning season, usually were classed by us as "developing" or in an early "yellow" stage; those not recently spent, the ovaries of which during fall and early winter were actually more or less dormant, were usually classed as "undeveloped," but when they began to approach a second spawning season were classed as "developing."

Louisiana

Because of the complications just mentioned, we have only one year (December 1941 to November 1942) for the Louisiana offshore fishery [7] in which we believe our records are complete with

[6] See King (1948) for a description of these various stages.

[7] We have divided the Louisiana fishery into two sections (Anderson, Lindner, and King, 1949) based on fishing grounds. The inshore fishery includes the inside waters (bays and bayous) and the outside waters out to about 5 fathoms. This area was fished by shallow-draft luggers, and it also represents the area covered by our research boat *Black Mallard*. About the beginning of 1938, a group of Florida-type trawlers migrated to Louisiana and began fishing the offshore area (outside waters from about 5 to 35 fathoms, although the boats usually did not go much beyond 20 fathoms). This area had never been fished extensively by the inshore fleet. After the offshore fishery was developed, some of the larger boats from the inshore fleet would fish offshore on occasions. The offshore fleet, however, never fished the inside or estuarine waters. Generally the areas fished by the two fleets were quite distinct.

respect to maturation and spawning. In figure 27 we show the size distribution of the five different ovarian stages from random samples taken from the offshore fleet during this period. This figure is plotted in percentages, with the total number of females examined in any month equal to 100 percent. Inasmuch as the ripe and spent shrimp were only a small percentage of the population and difficult to follow in figure 27, we have shown these separately and by actual numbers in figure 28.

Following the progression of these curves (fig. 27), we find that in December the largest females had spent ovaries, although most of them were in a resting stage and appeared undeveloped. The majority of these were probably summer spawners. These spent shrimp constituted less than 2½ percent of the specimens in our samples; all of the others were spring-spawned and had undeveloped ovaries. By January (we could no longer distinguish between shrimp which had previously spawned and those which were maturing for the first time) many had developing ovaries and a few were in the yellow stage. The first ripe shrimp appeared in March and the first spent ones in April. No shrimp with undeveloped ovaries remained in April. In May a second group of females approaching spawning began making their appearance in the shallow waters of the offshore fishery. These were smaller than their predecessors. Most of them had undeveloped or developing ovaries, and some had yellow ovaries. By June this second group of spawners dominated the offshore fishery which had now largely moved into comparatively shallow water; many were ripe, and a number were spent. In August the immature spring-spawned shrimp began making their appearance offshore. By September the spring-spawned shrimp dominated the fishery, the majority of the mature shrimp were spent, and there were none with developing ovaries. By October there were neither developing nor ripe shrimp and very few with yellow ovaries. Almost all the mature shrimp were spent by October.

The duration of the spawning season in Louisiana can be seen best in figure 29, which shows the percentage of females for each month with developing, yellow, ripe, and spent ovaries. We have eliminated (on the bases previously described) all immature shrimp from August through November; consequently this figure follows mature individuals only. It is apparent that the first ripe shrimp appear in March and the first spent ones in April. It is also evident that spawning is almost completed by the end of September. Since we did encounter (in selected samples) recently spent shrimp in late March and ripe shrimp as late as October, we believe that the earliest spawning occurs during the latter part of March, and that it may extend into October. Judging from the appearance of the young (which we shall treat later, and which is discussed to some extent in Anderson, King, and Lindner, 1949), spawning later than September probably is not effective. For all practical purposes the spawning season extends from the latter part of March or early in April through September.

The sequential appearance of the various ovarian stages (table 35) indicates that the developing stage occupies a period of 1 month or less, the yellow stage persists for from 1 to 2 months, and ripe ovaries become spent in less than a month. Assuming that an ovary may develop from the newly spent stage into the yellow stage in a period of a few days, it may take as much as 3 months or it may take less than 2 months to prepare for a new spawning, if such should occur.

If shrimp spawned but once a year and remained available to the fishery after spawning, we could expect the percentage of spent shrimp to increase markedly month by month. The summer-spawning shrimp, appearing in the shallower waters in June, form the main basis for the fishery almost from the time of their appearance and are detectable in the catches until well after the end of the spawning season. It is interesting that in this well-sampled population the percentage of spent ovaries remained low during June, July, and August; it was not until September that a rapid rise occurred. This phenomenon can easily be explained by assuming that these shrimp spawn twice. The persistence of a low percentage of spent shrimp in the population for 3 months suggests that after spawning these individuals enter a second yellow stage preparatory to production of another batch of eggs.

It is unfortunate that our data are not complete for the spring-spawning shrimp throughout the year. These shrimp, which initiate the spawning season in the deeper waters, were not taken in as large numbers after June as previously, and they became indistinguishable from the summer spawn-

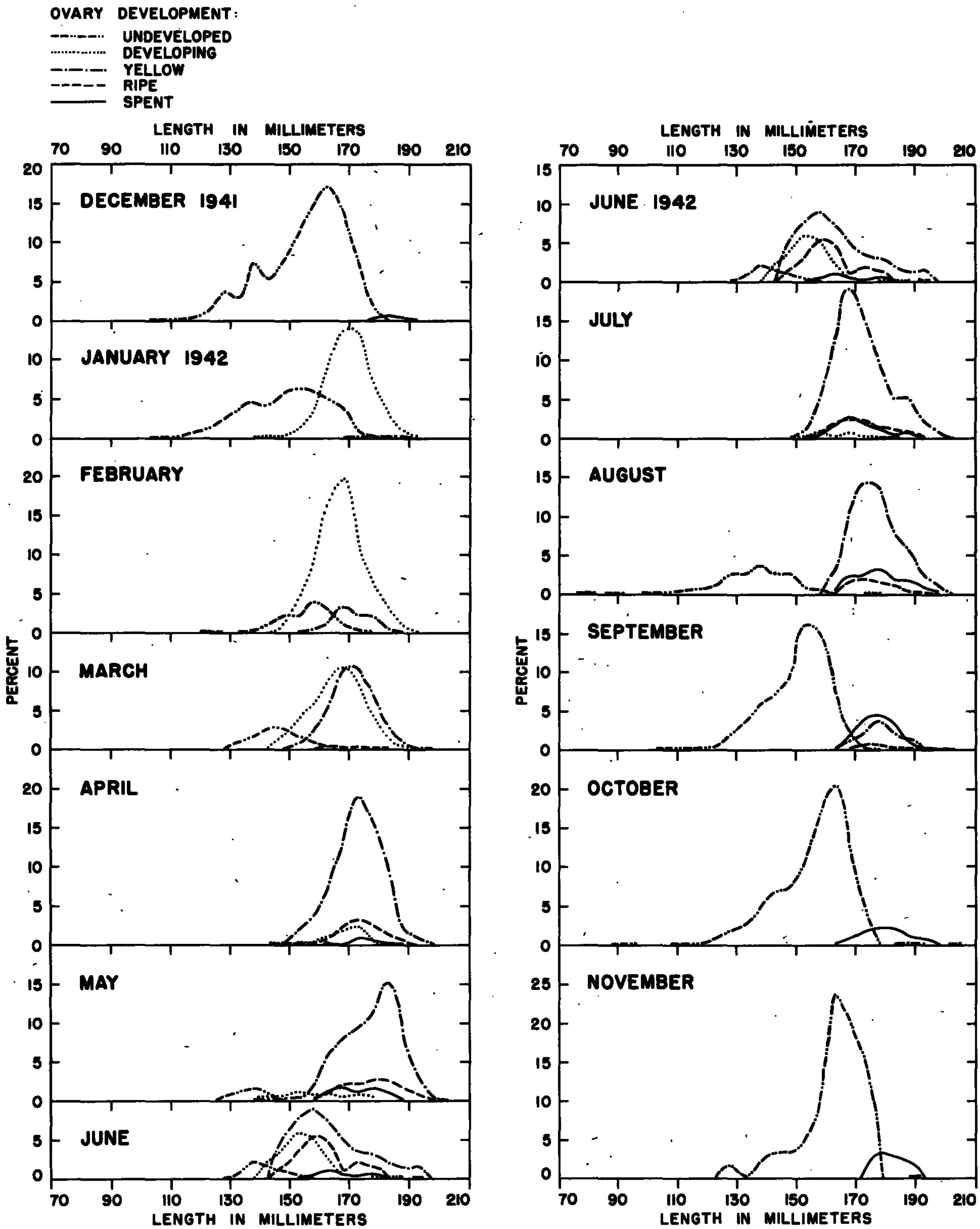

FIGURE 27.—Size distribution of female shrimp according to stage of ovarian development, for the Louisiana offshore fishery from December 1941 to November 1942. The curves represent percentages of the total population each month.

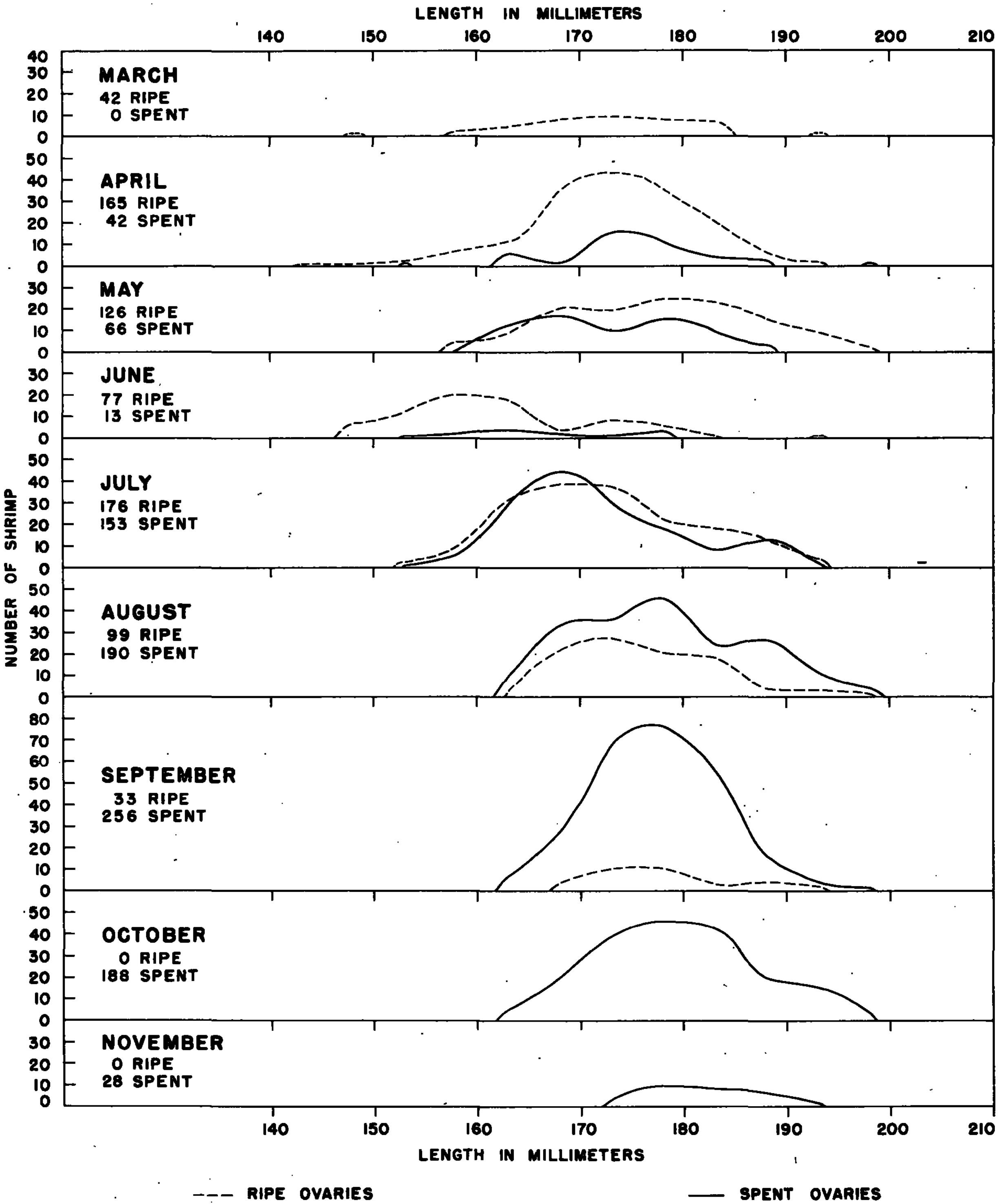

FIGURE 28.—Size distributions by numbers of ripe and spent female shrimp in the Louisiana offshore fishery from March to November 1942.

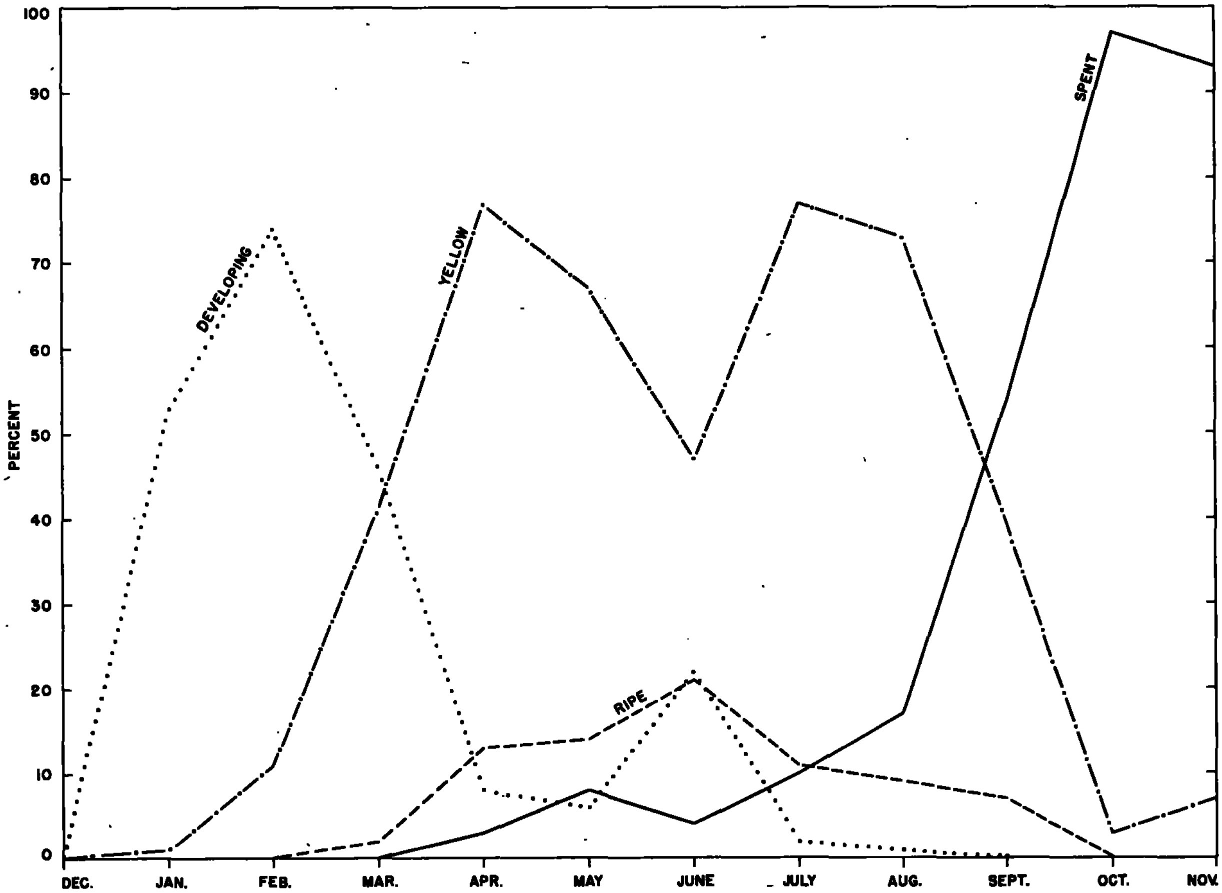

FIGURE 29.—Monthly percentage of female shrimp, according to stage of ovarian development, appearing on the spawning grounds in the Louisiana offshore fishery. The data are from the period December 1941 to November 1942. After August 1942 this figure includes only shrimp approximately 1 year old or more.

ers when the latter group became the mainstay of the fishery. Lack of material on this group in later months makes it impossible to determine the exact proportion of spent individuals during the summer.

How many times an individual shrimp spawns in a single season is unknown; while we have no definite proof that a shrimp spawns more than once, it is possible that the spring-spawning shrimp could spawn as many as four times in a season, if the proportion of spent shrimp in this population remained low throughout summer. King (1948), from histological studies, also believed that a female might spawn more than once during the spawning season, and the evidence of Burkenroad (1939) is not in disagreement.

On the basis of the presence of ripe and recently spent shrimp it may be stated that practically all spawning in Louisiana occurs offshore in depths greater than 4.5 fathoms. Probably most of it takes place between 5 and 17 fathoms (tables 35 and 36). The second group of spawners appearing in May obviously came from a more inshore area (table 35). They first appeared in May in depths under 5 fathoms; by June they were found as deep as 9 to 12½ fathoms. The immature spring-spawned shrimp appearing in August behaved in a similar fashion: they were found only in the shallowest depth in August, but by September they moved out to at least 9 to 12½ fathoms. This latter group, however, did not mature until the following year. We shall follow these various groups in detail when we discuss the size distributions. Here, we are merely trying to establish the location of spawning.

We believe that tables 35 and 36 suggest that the spring spawners deposit their eggs in the deeper waters well offshore early in the season, but that the summer spawners complete the process in lesser depths.[8] It is also suggested that the summer-spawning shrimp, when they have completed spawning, return to lesser depths. Viosca (1920) presented a number of major conclusions with respect to the life history of *P. setiferus* in Louisiana which are in accord with our own findings; it is unfortunate that he never published his data so that they could be compared in detail with ours.

TABLE 35.—*Distribution by stages of ovarian development and by depths, of female shrimp in Louisiana offshore fishery, December 1941 to November 1942*

Month, and stage of ovarian development	Number taken at depth of—						Total
	0-4½ fathoms	5-8½ fathoms	9-12½ fathoms	13-16½ fathoms	17 fathoms and deeper	All depths	
1941							
December:							
Undeveloped	280	633	22			935	958
Developing						0	
Yellow						0	
Ripe						0	
Spent	1	22				23	
1942							
January:							
Undeveloped		979	181	22		1,182	2,560
Developing		997	351	15		1,363	
Yellow		13	2			15	
Ripe						0	
Spent						0	
February:							
Undeveloped		19	71	19	42	151	1,011
Developing		16	410	264	58	748	
Yellow			50	49	13	112	
Ripe						0	
Spent						0	
March:							
Undeveloped			62	190	35	287	2,531
Developing			230	461	471	1,162	
Yellow			304	260	476	1,040	
Ripe				10	32	42	
Spent						0	
April:							
Undeveloped						0	1,322
Developing			3	33	65	101	
Yellow			39	442	533	1,014	
Ripe			4	49	112	165	
Spent			7	7	28	42	
May:							
Undeveloped	40					40	882
Developing	22		10	18	6	56	
Yellow	14		167	333	80	594	
Ripe			39	85	2	126	
Spent			17	43	6	66	
June:							
Undeveloped	25					25	365
Developing	74	5				79	
Yellow	45	95	31			171	
Ripe		66	11			77	
Spent		8	5			13	
July:							
Undeveloped	1			1		2	1,581
Developing	1	32	4	1		38	
Yellow	23	655	360	174		1,212	
Ripe	1	113	21	41		176	
Spent	22	70	50	11		153	
August:							
Undeveloped	259		2			261	1,370
Developing			5	2		7	
Yellow		94	453	266		813	
Ripe		9	59	31		99	
Spent	1	6	106	77		190	
September:							
Undeveloped	385	223	600			1,208	1,681
Developing						0	
Yellow		12	172			184	
Ripe		1	32			33	
Spent	12	19	225			256	

[8] It is obvious that in June 1942 our sampling did not cover the entire spawning population.

TABLE 35.—*Distribution by stages of ovarian development and by depths, of female shrimp in Louisiana offshore fishery, December 1941 to November 1942*—Continued

Month, and stage of ovarian development	Number taken at depth of—						Total
	0-4½ fathoms	5-8½ fathoms	9-12½ fathoms	13-16½ fathoms	17 fathoms and deeper	All depths	
1942—Continued							
October:							
Undeveloped	1,307	455				1,762	1,956
Developing						0	
Yellow	2	4				6	
Ripe						0	
Spent	121	67				188	
November:							
Undeveloped		167	76			243	273
Developing						0	
Yellow		2				2	
Ripe						0	
Spent		20	8			28	

TABLE 36.—*Percentage of ripe and spent females in Louisiana offshore fishery December 1941 to November 1942, arranged according to depth*

[0-class spring-spawned shrimp not included after July]

Month	Ovarian stage	Percent taken at depth of—				
		0-4½ fathoms	5-8½ fathoms	9-12½ fathoms	13-16½ fathoms	17 fathoms and deeper
1941						
December	Ripe	0.0	0.0	0.0		
	Spent	4.3	95.7	0		
1942						
January	Ripe		0	0	0.0	
	Spent		0	0	0	
February	Ripe		0	0	0	0.0
	Spent		0	0	0	0
March	Ripe			0	.4	1.3
	Spent			0	0	0
April	Ripe			.3	3.7	8.5
	Spent			.5	.5	2.1
May	Ripe	0		4.4	9.6	.2
	Spent	0		1.9	4.9	.7
June	Ripe	0	18.1	3.0		
	Spent	0	2.2	1.4		
July	Ripe	.1	7.1	1.3	2.6	
	Spent	1.4	4.4	3.2	.7	
August	Ripe	0	.8	5.3	2.8	
	Spent	.1	.5	9.5	6.9	
September	Ripe	0	.2	6.8		
	Spent	2.5	4.0	47.6		
October	Ripe	0	0			
	Spent	62.4	34.5			
November	Ripe	0	0	0		
	Spent	0	66.7	26.7		

Other localities

If we judge the spawning season by the presence of shrimp with yellow and ripe ovaries (table 37),[9] we find that—

1. In South Carolina, spawning probably begins in May and extends into September (our sampling was poor in April and August, and by September the spring-spawned shrimp dominated the fishery to such an extent that the mature shrimp were barely represented).

[9] Since we did not satisfactorily recognize spent shrimp throughout most of our collections, we have omitted these from our Louisiana data in this table. In interpreting the table, allowances must be made for our sampling technique (see section on size distributions).

2. In Georgia and northern Florida, spawning extends from April into September.

3. In central Florida (between St. Augustine and Cape Canaveral), spawning occurs from March until October.

4. In Louisiana, spawning takes place from March until October or November.

5. Near Galveston, Tex., it extends from April until September.[10]

6. Near Aransas Pass, Tex., spawning occurs from March or April until October.

TABLE 37.—*Distribution by months and by stages of ovarian development of female shrimp in Atlantic and Gulf coast fisheries*

Locality and month	Number whose ovaries were—				Monthly total	Total for locality
	Undeveloped	Developing	Yellow	Ripe		
South Carolina: Outside waters:						
January	701				701	
February	617				617	
March	559				559	
April	192	15	1		208	
May		83	319	54	456	
June		144	361	38	543	
July	195	50	178	18	441	7, 689
August	286	4	5		295	
September	861	5	4		870	
October	888	6			894	
November	1, 006	3			1, 009	
December	1, 094	2			1, 096	
Georgia and northern Florida:						
Creeks and rivers:						
January	1, 311				1, 311	
February	1, 242				1, 242	
March	1, 764	74	6		1, 844	
April	1, 855	886	302	4	3, 047	
May	702	855	767	6	2, 330	
June	86	739	436	15	1, 276	
July	1, 184.	105	48		1, 337	22, 919
August	2, 323	1	1		2, 325	
September	2, 350				2, 350	
October	1, 923				1, 923	
November	2, 157				2, 157	
December	1, 777				1, 777	
Sounds:						
January	1, 701				1, 701	
February	1, 764				1, 764	
March	2, 069	18	4		2, 091	
April	1, 358	821	574	11	2, 764	
May	270	606	434	3	1, 313	
June	24	642	772	27	1, 465	
July	578	113	155	43	889	22, 662
August	1, 802	12	14		1, 828	
September	2, 779	1			2, 780	
October	2, 193				2, 193	
November	1, 902				1, 902	
December	1, 972				1, 972	
Outside waters less than 1 mile offshore:						
January	932				932	
February	1, 306				1, 306	
March	740	19	4		763	
April	746	380	190	4	1, 320	
May	112	442	235	8	797	
June		231	446	28	705	
July	191	64	181	86	522	11, 276
August	516	62	34	4	616	
September	937				937	
October	1, 169				1, 169	
November	1, 124				1, 124	
December	1, 085				1, 085	

[10] Our data with respect to ovarian development are in error for Texas as our observer there (who covered both Galveston and Aransas Pass) tended to confuse shrimp in a late yellow stage with ripe shrimp. As a consequence our records for Texas show a greater number of ripe shrimp than existed.

TABLE 37.—*Distribution by months and by stages of ovarian development of female shrimp in Atlantic and Gulf coast fisheries*—Continued

Locality and month	Number whose ovaries were—				Monthly total	Total for locality
	Undeveloped	Developing	Yellow	Ripe		
Georgia and northern Florida—Continued						
Outside waters more than 1 mile offshore:						
January	1, 500				1, 500	
February	2, 238				2, 238	
March	190	5	3		198	
April	238	158	199	104	699	
May	138	251	659	90	1, 138	
June		156	391	104	651	15, 704
July	141	197	391	85	814	
August	989	87	158	42	1, 276	
September	1, 938	17	5		1, 960	
October	1, 637	9			1, 646	
November	1, 622	1			1, 623	
December	1, 959	2			1, 961	
Florida: Central outside waters between St. Augustine and Cape Canaveral:						
January	1, 120	23			1, 143	
February	881	152	21		1, 054	
March	154	172	213	2	541	
April	7	143	430	127	707	
May		51	225	34	310	
June	6	12	85	12	115	9, 467
July	3	87	388	9	487	
August	144	35	213	11	403	
September	972	57	64	2	1, 095	
October	1, 157	51	7		1, 215	
November	1, 159	5			1, 164	
December	1, 227	6			1, 233	
Louisiana:						
Inside waters, *Black Mallard* collections:						
January	851	1			852	
February	679	6			685	
March	1, 128	179			1, 307	
April	515	743	5		1, 263	
May	119	530	31		680	
June	551	112	4		667	13, 398
July	814	14	3		831	
August	1, 061	1		1	1, 063	
September	938	2			940	
October	2, 406				2, 406	
November	1, 172				1, 172	
December	1, 532				1, 532	
Outside waters, *Black Mallard* collections:						
January	962	21			983	
February	795	115	9		919	
March	336	453	154		943	
April	2	327	68		397	
May	14	451	188		653	
June	1	252	108	2	363	10, 306
July	386	119	153		658	
August	758	15	19	6	798	
September	686	69	3		758	
October	1, 991	34			2, 025	
November	845	2			847	
December	960	2			962	
Outside waters, offshore fleet and *Pelican* collections:						
0–4½ fathoms:						
January						
February						
March	412	98	1		511	
April	361	46	49		456	
May	61	56	30		147	
June	25	105	135	3	268	4, 774
July		2	121	17	140	
August	259				259	
September	460				460	
October	1, 757	1	2		1, 760	
November	288				288	
December	477	8			485	
5–8½ fathoms:						
January	979	997	13		1, 989	
February	158	101	13		272	
March	16	22	9		47	
April	47	19	88	3	157	
May	1	401	1, 150	184	1, 736	
June		188	892	240	1, 320	12, 121
July	1	138	1, 164	395	1, 698	
August		44	334	52	430	
September	359	38	137	11	545	
October	1, 482	3	8	5	1, 498	
November	1, 591	3	3		1, 597	
December	816	16			832	

TABLE 37.—*Distribution by months and by stages of ovarian development of female shrimp in Atlantic and Gulf coast fisheries*—Continued

Locality and month	Number whose ovaries were—				Monthly total	Total for locality
	Undeveloped	Developing	Yellow	Ripe		
Louisiana—Continued						
Outside waters, offshore fleet and *Pelican* collections—Con.						
9–12½ fathoms:						
January	722	391	2		1,115	
February	226	702	158		1,086	
March	89	290	400	59	838	
April	7	115	488	48	658	
May	1	307	1,297	201	1,806	
June	1	291	1,034	172	1,498	
July		57	643	63	763	10,047
August	2	61	711	85	859	
September	600		172	32	804	
October	210	9		4	223	
November	108				108	
December	207	82			289	
13–16½ fathoms:						
January	268	20			288	
February	19	264	49		332	
March	190	520	393	65	1,168	
April		72	576	89	737	
May		19	334	85	438	
June		15	63	13	91	
July	1	1	174	41	217	4,289
August		2	266	31	299	
September						
October						
November	3				3	
December	684	32			716	
17 and more fathoms:						
January	79	17			96	
February	43	58	13		114	
March	35	492	562	43	1,132	
April		65	533	112	710	
May		17	100	4	121	
June						2,287
July						
August						
September						
October						
November	10				10	
December	4	100			104	
Texas:						
Outside waters near Galveston:						
January	782				782	
February	822	4			826	
March	182	442	18		642	
April	80	350	183	245	858	
May	148	491	120	159	918	
June		482	96	77	655	
July		273	164	156	593	8,418
August	183	12	14	5	214	
September	190	80			270	
October	1,074	11			1,085	
November	814				814	
December	761				761	
Inside waters near Aransas Pass:						
January	154				154	
February	204				204	
March	1,032	155	1		1,188	
April	263	206	112	35	616	
May	94	209	583	159	1,045	
June	7	53	136	49	245	
July	387	7	1		395	16,345
August	1,669	86	8	1	1,764	
September	2,758	35	4		2,797	
October	2,983	15	1		2,999	
November	3,315	10			3,325	
December	1,613				1,613	
Outside waters near Aransas Pass:						
January	870	1			871	
February	1,051	39	3		1,093	
March	566	270	119	57	1,012	
April	486	415	206	210	1,317	
May	22	728	470	456	1,676	
June		317	321	529	1,167	
July	4	406	328	520	1,258	12,943
August	382	340	215	322	1,259	
September	283	65	6	9	363	
October	1,188	38	3		1,229	
November	757	29			786	
December	911	1			911	

TABLE 38.—*Mature females appearing in random samples from Louisiana offshore fishery at Morgan City, La., July–November 1942 and December 1941*

Month	Total females	Mature females	Percent mature
July 1942	1,581	1,581	100.0
August 1942	1,370	1,111	81.1
September 1942	1,681	473	28.1
October 1942	1,956	194	9.9
November 1942	273	30	11.0
December 1941	958	23	2.4

When we consider sampling technique and errors, it appears probable that there is little, if any, difference between the spawning seasons in any of the localities we covered between South Carolina and Texas. There probably is not more than about 2 weeks' difference in the beginning of spawning between any of the localities. Spawning may start later and end earlier in South Carolina and Georgia than it does in Florida, Louisiana, and Texas, but in all of the localities it probably begins either during the latter part of March or early in April and may possibly continue on into November, though probably it is completed by the end of September.

Wherever evidence is available, it appears that the shrimp of other areas select spawning grounds similar to those frequented by the Louisiana population. Judging by the presence of ripe shrimp and their proportion in the population, most spawning in Georgia and northern Florida is in outside waters more than 1 mile from shore, although some spawning may actually occur in inside waters in this area. Similarly, near Aransas Pass, Tex., most, if not all, spawning is in outside waters (table 37).

LONGEVITY

Immature and mature shrimp of the same total length can usually be distinguished by body proportions. Apparently, on approaching maturity, various irreversible changes take place in the body of the shrimp. Viosca (1920) showed the increase in width and Burkenroad (1934) mentions others.[11] In figure 30 we show the relation between rostrum length and total length for immature (which are spring-spawned) and mature female shrimp for the Louisiana offshore fishery in October 1941.

[11] We suspect, as possibly did Burkenroad, that most of the differences Burkenroad (1934) mentions between North Carolina and Louisiana shrimp are actually differences between immature North Carolina and mature Louisiana shrimp.

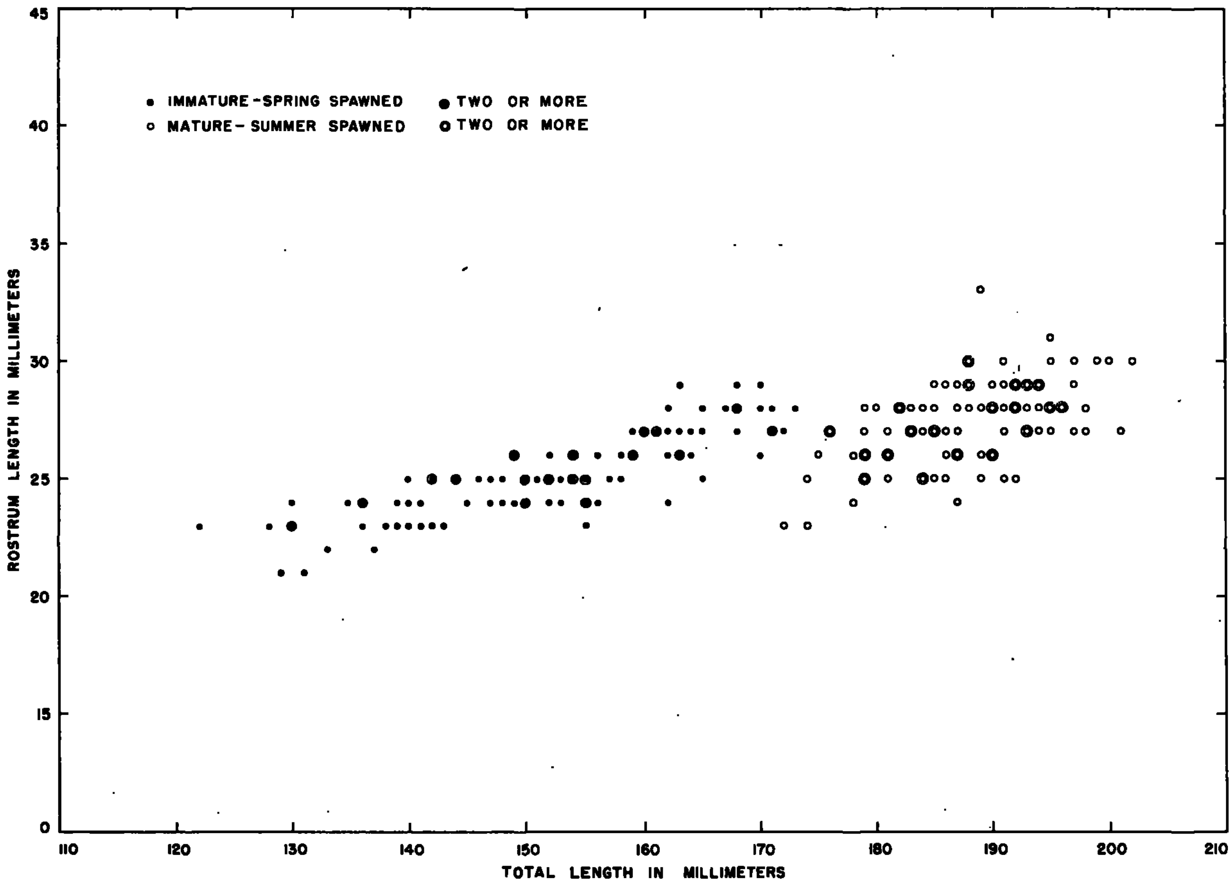

FIGURE 30.—Difference between rostrum length and total length in female immature and mature shrimp from the Louisiana offshore fishery in October.

Through body proportions and observations on the condition of the ovaries of the females, we were able to follow the mature group (which probably were mostly summer-spawned shrimp) until December (fig. 27). After this we lost them as they became indistinguishable from the spring-spawned animals which were beginning to mature. However, the summer-spawning group formed a conspicuous mode at about 90 mm. in the previous December (fig. 39), so there can be no doubt that they live more than 1 year. As will be shown in the section on size distributions, some of these shrimp were spawned in or before August; thus it may be stated that some shrimp live at least 16 months. Since the mortality is apparently high, the number that do live more than 1 year is small with respect to the total population. In figure 31 we show the percentage of mature female shrimp in the Louisiana offshore fishery from July to

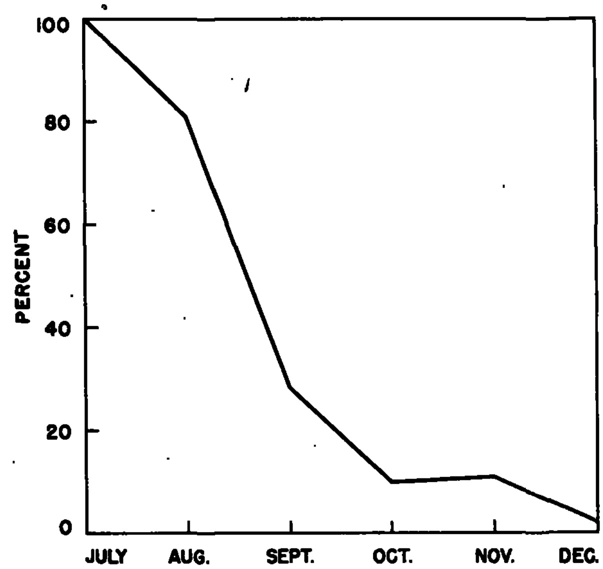

FIGURE 31.—Percentage of mature shrimp in the Louisiana offshore samples from July to December.

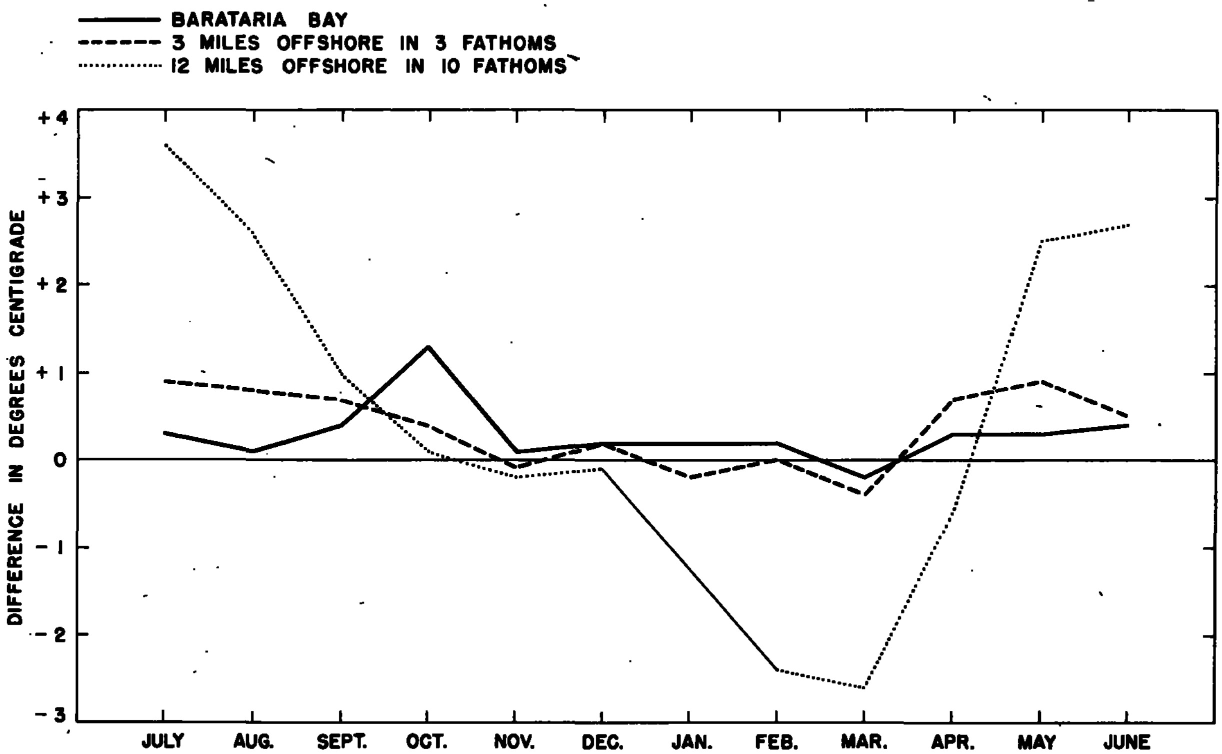

FIGURE 32.—Average monthly deviation of surface water temperature from bottom temperature (simultaneous observations) for three localities in Louisiana. We have no data for the 12-mile station during January.

November 1942 and in December 1941. The actual numbers of shrimp, from which this figure was derived, are presented in table 38. As can be seen, our sampling in November 1942 was poor, which probably accounts for the rather high percentage of mature shrimp during that month. In December, according to our samples, less than 3 percent of the offshore population was composed of mature shrimp. These December samples were taken from comparatively shallow areas out to 12½ fathoms. Undoubtedly, there were some shrimp in greater depths, many of which would be mature, but even if we doubled the number of mature shrimp to compensate for the incomplete sampling we would only have about 5 percent. When we consider the second group of immature shrimp which will move into the offshore fishery during the following April through July we are forced to conclude that after December the mature shrimp more than 1 year of age are not of great practical importance.

Weymouth, Lindner, and Anderson (1933) stated that on the Georgia coast shrimp disappeared from the fishery after 1 year, and these authors presumed that they died. We believe the data we present in this section prove Burkenroad's (1934, 1939) contention that shrimp live more than 1 year.

TEMPERATURE AND SALINITY RELATIONS

In Louisiana, we took surface and bottom water temperatures and salinities with each trawl haul made with the *Black Mallard* from 1931 to 1934. Along the Atlantic coast, where hauls were made with *Launch 58* from 1931 to 1935, we generally took only surface observations. For Texas, we have only the average surface water temperatures taken at Port Aransas Lighthouse, based on readings which were usually taken twice a day, at 8 a. m. and at 6 p. m., by the various lighthouse keepers from 1930 to 1936.

At times, even in the shallow water inhabited by shrimp, there are appreciable differences between surface and bottom temperatures (table 39, figs. 32 and 34), and comparable differences in salinities also occur (fig. 33). Since the shrimp is primarily a bottom form, we restrict our discussion of the influence of temperature and salinity as much as possible to the Louisiana area west of

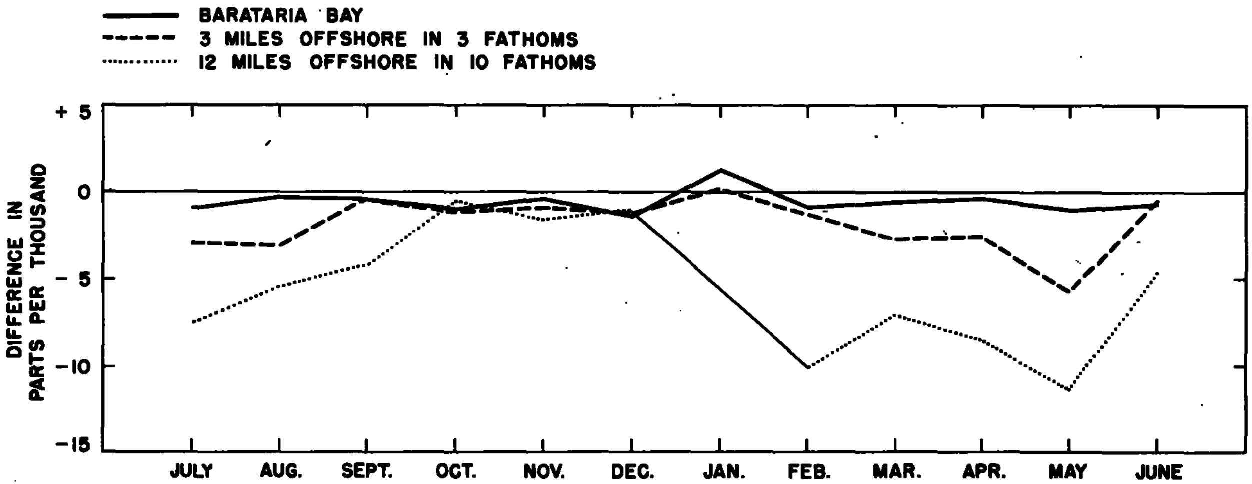

FIGURE 33.—Average monthly deviation of surface water salinity from bottom salinity for three localities in Louisiana. We have no data for the 12-mile station during January.

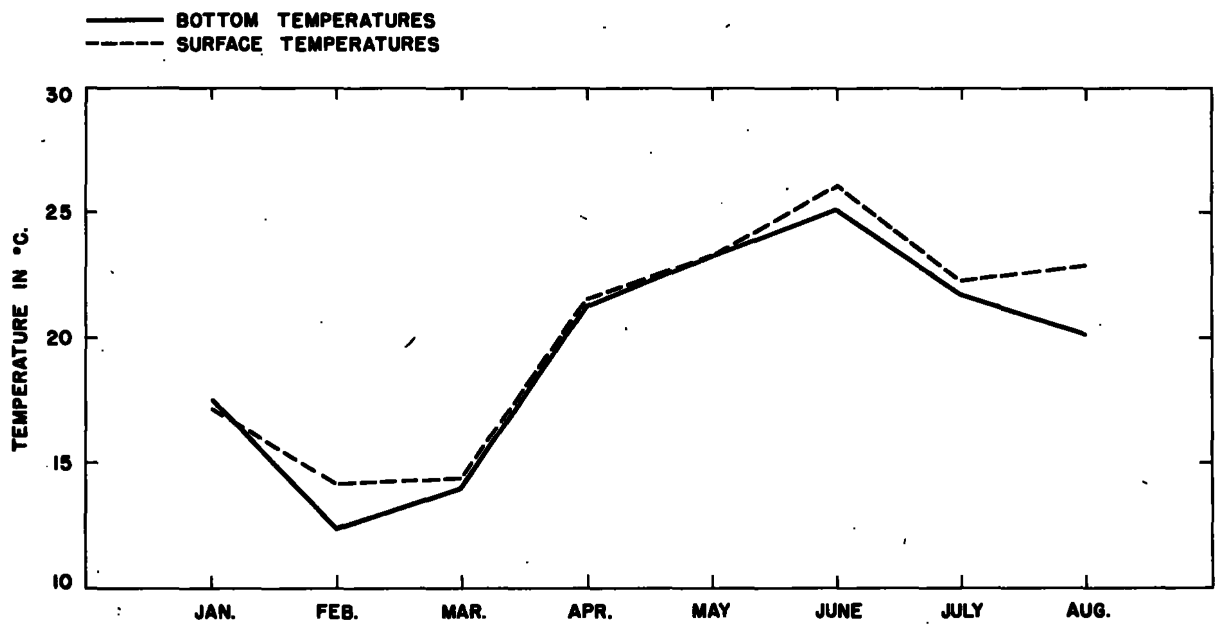

FIGURE 34.—Outside surface and bottom-water temperatures at St. Augustine, Fla., from January to August 1935.

the Mississippi River, the only region for which we have an appreciable amount of bottom data.

TEMPERATURE AND GROWTH

It is well established that temperature affects metabolism and hence the growth of all cold-blooded animals, such as shrimp. In table 40 and figure 35 we show the monthly average bottom water temperatures for three adjacent localities in Louisiana. These data were collected during the period 1932 to 1934. Unfortunately, no similar hydrographic data are available for the period 1939 to 1942 when the data on growth and spawning were collected. Although we fully realize that the marine climate may have changed somewhat in the intervening decade and that our conclusions may, as a result, not be valid, certain correlations between water temperatures in the early 1930's and growth and spawning of shrimp almost 10 years later are so interesting that we deem it advisable to discuss these correlations, assuming that the hydrographic conditions remained relatively stable. Although the temperature records may not reflect the exact conditions during the period in which the biological observations were made, there is an equal chance that they represent an average. If we accept these temperatures as representing the average and use them to interpret the periods of growth and dormancy, it appears that growth slows to almost nil near the end of October (see fig. 5), when the temperature drops to about 20° C., and is resumed in the spring when the temperature again reaches approximately that value.

TABLE 39.—*Deviation of average surface-water temperatures from bottom temperatures along Atlantic coast, November 1934 to August 1935*

[These represent temperatures taken in outside waters within 5 miles of shore in depths between 2 and 10 fathoms, and are recorded in ° C. The averages are from 2 or 3 surface and bottom samples taken simultaneously in each locality. The stations are: 1, Cape Romain, S. C.; 2, Stono Inlet, S. C.; 3, Gaskins Bank, S. C.; 4, St. Catherines Island, Ga.; 5, Brunswick, Ga.; 6, Fernandina, Fla.; 7, St. Augustine, Fla.; 8, New Smyrna, Fla.; 9, Cape Canaveral, Fla.]

Month	Deviation at station No.—								
	1	2	3	4	5	6	7	8	9
1934									
November	−1.0	+0.4	−0.5	−0.1	−0.2	−0.1	−0.1	+0.1	−0.4
December	+0.6	+.1	−.3	−.4	+.4	0	−2.0	+.6	+.2
1935									
January	+.4	−.2	−.2	+.1	+.3	0	−.4	−.5	+.7
February	−.1	0	−.2	+.5	−.2	+2.2	+1.8	−.1	+2.8
March	−.3	0	−1.1	+.4	−1.2	+.5	+.4	−.5	0
April	−.4	−.4	+.2	+.4	+.7	+.3	+.3	+.8	0
May	+.5	+.1	+.9	−.2	+.1	+.5	0	+.6	+.9
June	+.1	+.7	+.1	+.2	+.2	+1.1	+1.0	+.6	+1.3
July	+.5	−.1	+.2	0	+.2	+2.5	+.6	+1.3	+3.4
August	-----	-----	-----	-----	-----	−2.3	+2.8	+2.4	-----

TEMPERATURE AND SPAWNING

Spawning in Louisiana appears to be more closely associated with rising and falling temperatures than with absolute temperature. As we have shown, it begins in the greater depths during the latter part of March or early April and is nearly completed by the end of September. In figure 35 there is an indication that the rise in temperature from the winter low begins later in the deeper waters than in shallow areas closer to shore. If this is true it is probable (though we cannot establish this from our meager temperature data) that the bottom temperatures on the spawning grounds begin to rise about the first of April and are falling rapidly by the end of September. Thus, the comparatively abrupt rise in the spring temperature coincides rather closely with the beginning of the spawning season and may, indeed, initiate it, while the season seems to terminate as soon as the temperatures begin to decline rapidly in the fall, even though they are at that time appreciably higher than those which evidently induced spawning in the spring.

TEMPERATURE AND MIGRATIONS

At first glance, it seems that there is little relation between temperature and migrations. In Louisiana, spring-spawned shrimp appear first in the trawl catches in inside waters in June, in outside waters adjacent to the coast in July, and offshore in August. This well-defined outward movement cannot be temperature-induced, since it occurs well before there is any appreciable drop in temperature. Judging from the behavior of the shrimp during this period, we believe the offshore movement is primarily associated with the approach of adulthood and spawning. However, this offshore movement is later accelerated by falling temperatures. The phenomenon, evidently initiated by physiological changes in the organism itself, seems to be hastened and intensified during fall and winter by the external factor of declining temperatures.

Concomitant with the accelerated fall and winter offshore movement of the adults and subadults, the smaller, more immature shrimp move from the very shallow inland waters toward the Gulf of Mexico. These very small shrimp, which during summer are most abundant toward the heads of the bays, are during midwinter more abundant near the mouths of the bays and in the Gulf adjacent to the shore, where the temperatures are not so readily depressed.

The change in habitat caused by winter temperatures can probably best be described as a general shift toward warmer waters, but with all sizes of shrimp still maintaining their size-locality separations. In Louisiana this shift is toward the Gulf because the bottom temperatures are warmer offshore.

Along the coast of Louisiana during winter there is an offshore belt of warm bottom water, on either side of which the bottom water becomes progressively colder. The shallower inshore waters reflect the temperature of the land, whereas the thermal belt reflects the temperature of the tropical oceanic waters of the Gulf of Mexico. Figure 35 shows the progression in winter bottom temperatures from the land toward, and probably into, the thermal belt.

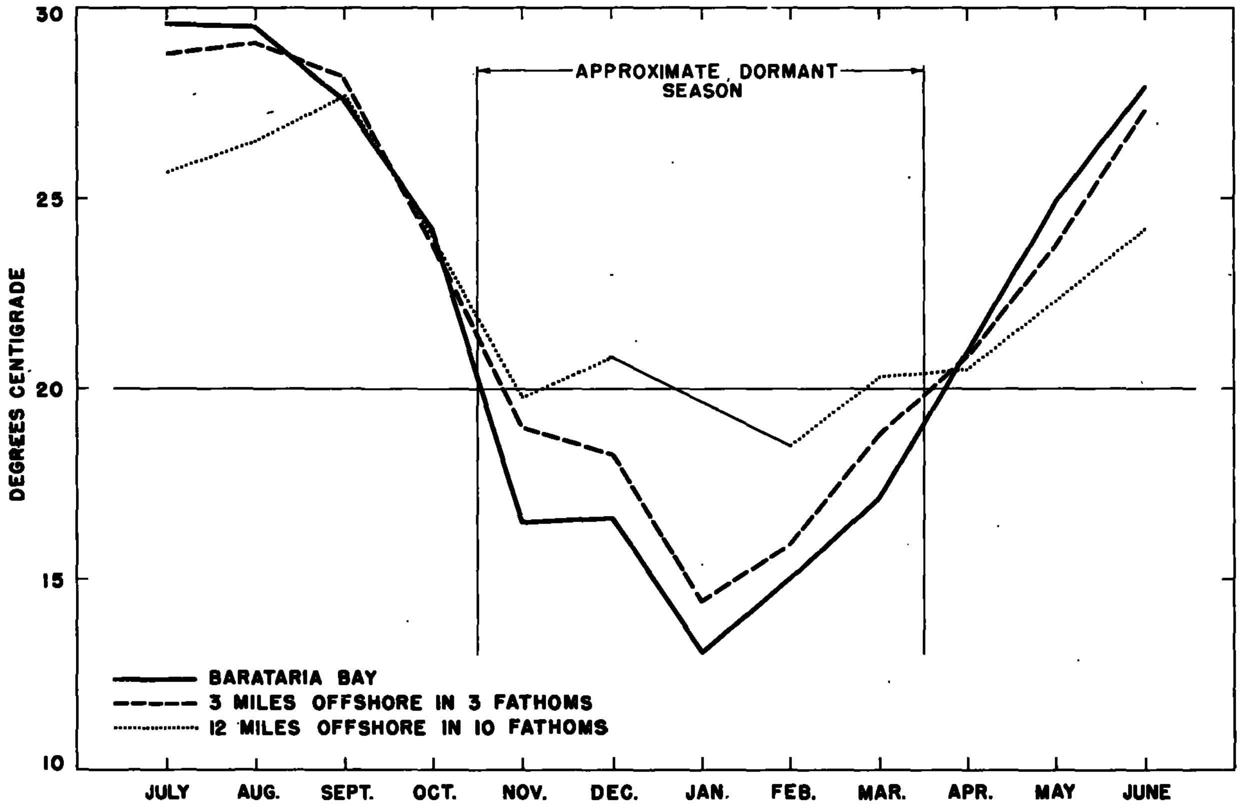

FIGURE 35.—Seasonal changes in bottom temperatures in three parts of the shrimp habitat in Louisiana.

Between midsummer and midwinter there is a complete reversal of bottom-temperature gradients between the estuarine waters and the inner littoral waters of the more stable thermal belt. We do not know to what depths offshore this belt extends, but on the basis of the depths at which shrimp have been taken in midwinter we believe that it does not normally extend much beyond 30 or 35 fathoms, if that far.

In central Texas there is probably a winter offshore gradient in temperature similar to that along the Louisiana coast. At least, the temperature records of Springer and Bullis (1952) indicate that such a gradient existed in November 1950. In addition to this there undoubtedly is also a coastal temperature gradient with increasing temperatures toward the south. During winter, larger shrimp from this section disappear from the shallower waters near the coast. They go offshore or southward. The greatest depth at which we encountered shrimp off central Texas in winter was 18 fathoms.

In Georgia and northern Florida, the spring-spawned shrimp appear almost simultaneously in the trawl catches in the inside and outside waters in July, although initially they are relatively much more abundant in the inside waters.[12] This summer movement from inside to outside waters is comparable to that in Louisiana and does not appear to be influenced by temperature. However, when the temperature begins to decline rapidly in the fall the large shrimp move southward along the coast rather than offshore as they do in Louisiana. We suspect their failure to go offshore results from the lack of suitable bottoms for feeding in this area along the Atlantic coast. As a consequence of this southward movement of the larger shrimp, with the largest tending to go farthest south, there is in midwinter a correlation along the Georgia and Florida coasts

[12] We suspect that the almost simultaneous appearance of spring-spawned shrimp in both inside and outside waters in this area results from the very narrow inside nursery-ground belt in this section of the Atlantic coast as compared with the Louisiana nursery grounds and those of central Texas. The nursery grounds in Georgia and northern Florida average about 10 miles in width, those near Aransas Pass, Tex., about 20 miles, and those in the vicinity of Barataria Bay, La., about 40 miles. Near Aransas Pass, Tex., the spring-spawned shrimp first appear in the inside trawl catches in July and in the outside catches in August. See Collier and Hedgpeth 1950 for details on hydrography of a Texas bay.

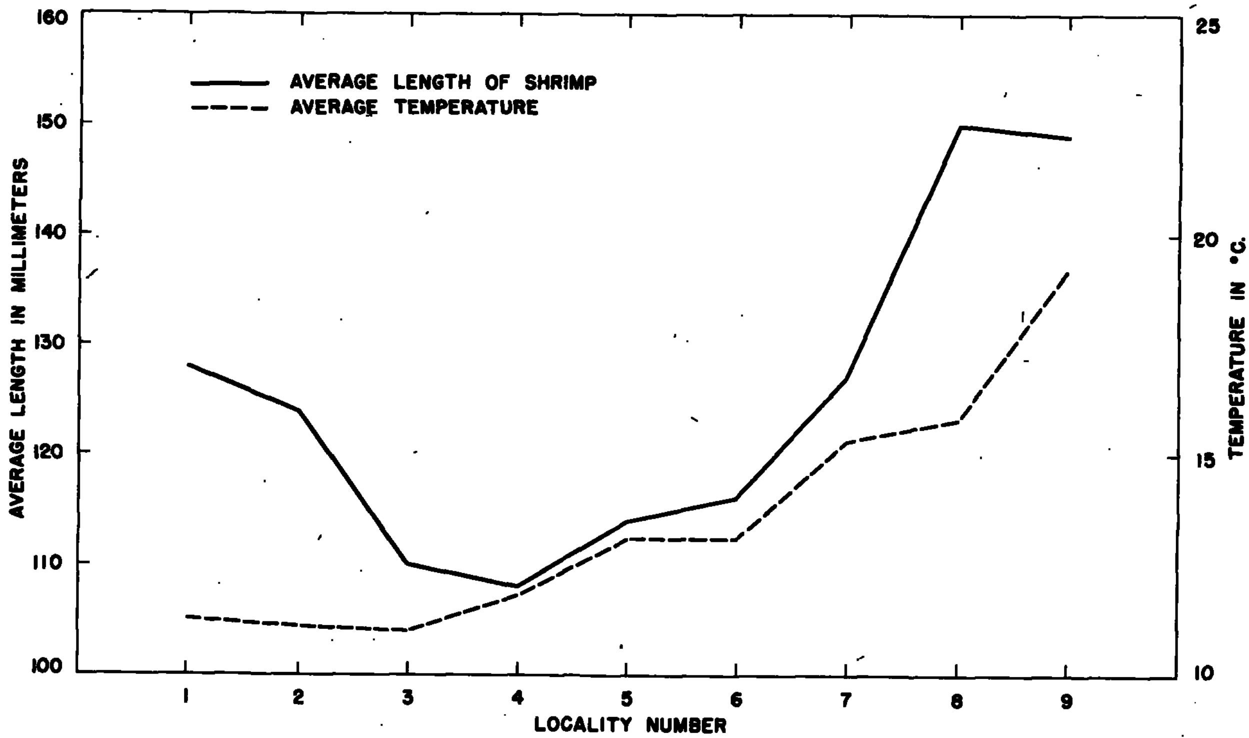

FIGURE 36.—Average outside surface water temperature and average median lengths of shrimp along the Atlantic coast during January and February, 1934 and 1935. The localities are (1) Cape Romain, S. C., (2) Stono Inlet, S. C., (3) Gaskins Bank and Fripp Island, S. C., (4) St. Catherines Island, Ga., (5) Brunswick, Ga., (6) Fernandina, Fla., (7) St. Augustine, Fla., (8) New Smyrna, Fla., (9) Cape Canaveral, Fla.

between water temperature and the average length of shrimp (fig. 36).

Apparently, some of the migrants from farther north become trapped along the South Carolina coast and a northward movement of these shrimp may occur in this section in midwinter. This is suggested by the progressive increase in the average length of shrimp to the north of St. Catherines Island. Our tagging would not show this northward movement, since we did not tag in South Carolina during midwinter. The numbers of shrimp which become winter-trapped in South Carolina are relatively few and variable from year to year. The bulk of the population of larger shrimp is along the coast of Florida at that time.[13]

Burkenroad (1949) reports sporadic offshore trawler catches of large shrimp in winter between Capes Hatteras and Lookout. Broad (1951) mentions finding them offshore near Diamond Shoals during winter but not in commercial quantities, and Gutsell (our records) also once encountered a school of large shrimp in this area in January. Apparently some of the North Carolina shrimp go offshore in winter in an attempt to escape the rigorous temperatures close to shore, although the majority go south. The proportion of the North Carolina shrimp population that goes south, north, and offshore in the fall and winter undoubtedly varies considerably from year to year.

In table 39 we give the differences between surface and bottom temperatures for nine stations along the Atlantic coast. Atlantic temperatures between Cape Canaveral and Fernandina, Fla., are interesting since they indicate the probable occurrence of a mass of cold bottom water striking the coast in this area during July and August. This was particularly noticeable in 1935 (fig. 34). An examination of table 41 suggests that the mass of cold water was also present in 1933 and 1934. Green (1944) attributes this phenomenon to upwelling. This mass of cold water may be one of the causes for the scarcity of shrimp during summer, between St. Augustine and Cape Canaveral.

[13] Parr (1933) foresaw the possibility of a winter northward migration of fishes in this general area.

Although the fall and winter migrations of shrimp appear to be primarily related to temperature, they also seem to be regulated by the type of bottom, which implies food. In general, along the Atlantic coast between Capes Lookout and Canaveral and between the 10- and 100-fathom contours the bottom is a marine desert of sand, shell, and coral. Along the Alabama and Mississippi coasts the same condition prevails. Near the mouth of the Mississippi River, however, the bottom changes to mud and apparently the large shrimp east of the Mississippi winter near its mouth, because both food and suitable temperatures are available. Along the Louisiana coast west of the Mississippi River these same suitable conditions are met between Ship and Trinity Shoals.

WINTER KILL

Sudden, severe drops in temperature in some localities will kill shrimp and in other localities will cause them to move offshore considerably beyond their normal range. We mentioned, in our discussion of migrations in Louisiana, the occurrence of such a drop in temperature in January 1940. This cold wave was general throughout the south Atlantic and Gulf areas of the United States.

In figure 37, we show (based on data from Local Climatological Summary for New Orleans, La., 1951, published by the U. S. Weather Bureau) the average monthly air temperatures at New Orleans for the winter of 1939–40 compared with the 78-year average. Lindner (1936) has shown a rather close relation between the New Orleans air temperatures and the surface water temperatures at Oyster Bayou Light, La.; consequently, we believe the temperatures of the shallow inland and coastal waters of Louisiana had a drop in January somewhat comparable to that shown for the New Orleans air temperatures.

Immediately after this January freeze, fishermen reported finding dead shrimp in the inland and adjacent coastal waters of Louisiana. However, in Louisiana we received no reports of great mass mortalities of fishes and shrimp, such as were reported by Gunter (1941) for Texas. We believe Gunter and Hildebrand (1951) have the correct explanation for the Texas mortalities when they state (p. 736) that, "The shallowness of Texas bay waters, their practically landlocked condition and the rapidity with which cold northers strike the coast are factors making the marine life of this area particularly subject to mortality from cold waves every few years." In Louisiana, on the other hand, the numerous passes between bays and the Gulf permit ready escape of the shrimp from the shallow inland areas to the deeper and warmer waters offshore. Although many small shrimp were killed in inside waters by the January freeze of 1940, the majority of them were undoubtedly driven off the coast by the cold and sought refuge in deeper waters, where we found and marked them in February and March.

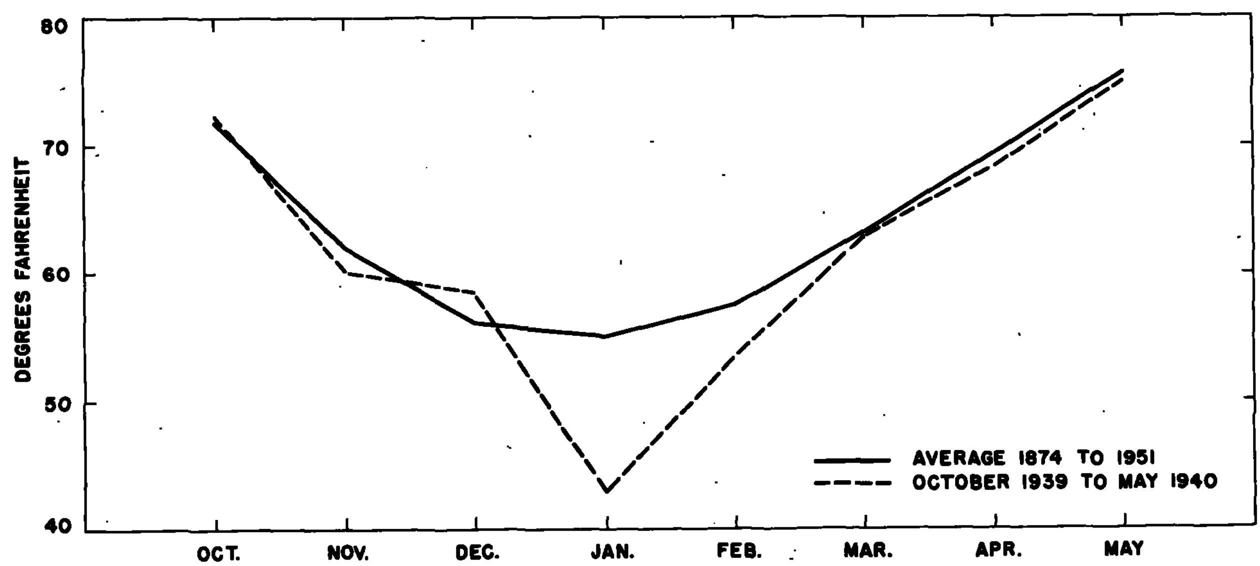

FIGURE 37.—Average monthly air temperatures for New Orleans, La., from October to May for the period 1874–1951, and from October 1939 to May 1940.

Along the Atlantic coast, the 1940 cold wave decimated the shrimp in South Carolina and Georgia to about as far south as Brunswick, but apparently had little effect in Florida. The effects of this cold wave were so severe that there were scarcely any shrimp during the spring in South Carolina and Georgia.

We were so concerned about a complete failure of the fishery at the time, that we recommended the immediate cessation of all shrimp fishing. The recommendation was not needed, as the fishermen, unable to catch enough shrimp to pay operating costs, stopped of their own accord. Owing to the scarcity of shrimp, the Brunswick, Ga., fleet was tied up so long that sparrows nested in the rigging of one boat. The occasional Georgia fishing boat that was sent out that spring to search for shrimp along the northern coast of the State would catch only 5 or 6 shrimp in an entire day's fishing.

The results of our experimental trawling corroborated those of the commercial fishermen in every respect. Immediately after the cold wave, we conducted trawling operations along the Atlantic coast between the 2- and 100-fathom contours from Fort Pierce, Fla., to Cape Hatteras, N. C. We used a 10-foot (spread at mouth) shrimp trawl, and the hauls were 30 minutes each. We usually covered between 3 and 3½ miles of bottom per haul. At about the same time we were operating offshore, the State of Georgia very kindly provided us with a launch so that we could also survey the inland waters. Here the hauls were also 30 minutes each and were made with the same type of 10-foot trawl that we used offshore. With the launch we averaged about 3 miles per haul.

The results of these operations are shown in tables 42, 43, and 44 and indicate that the catastrophe had almost completely depopulated the northern shrimp grounds. Apparently a few of the North Carolina shrimp moved offshore into warmer waters and did not perish. (See Parr, 1933, for average temperature contours.) In South Carolina very few shrimp survived the freeze. Inasmuch as all our hauls in this State in depths of 10 fathoms or less were on known fishing grounds that usually had shrimp during that time of year, and (1) our trawls covered between 80 and 100 miles of these bottoms, (2) our offshore trawling extended out from the known fishing grounds, and (3) we caught other peneid shrimps which normally were much less abundant than *P. setiferus*, we believe that had there been *P. setiferus* in any quantity we would have found them. Judging from our data and from firsthand knowledge of the experience of the Georgia fishermen, we think that there were scarcely any spawners left along the South Carolina and northern Georgia coasts that spring. All the *P. setiferus* we caught in inside waters were south of Sapelo Sound, Ga. We caught none in outside waters north of Jekyll Island, Ga., except one specimen taken in North Carolina southwest of Cape Fear in 13 fathoms. So far as we know, this specimen represents a depth record for *P. setiferus* off the Atlantic coast.

The migrants that had gone into Florida waters during the fall and early winter had been greatly depleted by fishing and few were left to return northward. There was very little spawning stock left north of central Georgia and practically none in South Carolina.

The results from the spawning of this depleted fishery were most interesting. In North Carolina, the 1940 fall fishery, although about 90 percent of normal as compared to the 2 previous years, was based not on the white shrimp (*Penaeus setiferus*) but almost entirely on "brownies" (Burkenroad's [1939] Division II of *Penaeus*).[14] In South Carolina, the 1940 calendar-year catch was down to only about 46 percent of the average of the previous two years. In Georgia and Florida it was about 90 percent of the previous 2-year average, which probably was well within the range of normal fluctuation; the limited drop could be caused by the lack of South Carolina migrants and a poor catch that spring. In 1941, fishermen reported their catches to be normal along the entire coast. The depopulated northern areas, as well as the more fortunate southern regions, had in this short period of time recovered completely from the catastrophe, and shrimp were as numerous as ever.

The remarkable thing about the shrimp and the 1940 cold wave is not the kill but the recuperative powers of the shrimp. The evidence of the Atlantic coast, incomplete as it may be, is certainly highly indicative that a normal crop may be produced by a few spawners. It seems doubtful

[14] The information on the composition of the North Carolina catch was furnished us at the time in a personal communication by Dr. H. F. Prytherch, who was then Director of the Beaufort, N. C., Fishery Station. See Anderson, Lindner, and King (1949) table 2, for catch statistics.

whether man, by fishing, could reduce the shrimp to a level where there was a direct relation between the number of spawners and the resultant crop. Apparently, except under most unusual conditions such as the 1940 cold wave, there is always a superabundance of spawners.

There was no indication that the January 1940 cold wave had any effect on the shrimp catches for that year in either Louisiana or Texas. In Louisiana the shrimp apparently escaped offshore. In central Texas during midwinter (as Gunter, 1950, has shown, and we confirm) there were very few shrimp in the bays, and probably even if all were killed it would have made no appreciable difference in the spawning population.

Gunter (1947) has demonstrated that smaller fishes are less susceptible to lower temperatures than are the larger ones. It appears from the winter distributions of shrimp, as shown by our data, that the smaller shrimp, like the smaller fishes, are probably better able to withstand cold than are the larger ones.

SALINITY

The reaction of the shrimp to salinity is not clear-cut. The young apparently seek the inland areas of low salinity, and on approaching adulthood they move towards the more saline waters of the sea to spawn. It seems that the shrimp (at least the subadults) are rather insensitive to large fluctuations in salinity but that they are very sensitive to small changes in temperature.

SIZE IN RELATION TO SALINITY AND TEMPERATURE

In every locality there was a general progression, from inside to outside waters, in the size of the trawl-caught shrimp; the smallest ones were taken in the waters of lowest salinity farthest from the sea, the largest ones were captured in the outside waters where the salinity was highest. Superficially this appeared to be a high positive correlation between salinity and size of the shrimp, but there were certain anomalies. In Louisiana, for instance, we would on occasions find much larger shrimp in Little Lake and Lake Salvador than we would in the upper reaches of Barataria Bay, although the salinity was much less in Little Lake. With a seine, we would also find very small shrimp along the banks of Bayou Rigaud (near the mouth of Barataria Bay) and along the edges of the marsh and among the mangroves bordering the bay where the salinity was relatively high.

To test the significance of the apparent relation between size of trawl-caught shrimp and salinity and temperature, we selected 17 sets of data we

TABLE 40.—*Average monthly bottom temperatures and salinities for 3 localities in Louisiana, 1932 to 1934*

[Temperatures in degrees centigrade; salinities in parts per thousand]

Month	Barataria Bay			3 fathoms			10 fathoms		
	Number of observations	Temperature	Salinity	Number of observations	Temperature	Salinity	Number of observations	Temperature	Salinity
January	[1] 17	13.1	11.7	5	14.4	26.7	------	------	------
February	16	15.0	10.4	4	15.9	24.9	1	18.5	33.6
March	22	17.1	8.0	7	18.8	26.5	3	20.3	34.6
April	31	21.0	11.6	8	20.8	28.3	6	20.5	34.4
May	[2] 27	24.9	12.7	5	23.8	26.9	6	22.3	34.0
June	24	27.9	11.4	6	27.3	23.8	3	24.2	35.6
July	[3] 14	29.6	16.7	[4] 7	28.8	32.1	4	25.7	35.6
August	11	29.5	13.7	3	29.1	29.5	[6] 3	26.5	34.0
September	[3] 13	27.6	16.7	3	28.2	29.7	3	27.7	33.3
October	20	24.2	17.8	6	23.8	30.9	3	24.0	32.5
November	13	16.5	13.6	[5] 4	19.0	31.9	[7] 2	19.8	33.5
December	17	16.6	15.7	3	18.3	29.3	2	20.8	34.5

[1] Only 16 salinity observations.
[2] Only 23 temperature observations.
[3] Only 12 temperature observations.
[4] Only 6 salinity observations.
[5] Only 3 salinity observations.
[6] Only 2 temperature observations.
[7] Only 1 salinity observation.

TABLE 41.—*Mean surface temperatures in °C for nine stations along Atlantic coast, May 1933 to August 1935*

[The stations are: 1, Cape Romain, S. C.; 2, Stono Inlet, S. C.; 3, Gaskins Bank and Fripp Island, S. C.; 4, St. Catherines Island, Ga.; 5, Brunswick, Ga.; 6, Fernandina, Fla.; 7, St. Augustine, Fla.; 8, New Smyrna, Fla.; 9, Cape Canaveral, Fla.]

Month	Mean temperature at station No.—								
	1	2	3	4	5	6	7	8	9
1933									
May	------	24.2	23.7	24.3	25.6	25.7	25.7	26.4	26.4
June	------	27.5	27.2	28.7	29.0	26.7	25.7	27.8	26.7
July	------	26.8	27.2	28.6	27.9	27.3	26.8	25.6	26.7
August	------	28.4	28.9	29.6	28.9	28.9	27.5	26.4	28.3
September	------	28.9	29.0	26.4	27.3	27.5	26.7	30.8	29.4
October	------	20.6	21.1	21.6	25.0	22.2	24.7	26.4	26.1
November	------	17.3	16.7	16.8	16.7	19.3	21.1	21.6	21.1
December	------	15.4	14.5	14.1	14.7	16.7	19.2	20.4	20.7
1934									
January	------	12.8	12.7	12.9	12.8	13.6	15.8	16.8	19.6
February	------	9.0	9.0	10.2	11.9	11.1	13.6	15.7	18.3
March	------	12.1	14.3	13.8	12.5	------	17.2	18.3	20.0
April	------	18.6	17.3	16.6	19.3	16.8	17.9	21.7	23.3
August	------	28.9	28.3	28.2	29.6	26.7	23.9	28.1	------
September	27.1	26.8	27.2	28.2	28.7	27.5	27.2	28.4	28.6
October	21.6	21.1	20.7	23.4	23.9	26.6	27.3	27.5	27.8
November	13.6	14.3	13.1	15.0	16.4	18.9	22.3	23.6	23.2
December	13.6	12.7	12.3	13.1	15.6	16.1	18.3	21.6	22.2
1935									
January	12.7	12.5	12.2	12.8	14.6	15.7	17.2	17.1	21.0
February	10.0	10.0	10.0	11.3	13.2	12.5	14.2	13.4	17.8
March	13.8	12.8	14.9	13.6	14.3	12.8	14.4	16.9	17.2
April	16.6	16.7	19.3	19.7	21.0	20.4	21.6	23.1	23.4
May	23.6	23.3	24.7	24.4	26.0	24.3	23.3	24.4	25.4
June	25.8	26.7	26.4	26.7	26.7	26.0	26.1	25.6	26.8
July	27.8	27.1	27.7	27.3	27.2	26.6	22.3	24.7	24.9
August	------	------	------	------	------	24.0	22.9	22.7	------

had for Louisiana which met the following requisites: (1) Almost simultaneous observations for all of four stations; (2) not less than 20 shrimp caught per haul; and (3) both bottom temperature and salinity observations at the time and place of each haul. We show these data in table 45. Most of the months of the year are represented, although we lack data for March, May, and June. Gunter (1938) gives the location of the stations.

TABLE 42.—*Percentage at each depth grouping, of hauls with* P. setiferus *present following January 1940 cold wave*

Depth	North Carolina	South Carolina	Georgia	Florida
2-5 fathoms	0	0	10	75
6-10 fathoms	0	0	9	28
11-20 fathoms	[1] 2	0	0	[2] 2
21-50 fathoms	0	0	0	0
51 fathoms and deeper	0	0	0	0

[1] One shrimp caught in 13 fathoms.
[2] One shrimp caught in 11 fathoms.

TABLE 43.—*Number of trawl hauls along Atlantic coast following January 1940 cold wave, showing presence or absence of shrimp*

Locality and depth	Number of trawl hauls: Total	With *P. setiferus*	With other peneids
North Carolina: [1]			
2-5 fathoms	1	0	1
6-10 fathoms	27	0	3
11-20 fathoms	46	1	4
21-50 fathoms	13	0	0
51 fathoms and deeper	4	0	0
Total	91	1	8
South Carolina: [2]			
2-5 fathoms	5	0	3
6-10 fathoms	18	0	2
11-20 fathoms	27	0	4
21-50 fathoms	16	0	4
51 fathoms and deeper	4	0	0
Total	70	0	13
Georgia: [3]			
2-5 fathoms	20	2	6
6-10 fathoms	22	2	4
11-20 fathoms	30	0	11
21-50 fathoms	15	0	6
51 fathoms and deeper	2	0	1
Total	89	4	28
Florida: [4]			
2-5 fathoms	4	3	2
6-10 fathoms	94	26	15
11-20 fathoms	52	1	7
21-50 fathoms	19	0	6
51 fathoms and deeper	7	0	0
Total	176	30	30

[1] All hauls between February 13 and March 8.
[2] 45 hauls between February 3 and February 13; 25 hauls between March 9 and March 13.
[3] 47 hauls between January 26 and February 2; 24 hauls between March 14 and March 16; 18 hauls between April 17 and April 18.
[4] 71 hauls between January 17 and January 25; 105 hauls between March 27 and April 17.

If we range these data from 1 to 4, giving the value 1 to the lowest or smallest observation and 4 to the highest or largest, we obtain the results shown in table 46. By this method we find an almost perfect correlation between size of trawl-caught shrimp and salinity, and rather good correlations between size and temperature and between temperature and salinity. However, when we eliminate the effect of locality by means of partial correlations we find the correlation between length and salinity to be only +0.0622, which is not significant, and the correlation between length and temperature to be +0.2184, which is significant.

TABLE 44.—*Average number of shrimp per haul in inside waters along Georgia and northern Florida coast following January 1940 cold wave*

[Localities are from north to south and all hauls were made between April 24 and May 8, 1940]

Locality	Number of hauls	Average number of *P. setiferus* per haul
Wassaw Sound to Sapelo Sound	15	0.0
Sapelo Sound to St. Simons Sound	13	2.1
St. Simons Sound to St. Marys Entrance	22	14.9
St. Marys Entrance to St. Johns Inlet	11	17.7

Our interpretation of the foregoing is that the apparent relation between size of shrimp and absolute salinity within relatively large ranges of salinity does not exist for these four stations. The relation normally is between size and locality. That is, certain sizes of shrimp will be found in certain localities at certain seasons regardless of what the salinity may be (within relatively large ranges) at that particular locality and time. This does not mean, however, that there is no relation between size and salinity. Why is it that as the shrimp increase in size they move toward the sea? We suspect this to be a reaction to salinity, related to spawning, or maturity. We have observed that if the salinity becomes too low in an area, the shrimp will leave. Figure 38, based on the data presented in table 40, shows the marked differences in salinity between the nursery grounds in Barataria Bay and the offshore spawning areas. The salinity gradient indicated is certainly abrupt enough to lead us to suspect that it might serve as an effective stimulant for migration.

TABLE 45.—*Median size of shrimp captured, bottom temperature, and bottom salinity for four stations in Louisiana*

Inclusive dates of sampling	Data[1] for St. Mary's Point station				Data[1] for Middle Ground station				Data[1] for Four Bayou Pass station				Data[1] for station 3-6 miles southeast of Fort Livingston			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
1932																
Sept. 28-30	200	105	25.3	6.6	200	122	25.4	24.4	200	129	27.2	27.2	200	130	27.2	30.4
Oct. 1-4	199	110	26.2	9.9	200	122	25.2	23.5	185	142	25.6	29.1	200	141	26.7	30.5
Oct. 12-15	195	96	21.2	10.3	200	125	23.6	30.4	200	131	22.7	31.3	200	135	23.8	31.6
Oct. 16-18	200	102	22.0	9.6	200	117	23.0	29.8	200	128	25.6	34.4	200	140	22.6	31.0
Oct. 28-31	200	86	18.9	2.3	200	123	21.2	18.5	200	135	22.6	31.1	195	149	22.1	32.5
Nov. 1-4	200	83	20.1	1.5	200	116	19.3	23.1	82	124	19.4	30.6	200	127	21.0	32.3
Dec. 1-4	112	63	11.7	14.8	200	83	15.7	28.4	200	102	14.7	30.9	200	129	16.1	32.1
1933																
Jan. 29-31	56	64	13.9	1.2	200	85	14.4	21.5	200	102	15.6	24.4	200	111	15.4	24.5
Feb. 2-4	200	79	16.3	2.9	200	87	15.7	23.5	200	106	15.9	22.9	200	113	15.8	24.0
Apr. 16-18	113	115	18.0	.8	200	130	20.3	15.9	33	133	20.5	30.9	20	135	21.0	34.7
Apr. 28-29	122	127	25.1	3.2	200	139	25.6	17.4	200	141	23.6	13.8	200	145	24.3	18.3
July 12-14	200	111	28.2	7.2	200	104	28.4	13.2	118	116	27.5	34.3	200	122	27.6	32.4
July 19-20	200	110	29.4	11.0	200	118	30.2	29.7	200	125	31.1	30.9	47	141	28.3	34.2
Aug. 9-11	83	121	28.8	7.5	26	125	28.6	18.5	200	129	29.3	23.8	200	126	28.8	25.9
Nov. 18-19	200	94	18.2	15.9	200	117	18.0	23.9	200	120	18.6	32.3	200	120	19.1	31.2
Dec. 14-16	200	89	20.1	15.2	200	95	19.4	25.0	200	99	20.3	28.9	200	110	20.3	30.9
1934																
Jan. 12-13	200	79	12.0	15.9	200	95	12.9	28.5	200	97	16.0	32.1	200	99	16.4	32.6

[1] A=number of specimens; B=median length of the shrimp in millimeters; C=bottom temperature in degrees centigrade; and D=bottom salinity in parts per thousand.

TABLE 46.—*Relations between median size of shrimp captured, bottom temperature, and bottom salinity for four stations in Louisiana*

[Data were ranked from 1 to 4 for each of 17 periods; 1 is smallest or lowest and 4 is largest or highest]

Item	Rank	Rank 1	Rank 2	Rank 3	Rank 4
		Bottom salinity			
Median size	4	-------	-------	4.5	12.5
Do	3	-------	2	10.5	4.5
Do	2	1	14	2	-------
Do	1	16	1	-------	-------
		Bottom temperature			
Do	4	1	5	3.5	7.5
Do	3	2.5	3.5	4.5	6.5
Do	2	6	5	5	1
Do	1	8	3.5	3.5	2
		Bottom salinity			
Bottom temperature	4	1	1	7	8
Do	3	4.5	5	3	4.5
Do	2	3.5	5	6	2.5
Do	1	8	6	1	2

The correlation which our data shows between size and temperature is caused by the large number of cold-weather observations. In winter there is a definite relation between size and temperature, with the largest shrimp seeking the warmest temperatures. This correlation does not exist during summer. In fact the summer size-temperature relation is negative, but we can see no cause-and-effect connection.

INFLUENCE OF SALINITY AND TEMPERATURE ON MOVEMENTS

We wish to refer the reader to Gunter's papers on the distribution of fishes and invertebrates both in Louisiana and Texas. In general we agree with his conclusions on the relation between shrimp and both temperature and salinity. We do not entirely agree, however, with his statement that, "This general exodus of shrimp and other invertebrates as well as fishes from the bays is correlated with the annual temperature cycle and not with salinity changes or any other phenomenon." (Gunter 1950, p. 44.) Our data indicate that the shrimp normally leave the Texas bays as they approach adulthood. This movement is started in summer, long before there is any appreciable drop in temperature, and in spring with rising temperatures, and in some way seems to be related to salinity as well as to maturity or spawning. Dropping temperatures merely hasten and tend to obscure the other causes of this normal movement.

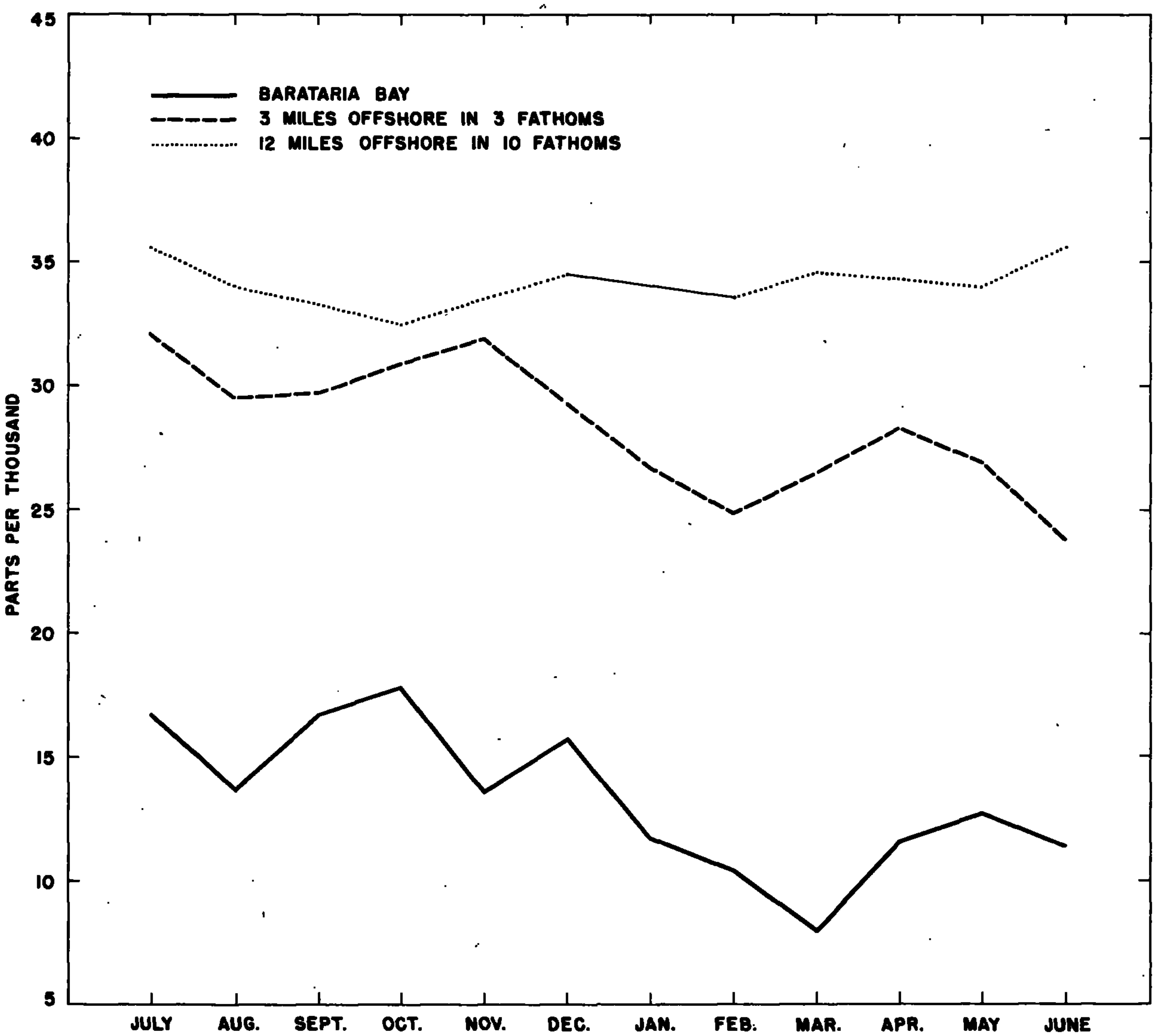

FIGURE 38.—Seasonal changes in bottom salinities in three parts of the shrimp habitat in Louisiana. We have no data for the 12-mile station during January.

SIZE DISTRIBUTIONS

SAMPLING PROCEDURE

Since Lindner (1933), Weymouth, Lindner, and Anderson (1933), and Gunter (1938) have described our sampling procedures in detail we shall not discuss them at length here. There are, however, certain rather obvious things connected with the sampling that should be pointed out. In the first place, in any fishery it is extremely difficult, if not impossible, to get samples that represent the population in its entirety. Our samples deal only with trawl-caught shrimp after they appear on the fishing grounds.

In samples taken from boats which we operated, there was a tendency for some of the smaller shrimp (about 60 mm. or less) to escape through the meshes of the trawl when fish and shrimp were not abundant. We do not believe this to be a serious factor in our sampling, since shrimp smaller than 60 mm. generally were not abundant on the fishing grounds. The small post-larval shrimp inhabit the marginal areas of the inland waters and apparently do not move to the inland fishing grounds until about 50 mm. or more in length (Anderson, King, and Lindner, 1949).

Along the Atlantic coast, from February 1931 through April 1933, our samples included only shrimp caught by our own boat in Georgia and northern Florida.[15] Numerous hauls were made each month in both the inside and outside waters in localities frequented by the commercial fishery. From each haul a random sample of 200 shrimp was measured. If less than 200 shrimp were caught, the entire catch was used as a sample. In May 1933 we changed our sampling procedure but not the number of shrimp measured in each haul. We curtailed our operations in Georgia and extended them to cover South Carolina and central Florida. In Georgia we usually made only four hauls each month in inside waters. All our remaining hauls were in outside waters on known fishing grounds that were close to shore. We made two hauls each month in each locality. The localities and months we fished were as follows:

South Carolina:

1. Cape Romain, September 1934 through July 1935.
2. Stono Inlet, May 1933 through July 1935 with exception of May through August 1934.
3. Gaskins Bank or Fripp Inlet, same as locality 2.

Georgia:

4. St. Catherines Island, same as locality 2.
5. Brunswick, same as locality 2.

Florida:

6. Fernandina, same as locality 2.
7. Mayport, May 1933 through April 1934, and August 1934.
8. St. Augustine, May 1933 through April 1935 with the exception of May through July 1934.
9. New Smyrna, same as locality 8.
10. Cape Canaveral, same as locality 8.

Our original objective (not always attained) was to sample on a semimonthly basis. After May 1933, when the area under study was expanded, the procedure was modified, and monthly samples became the goal for the remaining period of the work.

The numbers of shrimp upon which the size-distribution curves for this section of the coast are based are shown in tables 47 and 48. In all instances, data called "Georgia and northern Florida" include the entire Georgia coast and northern Florida as far south as Mayport.

[15] We have always appreciated the difficulties inherent in one-boat samples as recently pointed out by Gunter (1950), but we believe that the size selectivity generally exerted by the commercial fleet in inside waters, both from choice of fishing localities and from sorting, probably is equally bad.

TABLE 47.—*Numbers of shrimp in random samples used for determining Georgia and northern Florida size-distribution curves shown in figure 45*

Source and month	1931	1932	1933	1934	1935	Total
Inside waters:						
January	--------	1,463	2,590	800	799	5,652
February	1,417	408	2,400	800	800	5,825
March	2,086	1,780	2,400	800	501	7,567
April	3,149	4,343	2,518	730	456	11,196
May	3,736	1,474	788	--------	800	6,798
June	1,706	1,255	730	--------	141	3,832
July	1,090	1,934	788	--------	782	4,584
August	3,623	3,232	800	800	679	9,134
September	5,199	3,201	800	800	--------	10,000
October	3,016	3,200	800	611	--------	7,627
November	2,792	3,200	800	800	--------	7,592
December	2,599	3,045	800	800	--------	7,244
Total	30,413	28,535	16,204	6,941	4,958	87,051
Outside waters:						
January	--------	558	1,321	1,600	1,143	4,622
February	2,290	849	1,280	1,525	714	6,658
March	139	224	1,294	43	287	1,987
April	53	1,179	1,720	422	679	4,053
May	1,099	256	1,753	--------	650	3,758
June	400	692	1,679	--------	227	2,998
July	574	441	1,747	--------	305	3,067
August	944	1,310	1,244	1,040	--------	4,538
September	1,091	1,800	1,600	1,240	--------	5,731
October	1,118	1,680	1,600	1,200	--------	5,598
November	1,000	1,800	1,600	957	--------	5,357
December	600	1,832	1,600	1,200	--------	5,232
Total	9,308	12,621	18,438	9,227	4,005	53,599

TABLE 48.—*Numbers of shrimp in random samples used for determining Atlantic-coast size-distribution curves shown in figure 46*

Source and month	1933	1934	1935	Total
South Carolina:				
January	--------	800	553	1,353
February	--------	800	396	1,196
March	--------	800	297	1,097
April	--------	50	365	415
May	786	--------	170	956
June	842	--------	371	1,213
July	731	--------	416	1,147
August	805	76	--------	881
September	800	1,200	--------	2,000
October	800	800	--------	1,600
November	800	1,200	--------	2,000
December	800	1,200	--------	2,000
Total	6,364	6,926	2,568	15,858
Georgia and northern Florida:				
January	--------	1,600	1,143	2,743
Feburary	--------	1,525	714	2,239
March	--------	43	287	330
April	--------	422	679	1,101
May	1,753	--------	650	2,403
June	1,679	--------	227	1,906
July	1,747	--------	305	2,052
August	1,244	1,040	--------	2,284
September	1,600	1,240	--------	2,840
October	1,600	1,200	--------	2,800
November	1,600	957	--------	2,557
December	1,600	1,200	--------	2,800
Total	12,823	9,227	4,005	26,055
Central Florida:				
January	--------	947	1,145	2,092
February	--------	1,200	844	2,044
March	--------	819	217	1,036
April	--------	1,189	193	1,382
May	599	--------	--------	599
June	256	--------	--------	256
July	705	--------	--------	705
August	540	252	--------	792
September	1,001	1,200	--------	2,201
October	1,199	1,200	--------	2,399
November	1,200	1,050	--------	2,250
December	1,200	1,200	--------	2,400
Total	6,700	9,057	2,399	18,156

In Louisiana our samples were of two types: Those from our own boat in which we occupied the same stations month after month, and those from the offshore commercial fishery. When we used our own boat we attempted to occupy 3 inside and 3 outside stations twice each half month, but we were not always successful in occupying all stations each month. Also, since we are certain that our trawl did not always function properly at our outermost station which was 9 to 12 miles southeast of Fort Livingston Light, we have omitted the records of this station from our si>e-distribution data. Consequently, what we call "5-stations data" include 3 stations within Barataria Bay and 2 offshore from this bay, the outermost one 3 to 6 miles southeast of Barataria Pass. Gunter (1938, fig. 1) shows the location of these stations. The months in which we occupied them can be determined from table 49. As on the Atlantic coast, we measured only a random sample of 200 shrimp from each haul, even though we often caught more specimens.

In the Louisiana offshore fishery there was a definite tendency for the fleet to seek areas where shrimp were most abundant, and this may have affected the size distributions to some extent. However, the fishermen in Louisiana rarely discarded any of the shrimp (as they often did in Texas) since they seldom caught more than a few small ones.

For our Louisiana offshore-fleet size distributions we took a random sample of 50 shrimp from the last haul made by each boat we sampled. The boats were always away from port for more than 1 day, but they always knew where they had made their last haul.

Our samples contain shrimp from various depths as follows:

1. Under 5 fathoms: March through December, but heaviest in September and October.
2. In 5 to 8½ fathoms: Every month, but heaviest from May through January,
3. In 9 to 12½ fathoms: Every month, but heaviest from January through September.
4. In 13 to 16½ fathoms: November through August, but heaviest during March, April, and December.
5. In 17 or more fathoms: November through May, but heaviest during March and April.

In the Louisiana offshore fishery we attempted to collect the samples on a semimonthly basis from April 1941 through November 1942; thereafter they were taken only periodically. The months of our sampling can be seen in table 50.

In samples from the commercial fishery at Aransas Pass, Tex., several factors enter which appreciably affect our size distributions. There the commercial trawlers tended to do selective fishing for the larger shrimp (greater than about 100 mm. in length), since these shrimp commanded a higher price. The fishermen also resorted to culling the small shrimp and discarding them. The distortion of the data based on samples of shrimp from a commercial catch treated in this way is probably as great as any which would characteri-e those based on 1-boat samples, as has previously been mentioned.

TABLE 49.—*Numbers of shrimp in random samples used for determining Louisiana 5-stations size-distribution curves shown in figure 40*

Source and month	1931	1932	1933	1934	Total
Inside waters:					
January		618	335	837	1,790
February			977	403	1,380
March		1,538	912		2,450
April		726	1,484	500	2,710
May		503	869	115	1,487
June		232	580	418	1,230
July	345	320	1,200		1,865
August	2,222	689	628		3,539
September		1,039	571		1,610
October	788	2,394	1,200		4,382
November	623	820	1,200		2,643
December	600	948	1,139		2,687
Total	4,578	9,827	11,095	2,273	27,773
Outside waters:					
January			1,002	611	1,613
February			1,197	300	1,497
March		300	562		862
April			611	255	866
May		584	200	201	985
June		417	378		795
July	140	718	565		1,423
August	442	233	848		1,523
September		800	401		1,201
October		1,780	249		2,029
November		682	600		1,282
December		600	600		1,200
Total	582	6,114	7,213	1,367	15,276

Our samples at Aransas Pass, Tex., were all from the commercial fishery. Here the boats went out early in the morning and returned with their catch early in the afternoon of the same day. We took 100 shrimp from each boat sampled. An attempt was made each week to equalize the number of samples from the inside and outside fishery. The numbers of shrimp we obtained are shown in table 51.

At Galveston, Tex., although fishing was permitted only in outside waters, the boats operated on a daily basis as did those at Aransas Pass. Our samples here consisted of 100 shrimp per boat,

TABLE 50.—*Numbers of shrimp in random samples from commercial boats, used for determining Louisiana size-distribution curves shown in figure 39*

Source and month	1931	1932	1933	1934	Total
Five stations:					
January		618	1,337	1,448	3,403
February			2,174	703	2,877
March		1,838	1,474		3,312
April		735	2,095	755	3,585
May		1,087	1,069	316	2,472
June		649	958	420	2,027
July	485	1,038	1,765		3,288
August	2,664	922	1,476		5,062
September		1,839	972		2,811
October	788	4,174	1,449		6,411
November	623	1,502	1,800		3,925
December	600	1,548	1,739		3,887
Total	5,160	15,950	18,308	3,642	43,060

Source and month	1941	1942	1943	1944	Total
Offshore fleet:					
January		5,899		1,800	7,699
February		2,150	1,346		3,496
March		6,050	200	400	6,650
April	2,099	2,900	700		5,699
May	4,900	1,900			6,800
June	4,850	792	599		6,241
July	800	3,092	400	1,000	5,292
August	1,100	2,658			3,758
September	850	3,550			4,400
October	2,700	4,385	1,200		8,285
November	3,200	600			3,800
December	2,050		2,199	699	4,948
Total	22,549	33,976	6,644	3,899	67,068

and we attempted to sample on a monthly basis. The numbers of shrimp comprising the size-distribution curves for Galveston are shown in table 52.

We are still not certain how adequate or representative our sampling was or how truly our curves represent the shrimp population. We considered various methods of weighting our samples, but after giving consideration to each we arrived at the conclusion that no method we could devise would give a true representation of the entire shrimp population at any one moment. The principal difficulty arises from the fact that as the shrimp increase in size they change their habitat. This change of habitat is not correlated with size alone; it is also dictated by winter temperatures and influenced by spawning. As a consequence, we generally find that in any one locality there is almost always an immigration and emigration of shrimp. For these reasons we have used rough methods in arriving at our size-distribution curves; we believe that any attempt at refinement would add nothing to their accuracy.

In arriving at the size-distribution curves which we present, we have followed the same procedure in each instance. The shrimp in all hauls of each month from a similar source were combined, with

TABLE 51.—*Numbers of shrimp in random samples used for determining Aransas Pass, Tex., size-distribution curves shown in figure 42*

Source and month	1931	1932	1933	1934	1935	1936	1937	Total
Inside waters:								
January				300				300
February			400					400
March			2,000	300				2,300
April		100	1,200					1,300
May	582		1,200	300		300		2,382
June	100		600					700
July		200	300		300		300	1,100
August		1,800	600	500	400	400	600	4,300
September	1,025	1,000	1,200	1,100	800	400	600	6,125
October	1,600	1,200	1,200	1,000	400	300	300	6,000
November	1,800	1,400	1,200	1,000	600	200	600	6,800
December	1,200	400	600	500		300		3,000
Total	6,307	6,100	10,500	5,000	2,500	1,900	2,400	34,707
Outside waters:								
January		800		300	500	300		1,900
February		1,000	400	500	800		400	3,100
March		1,000	600	600	200	200		2,600
April		1,000	1,200	900	100	200		3,400
May	449	1,200	1,700	1,200				4,549
June	1,600	600	900	400	200	700		4,400
July	1,200	1,000	1,200	800	200	300		4,700
August	1,200	400	900			200		2,700
September	600	200						800
October	800	1,400			400			2,600
November		1,000	300			200		1,500
December	600	200		600	500	400	200	2,500
Total	6,449	9,800	7,200	5,300	2,900	2,500	600	34,749

TABLE 52.—*Numbers of shrimp in random samples used for determining Galveston, Tex., size-distribution curves shown in figure 44*

Source and month	1933	1934	1935	1936	Total
Outside waters:					
January		500	500	500	1,500
February		1,000	200	400	1,600
March		800	500		1,300
April		1,000	400	400	1,800
May		1,000	500	400	1,900
June		1,000	200		1,200
July		600	400		1,000
August		400	500		900
September		500			500
October	1,000	500	500		2,000
November	1,000	400			1,400
December	1,000	500			1,500
Total	3,000	8,200	3,700	1,700	16,600

each year treated separately. Then the particular months from the various years were combined by percentages of shrimp in each size group. Each month for any one year has the same weight in determining the shape of the curve for that month as does the same month in any other year. For example, in figure 39 for the 5-stations data (table 50), January 1932 with 618 shrimp has as much influence in determining the shape of the curve for January as does January 1934 with 1,448 shrimp.

Furthermore, although Weymouth, Lindner, and Anderson (1933) have shown that, after approaching maturity there is considerable difference in size between adult male and female shrimp for Georgia, and we have found no startling variation

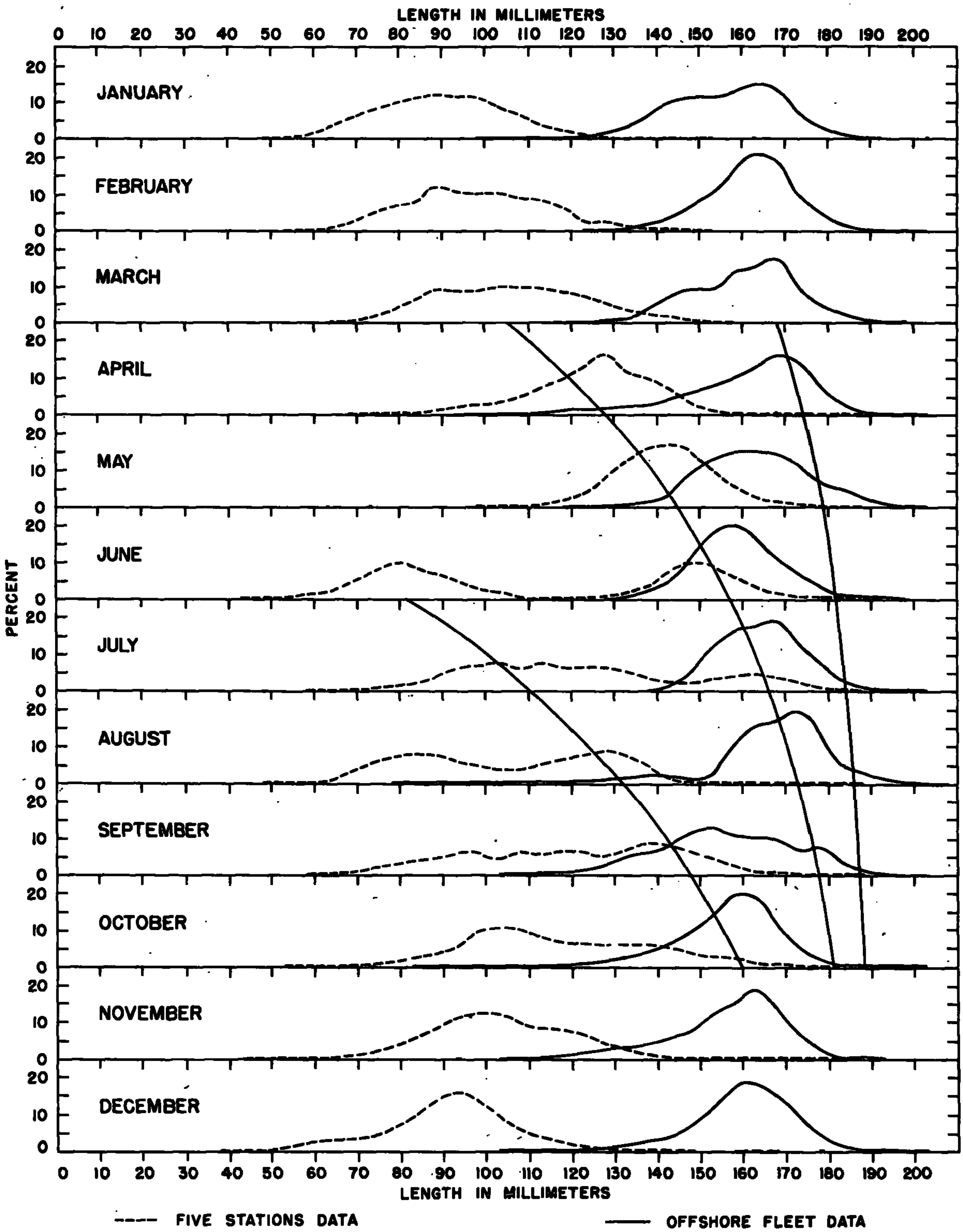

FIGURE 39.—Average monthly size distributions for Louisiana, separated into 5-stations data and offshore-fleet data.

from this in any of the other localities studied, we have grouped male and female shrimp together, for two reasons. First, the industry does not separate the sexes in commercial fishing and second, we suspect the variations in the data generally are sufficient to obscure most variations between sexes. Our method of treating the data tends to broaden the curves.

CATCH RECORDS

For the Louisiana total catch curve we have used the New Orleans Fishery Market News Service records (table 53), though they are not complete. We did not use the State records because they are based on tax receipts which were credited to the month in which the taxes were paid rather than the month in which the shrimp were caught. Our records for the Louisiana offshore fleet (table 54) were copied from the books of almost all of the companies engaged in this fishery. We are indeed grateful to these companies for their splendid cooperation. We think that our catch records for the Louisiana offshore fleet include between 90 and 100 percent of the catch of the entire fleet, and that the average monthly trend of production as shown by the Market News Service represents the total Louisiana production trend fairly accurately.

TABLE 53.—*Total Louisiana landings of shrimp, by months, 1940 to 1946*

[In thousands of barrels. A barrel is equivalent to 210 pounds of whole shrimp. Figures do not include shrimp used for drying. Data from Fishery Market News Office, New Orleans]

Month	1940	1941	1942	1943	1944	1945	1946
January	5.1	19.0	15.4	9.4	12.4	14.7	8.4
February	7.4	10.6	5.5	11.8	8.4	4.0	6.5
March	10.7	2.1	6.0	3.6	5.0	3.9	3.5
April	18.7	5.8	15.4	6.4	4.7	5.7	7.4
May	28.8	16.3	16.9	24.8	10.5	14.4	12.8
June	15.4	13.4	18.7	15.9	14.8	9.9	13.8
July	10.4	1.8	7.1	9.9	5.1	3.8	4.2
August	32.5	30.5	30.3	51.1	41.3	27.2	30.2
September	53.0	27.7	40.8	48.3	51.0	28.6	36.2
October	54.7	56.1	54.6	37.3	53.9	29.2	33.2
November	12.7	36.3	27.3	26.8	25.0	17.2	21.3
December	14.6	18.0	21.1	17.9	13.2	9.2	16.6
Total	264.0	237.6	259.1	263.2	245.3	167.8	194.1

TABLE 54.—*Louisiana offshore-fishery landings of shrimp, by months, 1938 to 1946*

[In thousands of barrels; a barrel is equivalent to 210 pounds of whole shrimp]

Month	1938	1939	1940	1941	1942	1943	1944	1945	1946
January	0.7	3.3	2.9	9.7	8.0	4.4	8.0	6.7	5.8
February	2.5	2.0	6.7	7.5	2.8	9.5	6.8	1.7	5.5
March	2.2	2.9	7.5	1.8	7.6	1.4	2.2	4.2	2.1
April	1.3	3.4	6.2	4.2	13.7	4.8	4.3	6.9	7.4
May	4.9	6.1	12.7	11.2	10.8	15.5	7.4	11.6	10.5
June	4.5	5.1	10.2	13.0	13.7	9.3	12.2	7.2	10.7
July	3.4	6.1	9.1	.3	9.0	6.6	7.7	6.0	7.1
August	2.8	5.5	4.0	3.2	5.3	5.7	7.2	5.5	1.7
September	3.2	4.1	3.0	2.5	7.1	7.1	12.9	7.8	2.0
October	4.7	4.4	12.4	11.7	16.2	12.4	23.1	13.4	10.0
November	4.6	5.6	6.0	15.2	8.4	13.4	13.8	10.1	8.1
December	5.7	7.4	8.4	8.5	6.8	9.1	10.3	6.9	8.4
Total	40.5	55.9	89.1	88.8	109.4	99.2	115.9	88.0	79.3

LOUISIANA

In our discussion of the size distributions we treat the Louisiana curves first, as we believe them to be easier to interpret since they are complete in that they follow the fishable shrimp population throughout the year, and they are less distorted by migrations than are the curves of the other localities. In each instance, we have superimposed growth curves on the size-distribution illustrations to facilitate their interpretation. The growth curves were calculated from the formula $Y=51.00+0.7322X$.

In figure 39 we show curves derived from two distinct fishing localities in Louisiana. In June, about 2 months after spawning begins, young shrimp with a mode at about 80 mm. make their appearance on the inside fishing grounds (fig. 40). The larger of these shrimp begin moving to outside waters by July, and offshore by August. By October (fig. 39) they completely dominate the offshore fishery. This group can be followed as a distinct mode from the time of its appearance inland in June, through its dominance offshore in October, and until in May it becomes fused with, and in June dominated by, another oncoming group. Our calculated growth curve appears to fit the first group almost perfectly (fig. 39), both with respect to the midpoint and the upper and lower limits of the distribution.

By December (fig. 39), the shrimp have separated into two different size groups. The earlier-spawned shrimp are offshore, and the later-spawned shrimp are inshore. There is little growth in the offshore shrimp from November through February, and rapid growth apparently is not resumed until about mid-March. The small inshore shrimp do not appear to have reached their full recruitment until January, and although some growth seems to have taken place in February, rapid growth apparently does not occur until March.

Although we do not have seining data for this time of year from Louisiana, Gunter (1950) has shown quite clearly that in Texas this second group comes from very late spawning. We have no reason to suspect Louisiana shrimp to behave differently.

By April the small shrimp which wintered inshore start moving offshore. They dominate the offshore fishery by June and can be traced readily until they themselves become dominated in October by the oncoming young. The slight indication of bimodality in our offshore curves during summer, with the dip in July at 163 mm. and in August at 168 mm., results from sexual dimorphism (see figs. 8 and 9).

The curves suggest the entrance of a second wave in August, followed by more or less constant influxes thereafter until March. A false impression results from our technique of combining the data of several years, and actually the entrances were quite different from those indicated by figure 39. They occurred at irregular intervals. During the two years for which our data are complete, the entrances took place in June, August, October, and December 1932, and in June, September, and November 1933. There appears to be but little growth of the last arrivals between November and February. Recruitment into the lower end of this group seems to occur until January.

The entrance of the young into the Louisiana estuarine fishing grounds is most interesting. They appear in waves with distinct modes that can readily be followed. Apparently the only regularity of appearance is shown by those entering in June. They appeared for three consecutive years, and judging from our July 1931 records they had appeared in June of that year also. In both 1932 and 1933 this group could be detected in Barataria Bay until October.

In 1933 the first wave appeared in June at the head of Barataria Bay (Bayou St. Denis and St. Marys Point) with a mode between 78 and 83 mm. In July, it was found at all 5 stations with a mode that ranged between 113 and 123 mm. In August the mode was between 123 and 133 mm., in September between 133 and 148 mm., and in October it was easily distinguishable only near the mouth of the bay and in outside waters, where it ranged between 148 and 158 mm. The second wave appeared in September with a mode between 83 and 98 mm. and disappeared from the bay after November. In November its mode was between 118 and 123 mm. The third wave appeared in November at the head of the bay with a mode between 88 and 98 mm. This mode receded until January, which we suspect was caused by emigration of the larger shrimp and immigration of smaller ones. The variations each month in lengths of the modes represent variations between stations since the smallest shrimp were generally at the head of the bay and the largest in the Gulf.

Our 5-stations data are not suited for estimating the relative importance of the various waves entering the fishery, but our offshore-fleet curves reflect the relative importance of the individual influxes. We think it probable from figures 39 and 41 that the first and last successful spawnings are the most important. Since the Louisiana offshore fishery had no serious legislative restrictions and not too much seasonal fluctuation in fishing effort, it is probable that the offshore catch curve (fig. 41) closely follows the abundance trend. This curve reaches a low in August, rises in September and sharply in October, drops slowly until March, then rises to another peak in May. The October peak we can trace (fig. 39) to young shrimp appearing in inside waters in June, and the May peak to small shrimp wintering inshore.[16]

Since the data are not adequate, we cannot be certain from the 5-stations curves whether or not the first wave of young shrimp completely dominates the succeeding waves during the summer, and likewise the inshore fall fishery. It is possible that this group is important to the offshore fishery only because it largely escapes the inshore fishery. Nevertheless, the first wave certainly must contribute heavily to the inshore fishery during August and September, and from this it would seem likely that it completely dominates the other waves.

In spite of the shortcomings of our sampling technique and treatment of the data, and in spite of the rapid growth of the shrimp, the sharpness of the two December modes in figure 39 is apparent and hence indicates two relatively short periods of

[16] We realize the insecurity of our position in using, in combination, size-distribution data collected 10 years apart, but if, as we think, our data represent average conditions (and we have treated them to make them as nearly average as possible) then we are justified in using them. The displacement to the left of the offshore modes in exactly those months (May and June, and August and September) in which the 5-stations curves display a marked skewness or decline at their right extremities (indicating migration of the large individuals) certainly suggests that our method is valid.

The trend of the All Louisiana catch curve (fig. 41) is affected by changing fishing intensity caused both by closed seasons and by changing effort during the open season. July, for example, is low because of closed season while actually, with unrestricted fishing, we would expect it to be greater than June.

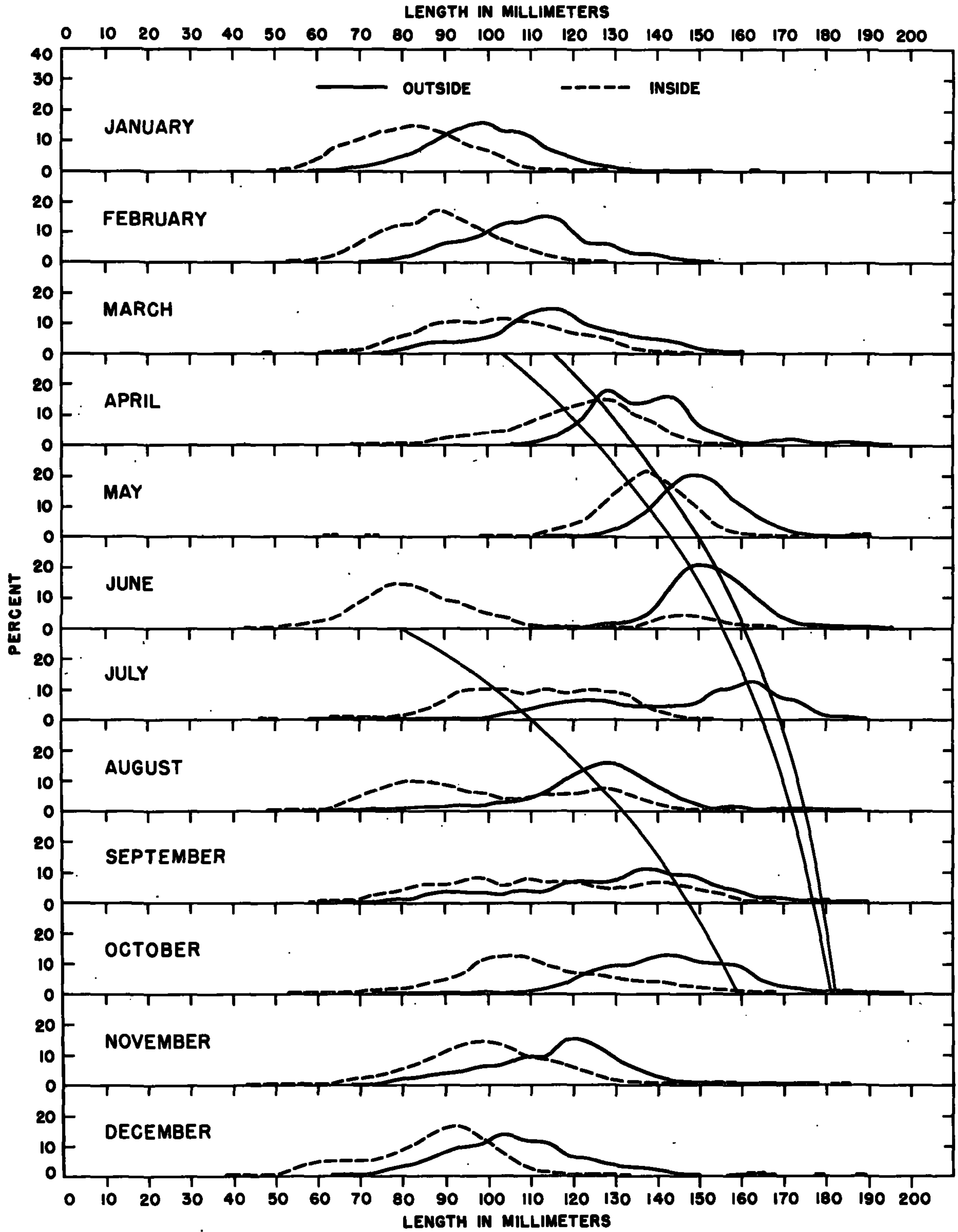

FIGURE 40.—Average monthly size distributions for Louisiana five stations, separated into shrimp caught in inside and in outside waters.

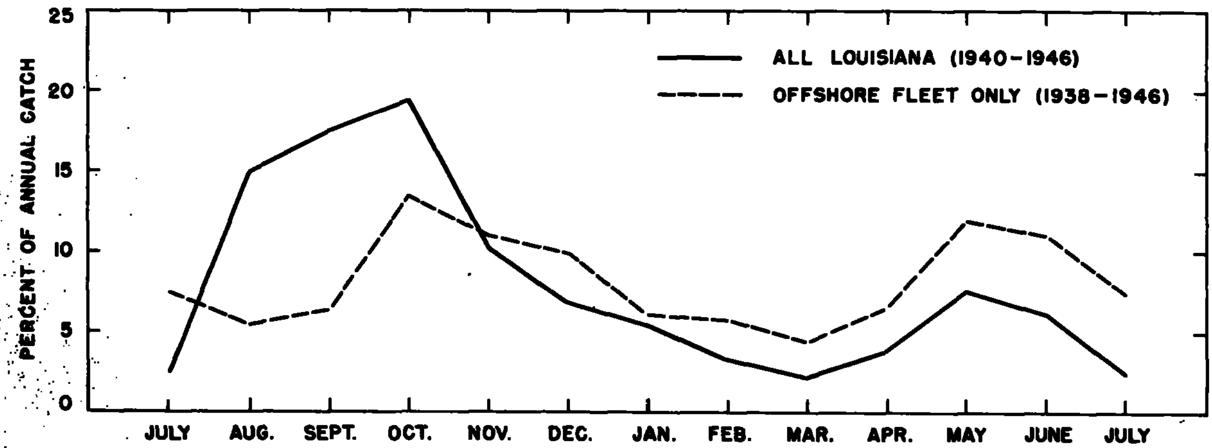

FIGURE 41.—Monthly percentage of average annual shrimp catch for all Louisiana (less shrimp used for drying) and for the Louisiana offshore fleet. See tables for further data.

successful spawning. This, supported by the evidence from the catch records (fig. 41) leads us to conclude that only the first and last waves of recently spawned shrimp are dominant, and that the intermediate waves are relatively insignificant.

If the progression of the modes which represent the shrimp entering the 5-stations area in June is considered together with the superimposed growth line, it will be seen that during the period June to September (when this population is comparatively free from shrimp of different spawnings) the midpoint of each mode coincides rather closely with the upper limit of the mode in the previous month and the lower limit of the mode in the succeeding month. In other words, the mode in each instance is well bracketed by allowing for 1 month's growth before and 1 month's growth after that represented by the midpoint. This would indicate that there is no more than 2 months' difference in the ages of the shrimp represented by the mode and that the spawning success extends over a 2-month period. However, since the curves represent samples taken over the entire month (during which growth had been taking place) rather than only at the midmonth, we can compensate for this growth by eliminating 2 weeks from either side, thereby restricting the period of spawning success for each mode to 1 month. Because of this and our spawning data, we believe that the shrimp producing the mode in inside waters in June at about 80 mm. come from shrimp spawned in April. Although this group can clearly be traced to the offshore mode at about 160 mm. in October, the marked spread at its lower end in this and subsequent winter months indicates that by this time the curve encloses some shrimp spawned in May, while those shrimp at its upper end, larger than 170 mm., were probably contributed by stock of previous years.

The range shown by the mode at about 90 mm. in December also represents about 1 month's spawning. During the spring this group can be traced in a manner similar to that previously described.

It appears then that about 6 months of growth are required for a shrimp to reach 160 mm. in length. The second mode, which appears in the 5-stations curves during winter, and which can readily be traced to its appearance offshore in June (fig. 39), could therefore be attributed to shrimp which in June had just slightly less than 6 months of growth. If we assume that no growth occurred from mid-October to mid-March it would place this group as having been spawned the previous July. However, if there was one month or more of growth during this 5-month period between October and March (which seems entirely within reason from our data) then most of these shrimp must have been spawned in August or later. Furthermore, as suggested by the data of Anderson, King, and Lindner (1949, fig. 1) and of Gunter (1950, fig. 1), if the very young are not slowed in growth during winter as much as the slightly larger sizes, most could have come from September, or possibly October spawning.

Apparently in Louisiana there are two important periods of spawning success, one at the beginning and the other at the end of the spawning season.

TEXAS

Aransas Pass

The curves for the shrimp at Aransas Pass, Tex., differ from those in Louisiana in that at Aransas Pass there appear to be three successful spawning groups instead of two. However, the second and third of these evidently contribute more to the fishery than does the first, so that actually there are only two successful spawning periods.

In figure 42 the young appearing in inside waters in July with a mode at about 115 mm. can, from our growth curve, be attributed to April spawning. A second group, which can be traced to late May or June spawning, enters the fishery in September with a mode at about 120 mm. The lower ends of the curves for September seem to show the effect of selective fishing and culling, and the modes shown in our curves for this month, therefore, probably are a few millimeters longer than the true mode for this group. The second group dominates the fall and winter fishery. We do not think the first group could have been fished out, as generally there was little fishing in inside waters during July and August. Furthermore, since this first group made but slight impression on the curves in outside waters in August and September we do not believe the shrimp comprising it to have been very abundant.

Because of selective sampling by the fishing fleet, the third group, which is comparable to the second or late-spawned group in Louisiana, does not appear continuously in our curves until February, although Gunter (1950, fig. 1) shows this group throughout the winter.[17] This third group, which produces the June peak in the catch (fig. 43), we can follow in the outside waters until September. The relation between the growth lines and the modes for this group of shrimp after June suggests that either this group grows much less rapidly than the comparable group in Louisiana or else the fishery was not operating on the entire spawning stock. From the skewness of the curves we suspect the latter explanation to be the more likely. The commercial fleet at Aransas Pass during the years we were sampling never operated far from land and if the shrimp spawn offshore (which we think they do) then our samples would be heavily weighted by the smaller sizes, because the larger shrimp tend to spawn first.

This same phenomenon occurs in our Atlantic-coast curves (figs. 45 and 46) and probably for the same reason, since most of our outside samples were taken close to shore. Our 5-stations curves (fig. 40) also show this for the immature shrimp from August through October. In this instance we can demonstrate that the slow advance in the upper mode results from the large shrimp moving offshore (fig. 39).

As we have mentioned, the first-spawned group, which appears in July with a mode at about 113 mm. (fig. 42) and which we attribute to April spawning, does not appear to be particularly abundant. This could be caused either by the lack of sufficient spawners or by some environmental phenomenon, which we do not know. If, as we believe, spawning is continuous once it begins, then the sharpness of the mode and its advance from July to August suggests some external cause rather than the lack of spawners.

On the other hand, apparently the bulk of the fall and winter catch in this region comes from shrimp spawned in late May or early June. This coincides with the beginning of spawning of the group which we show in February in inside waters with a mode at about 98 mm. If, as it appears from our curves, there are few early-spawning shrimp, then perhaps there may be a relation between the number of spawners and the resultant crop. However, such a relation would not account for the scarcity of very small shrimp during summer, as shown by Gunter (1950), nor would it account for the obviously very late-spawned shrimp which, as we demonstrate, cause the June peak in the catch.

Galveston

Our Galveston, Tex., curves (fig. 44) during part of the year (October to January) appear to be

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[17] Gunter (1950) has shown the scarcity of small shrimp in central Texas during midsummer, which he interprets to mean (as do we) two separated periods of successful spawning. We suspect that the mode which Gunter shows in June 1941 at 28 mm. accounts for the July mode at 83 mm. and the small September mode at about 133 mm. Attributing the shrimp appearing in July 1941 at 83 mm. to the group producing the prominent mode at 113 mm. in September would require either a slower growth rate for young Texas shrimp during summer than in spring (which does not appear to be true from our data, and the spring growth shown by Gunter's data from February to April 1942 is in complete accord with our growth rate), or a growth rate different from that in Louisiana, which does not appear probable. The mode he shows in July at 38 mm. could account for the mode he shows in September at about 113 mm. and in October at about 133 mm. This is according to our growth formula which may be entirely unreliable below 80 mm. If we assume that about one month is required from the time the eggs are laid until the young appear in his seine catches with modes between about 28 and 48 mm., then the mode Gunter shows in May 1942 could be attributed to April spawning and would also account for the shrimp about 133 mm. long he shows in August of both 1941 and 1942.

It must be remembered that Gunter's data, like much of ours, are not adequate.

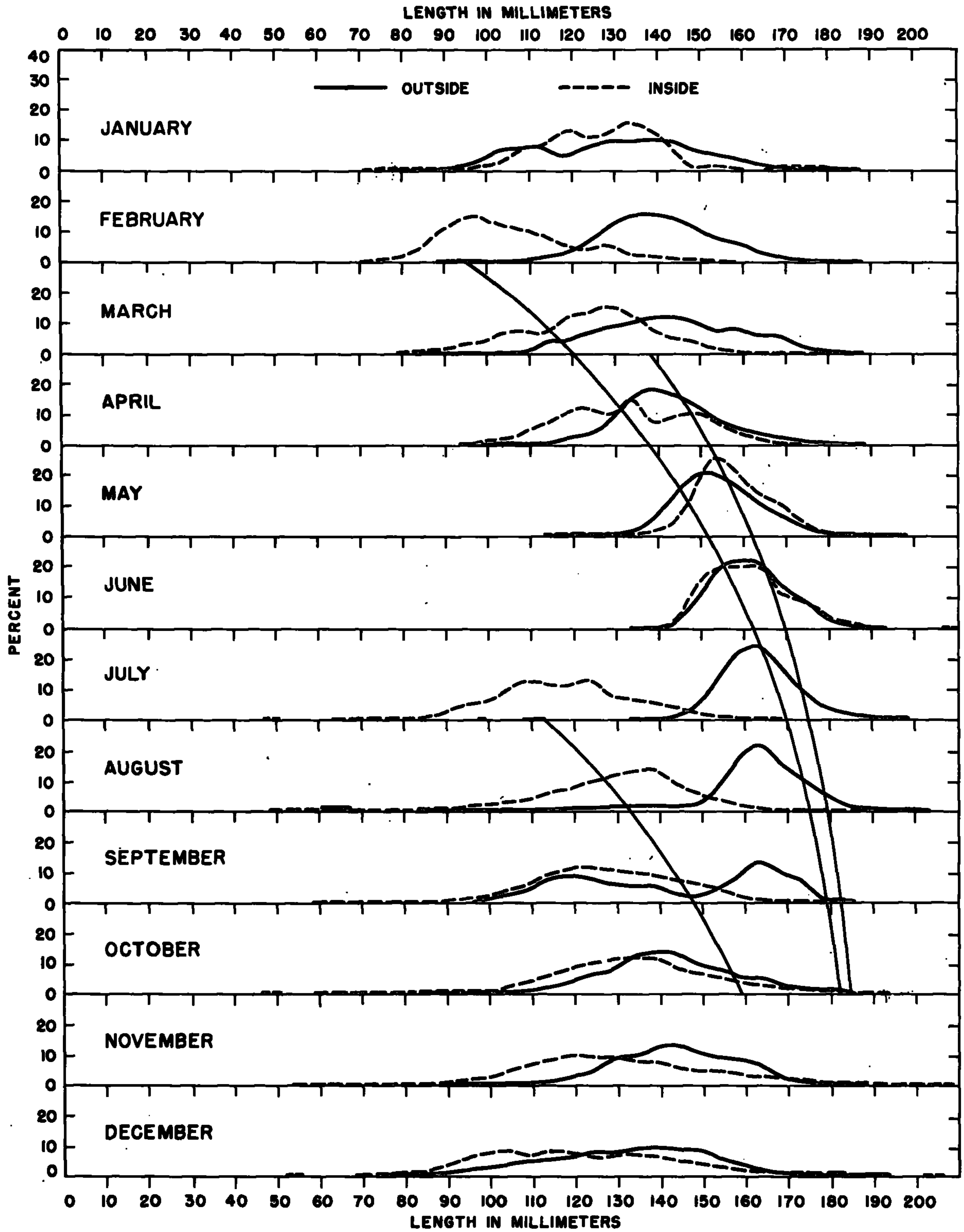

FIGURE 42.—Average monthly size distribution of the commercial catch at Aransas Pass, Tex., separated into shrimp caught in inside and outside waters.

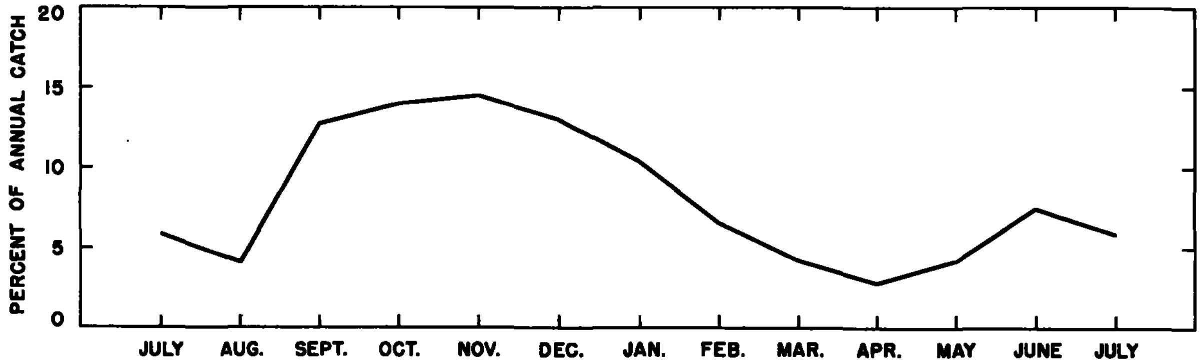

FIGURE 43.—Monthly percentages of average annual shrimp catch for Texas. This figure is derived from Anderson, Lindner, and King (1949, table 1).

intermediate between those for Louisiana and those for Aransas Pass, and during another part of the year (February to September) they appear comparable to the Louisiana offshore fleet curves. We think that actually the shrimp population at Galveston behaves in a manner comparable to the Louisiana population and that the anomalies in our curves result from inadequate sampling of the population by the fishing fleet and by ourselves. Throughout the year, the Galveston fleet fished relatively close to shore. In the fall and early winter this tended to deemphasize the proportion of April-spawned shrimp and overemphasize those spawned later. Nevertheless, the mode in March at about 160 mm. can be attributed to shrimp spawned the previous April, and that appearing in May at about 150 mm. can be attributed to shrimp spawned the preceding August or later.

The curve for September appears misplaced, but this is the result of sampling. It represents only 1 year, but is quite comparable to the September curve for the Louisiana offshore fleet. Most of the shrimp larger than 153 mm. were adults and are representative of the summer spawners.

ATLANTIC COAST

Our curves for the Atlantic coast (figs. 45 and 46) are difficult to interpret for two reasons. First, since the samples are from a single boat the data are inadequate, and the curves cannot be construed to represent the real abundance of shrimp by lengths. Second, coastwise migrations confuse their interpretation.

The curves can be interpreted in several ways. Their broadness and flatness suggest a more continuous spawning than occurs in the other localities. This may merely be a reflection of our sampling technique and treatment of the data. Both our curves and those of Weymouth, Lindner, and Anderson (1933, fig. 10) suggest three periods of spawning success: April, June, and August or later. The young from the first of these spawnings appear on the Georgia and northern Florida fishing grounds in July (fig. 45) with a mode at about 100 mm. (Apparently initial spawning success averages about 2 weeks later in this region than it does in Louisiana.) The young from the second spawning success appear in September with a mode at about 110 mm., and those from the third first form a mode in figure 46 at about 100 mm. in March.

Evidently all of the first group, and perhaps most of the second, migrate south into central Florida during late fall and early winter. All of the third group and the smaller shrimp of the second group remain. In our curves (fig. 46) the three groups are represented by modes at about 155 mm., 130 mm., and 100 mm., in February. In those of Weymouth and others (*loc. cit.*), the second and third groups demonstrate modes in February 1931 at about 140 mm. and at 100 mm.; and during the winter of 1931–32 they appear again, but at about 130 mm. and 100 mm., respectively. Of course, differential migration according to size and year can cause considerable shifting in the mode of the second group during winter. Also the imperfections of our sampling technique can result in shifts in all the modes.

If we accept the foregoing interpretation, then the young from the first and second successful spawnings produce the fall peak in the catch (fig. 15) in the northern and central sections, and the winter peak in central Florida. All three, but most likely those principally from the third, form the spring run with peak catches in June.

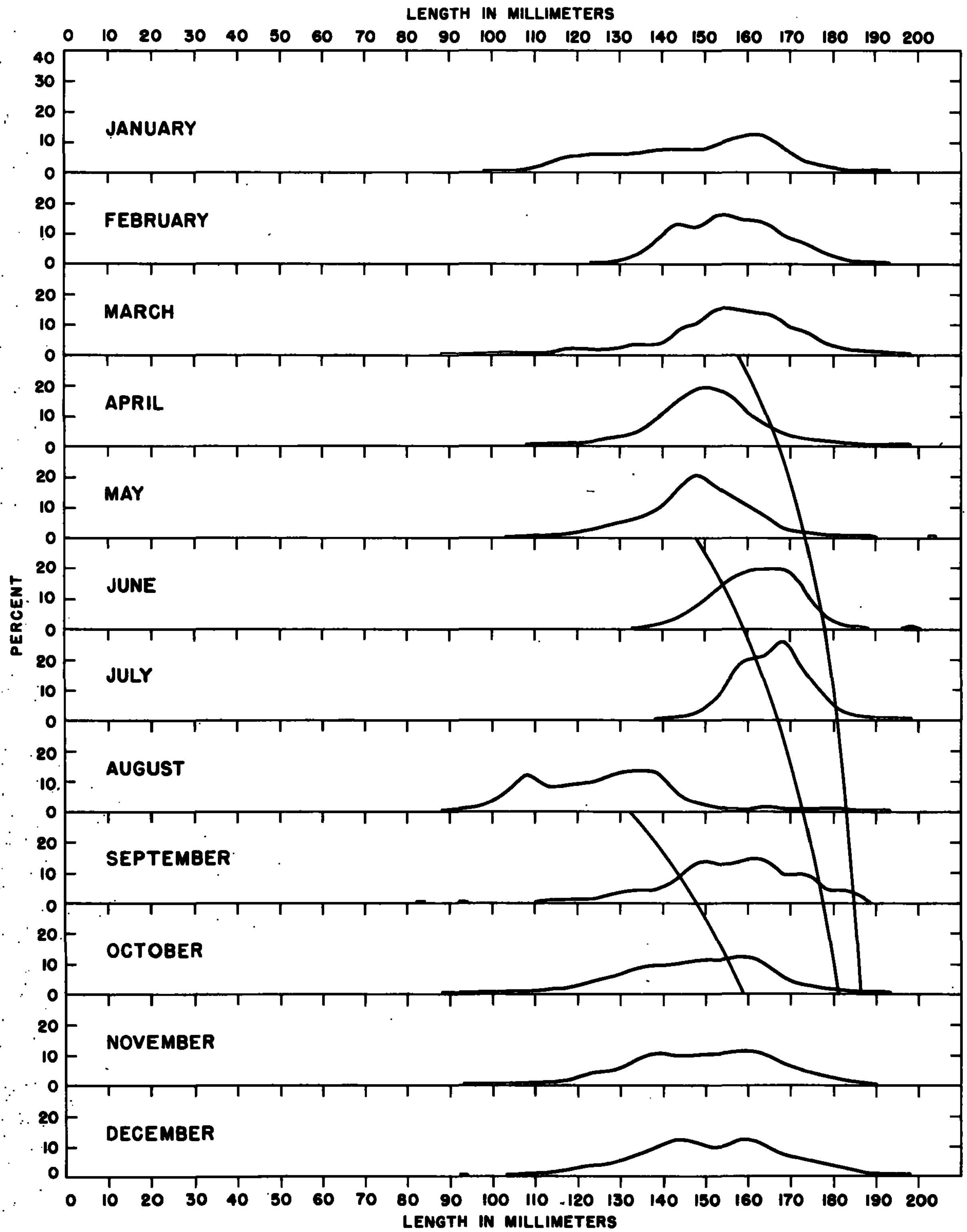

FIGURE 44.—Average monthly size distributions of the commercial fishery at Galveston, Tex. There was no inside fishery at Galveston.

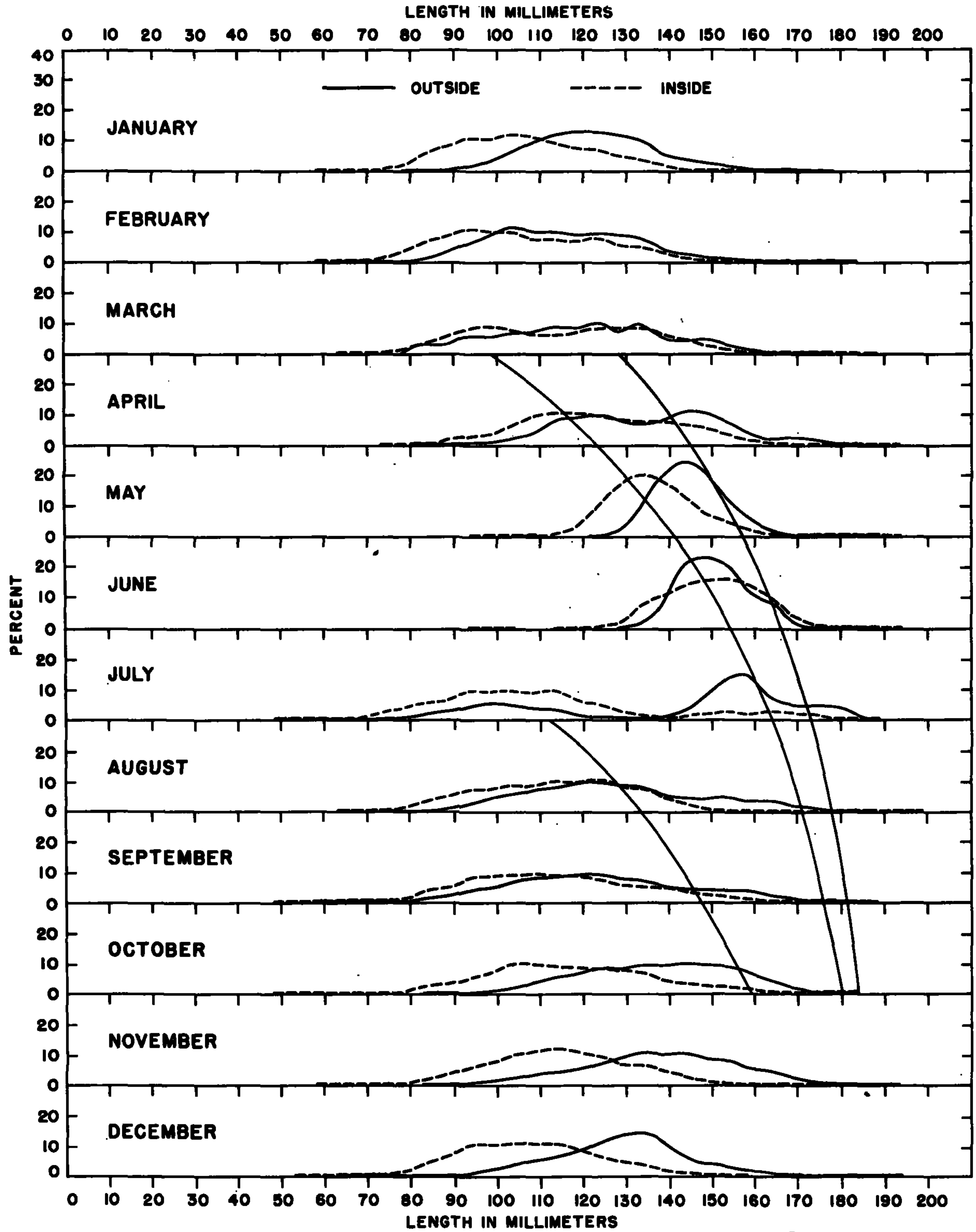

FIGURE 45.—Average monthly size distributions for Georgia and northern Florida, separated into shrimp from inside and outside waters.

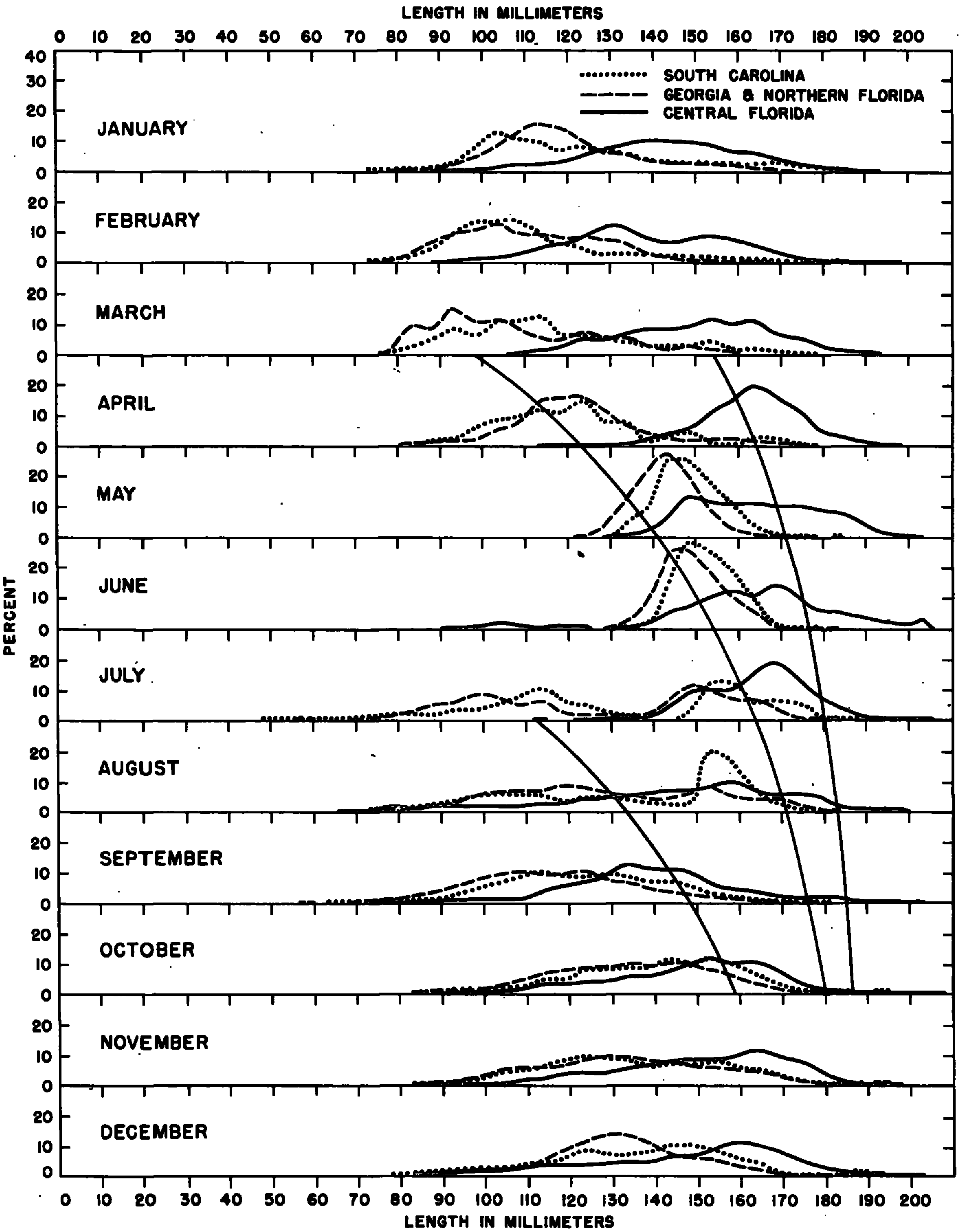

FIGURE 46.—Average monthly size distributions from outside waters of South Carolina, Georgia and northern Florida, and central Florida.

Our data are inadequate for differentiating between the relative importance of the three successful spawnings.

Except, perhaps, for the indication of a slightly earlier spawning success, the South Carolina curves are comparable to those for Georgia and northern Florida.

The appearance in central Florida of young shrimp with an average length of about 110 mm. in June suggests an occasional spawning in this section as early as mid-March.

SUMMARY

GROWTH

Tagged shrimp were measured both at release and after recapture. The increments thus observed were described with reference to the size at release. The increment was greater for the smaller shrimp. This relation of increment as a function of initial total length was described as linear. At 10 cm. total length, the 1-month increment is nearly 3 cm., while at 17 cm. total length, it is less than 1 cm.

From November to April, very little growth was observed. During the rest of the year, growth was rapid: After 12 months of growing season, these shrimp would have completed nearly all of their lifetime increase in length.

MIGRATION

From tagged shrimp released in various areas of the entire fishery and at various seasons, the location of recoveries demonstrated what movement, if any, occurred.

Releases during the fall months on the south Atlantic coast were recovered consistently south of the area of release, while those released during winter and early spring were recovered largely to the north.

Shrimp released along the major portion of the Gulf coast showed no indication of coastwise migration. They were recovered in all directions from the point of release, and they had not moved far; none had crossed the Mississippi-delta region. Only in the region of southern Texas may there be a coastal migration, but the evidence from this area is not adequate to prove or disprove it.

In all areas the small shrimp found in inside waters were eventually recovered from outside waters.

SPAWNING

The evidence from which inferences on spawning are derived consists in observations on the degree of maturity of the ovaries of female shrimp. Ripe ovaries were taken in most areas from April through September. The size composition of the ripening populations changed during this time, however, and there may be two or more groups of spawners, possibly spawning at different times of this season. Judging from size at maturity, shrimp spawned in the spring or summer probably spawn in the corresponding season of the following year.

DISCUSSION AND RECOMMENDATIONS

In all the localities we studied there appear to be 2 or 3 separated periods of spawning success. All localities are consistent in that the first appears to be associated with the beginning of the spawning period, and the last with the end of spawning. In those localities where there appear to be three periods, the middle one seems to be associated with the beginning of the spawning of the last group from the previous year. If spawning were rhythmic, with a beat in April, another in June, and a third in August or later, we could postulate a direct relation between the numbers of shrimp spawning and the crop produced. However, our spawning data indicate more or less continuous spawning from the beginning of the season until the end, with the peak of spawning in June or July. Consequently, it appears that some factor other than the number of spawners causes the interruptions in spawning success.

We do not know where the answer lies. Perhaps mass mortality of very small shrimp on either the spawning or nursery grounds is the cause of the fluctuations. This could result from any one or more of a combination of factors, such as unfavorable currents preventing the young from reaching the nursery grounds, periodic disease in epidemic form wiping out vast numbers of young, food scarcity caused by the first arrivals consuming all available food, and predation including cannibalism.

Perhaps the shrimp is its own worst enemy. The Louisiana data are certainly suggestive of this. Despite apparent continuous spawning throughout the season, evidently only the earliest and latest spawnings are really successful, and the latest is concomitant with the earliest-spawned shrimp moving offshore from the inland nursery grounds. The second successful spawning in Louisiana (and the last in all other localities) does not seem to occur until vast numbers of shrimp have departed from the nursery grounds. Also in Louisiana, waves of oncoming young shrimp appear to be spaced about 2 months apart, which suggests spawning successes coinciding with mass departures of the preceding wave from the inner to the outer nursery areas.

Preliminary analyses of some of our data, including those derived from tagging, suggest that the ratio between loss from natural mortality and gain in weight through the rapid growth of individual animals is such that the total poundage of shrimp available to the fishermen would be increased if the shrimp were protected from the time they appear on the inside fishing grounds in summer until they move to outside waters in fall. Likewise, on this same basis, it might be advantageous to afford protection to the small shrimp while they are growing rapidly during early spring, or possibly to this same group during winter.

Viosca (1920) noted that in the estuarine waters of Louisiana (and most recent workers including ourselves seem to be in agreement for many other areas) the shrimp is probably the most important animal with respect both to species-mass and to food conversion. When we consider this point it is unfortunate that we do not know enough about the shrimp to be able to predict with any assurance what will happen to the population provided man does this or that. For example, while we have suggested that it may be advisable to limit fishing for small shrimp, on the other hand, heavy exploitation from inside waters may result in a more extended spawning success owing to reduced cannibalistic predation, with the obvious consequence of greater production.

We therefore arrive at the conclusion that well-controlled fishing experiments, together with additional research, are required before we can determine with any degree of accuracy how the shrimp population will respond to changes in fishing effort or in fishing seasons. We have recognized the importance of the experimental fishing approach for some time (Lindner 1936a), and more recently Burkenroad (1951) also has recommended it. Because the growth of the shrimp is so rapid, we think the experiments, if followed by competent observers, need not be drastic in their approach. Perhaps even as short a period as a month's difference in open and closed seasons in alternate years might indicate whether the particular approach was profitable. On the basis of our present information, experimental fishing of small shrimp during the periods when they are growing rapidly seems most promising.

LITERATURE CITED

We wish to take this opportunity to clarify previous literature references made by us or our co-workers. The references that follow have been cited by King (1948) and by Anderson, King, and Lindner (1949) as manuscripts submitted for publication. These manuscripts will not be published; they are superseded by the present report:

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