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MOVEMENT OF TAGGED WHITE SHRIMP, *PENAEUS SETIFERUS* IN THE NORTHWESTERN GULF OF MEXICO

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Errata

page 5, paragraph 2, line 3 "Hold" should be "Holt".

page 8 - disregard footnote at end of left column

page 19, Table 6 - column headings are:

No. Studies Return Rates No Studies Return Rates

page 21, paragraph 3, line 4 "Arkansas" should be "Aransas"

page 24, right column, paragraph 1 - delete the sentence "We have..... to statistical subareas". There is no Figure 11.

In several locations "nm" should read "nmi"

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ABSTRACT

From July 1977 through January 1979, 50,863 tagged white shrimp *(Penaeus setiferus)* were released in the Gulf of Mexico along the coast of Louisiana, with 36,639 released inshore and 14,224 released offshore. Recapture rates were 10.6% and 5.6% for inshore and offshore releases, respectively.

Seventy-seven percent of the returns of tagged shrimp released in Caillou Lake were recaptured in this estuary and the adjacent offshore area. Predominant movement of the remainder of the recaptured stock from inshore releases was westerly, though some easterly movement occurred in fall and winter. Some juveniles released inshore were recaptured in estuaries other than Caillou Lake. The most distant recovery was a shrimp recaptured in East Galveston Bay, Texas.

There was little movement of shrimp released offshore in September and October 1977. Shrimp released in December 1977 showed some movement to the east as well as farther offshore. Those released offshore in January 1979 moved inshore during spring and summer with some returning to estuaries both east and west of the release longitude. These overwintering shrimp are the basis of the spring inshore white shrimp fishery as well as the brood stock for the next years fishery. No difference was noted in movement according to sex in either inshore and offshore studies.

Migration patterns noted in these studies are in general agreement with those of earlier investigations, especially the predominantly westward movement. Results of this study, however, differed from earlier ones in that some individuals tagged in this study traveled greater distances than those tagged in previous studies, and some individuals released offshore in winter moved into estuaries during spring and summer.

ACKNOWLEDGMENTS

This project was initiated through the cooperation of National Marine Fisheries Service, Seafood Division of the Louisiana Department of Wildlife and Fisheries, and Louisiana State University Center for Wetland Resources. We express our appreciation to the fishermen, processors, and retailers who returned tags and provided data to participating reporting agencies as well as those who patiently tagged and released the more than 50,000 shrimp utilized in the studies. We also extend our thanks to those who processed the accumulated data, and especially to Dr. Sammy Ray, Coordinator of Graduate Studies at Texas A & M University at Galveston, Texas, for editorial assistance.

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Movement of Tagged White Shrimp, *Penaeus setiferus*, in the Northwestern Gulf of Mexico

INTRODUCTION

Shrimp fisheries have been this Nation's most valuable commercial fisheries over the last 20 years. In the northern Gulf of Mexico, the white shrimp *(Penaeus setiferus)* landings are exceeded only by brown shrimp, *(Penaeus aztecus)* landings. In 1977, when most of the experiments discussed in this report were conducted, 28.9 million pounds (13,075 metric tons headless weight) of white shrimp with a dockside value of 48 million dollars were landed at commercial businesses in Louisiana. The combined commercial landings of white shrimp reported for all Gulf States for 1977 amounted to 44.9 million pounds[1] (20,299 metric tons) with a dockside value of 83.9 million dollars. Because of the biological, economic and social significance of this fishery, it has become imperative to assess, for management purposes, the white shrimp stocks of the northern Gulf of Mexico.

According to Lindner and Cook (1970) this species occurs along the coasts of the southeastern United States and the Gulf of Mexico. These investigators describe three major shrimp fishery regions: southeastern U.S. Atlantic coast, northern Gulf coast, and the southern part of the Gulf of Campeche. Osborn et al. (1969) showed the white shrimp fishery in the northern Gulf of Mexico as extending from northwest Florida to southern Texas with greatest fishing effort and production occurring off the Louisiana coast.

A major part of fishery assessment is delineation of stocks and definition of movement within a given area. In this paper we address the movement of white shrimp stocks in the northwestern Gulf of Mexico through a series of mark-recapture studies conducted inshore in the Caillou Lake estuary and offshore along the Louisiana coast.

Description of Study Area

The study area encompasses over 300 miles of the northwestern Gulf coastal area from longitude 89° West at the Mississippi River Delta to longitude 95° West at Galveston, Texas. The offshore study area (Figure 1) falls within six of the statistical subareas (13 through 18) designated by Kutkuhn (1962) and used by the National Marine Fisheries Service (NMFS) for reporting shrimp fishery landings. Tagged shrimp were released in offshore subareas 13 through 17.

The inshore release sites in the Caillou Lake estuarine system are located east of Atchafalaya Bay and west of Terrebonne Bay. The Caillou Lake estuarine system is an extensive saline to brackish marsh area with a myriad of lakes and bays interconnected by a complex network of bayous and canals (Perret et al., 1971). The two release sites for the inshore study, Grand Bayou du Large and a cove on the north shore of Caillou Lake, are shown in Figure 2. Although the salinity regime of Caillou Bay is less than that usually considered as oceanic it is considered offshore in this report.

MATERIALS AND METHODS

Marking animals has long been used as the basic method in biological studies for detecting movements of individuals and groups. Penaeid shrimp were marked in earlier studies with stains and organic dyes (Costello, 1964; Klima, 1965, 1974). Stains and dyes have shortcomings, however, since they do not provide individual identification. Thus, Petersen disc tags, modified Petersen discs, and internal tags (Neal, 1969a) were used later to obviate this shortcoming. Studies with modified Peterson disc tags have been successful for long-term retention on adult shrimp (Baxter, 1971), but are limited to shrimp larger than 55-mm tail length [2] (distance from posterior tip of telson to anterior of the first abdominal segment of the exoskeleton) due to tag bulk and high tagging mortality in small shrimp. Subsequently, Marullo et al. (1976) developed a vinyl streamer tag that was used successfully in pond studies on brown shrimp as small as 45-mm tail length (78-mm total length (TL)). More recently, the streamer tag was modified to produce the currently used polyethylene mini-ribbon tag with a narrowed midsection for better retention. The tag has positive buoyancy and will float if it becomes detached from the shrimp. This tag provided the first means for individually marking shrimp as small as 30-mm tail length (55-mm TL).

The mini-ribbon or modified streamer tag (Figure 3B) has tapered ends for easier penetration of the shrimp's body. Two thicknesses (4 and 6 mil) of polyethylene material are used: 4-mil tags for inshore studies on juvenile shrimp and 6-mil tags on adult shrimp tagged offshore. In the manufacturing process the tag is attached to a needle by means of a slot in one side of the needle's eye. Before inserting the needle into the shrimp, the pointed end is dipped in a prepared ointment (10% Achromycin V or Aureomycin and white petroleum jelly) developed in previous studies at the Galveston Laboratory (Neal, 1969b). The ointment retards or prevents infection and promotes healing of the puncture area thereby decreasing tagging mortality. The tag is attached to the shrimp by lateral insertion of the needle between the first and second abdominal segments (Figure 3A). Marullo et al. (1976) found that using this location eliminates interference with ecdysis. Also, it is the largest part of the abdomen with the most musculature and vertical spacing between the gut and venous system and is located sufficiently anterior so the tag does not stream behind the animal. Following insertion, the needle is pulled laterally until the narrow midsection of the tag is centered

[1]Shrimp Landings Annual Summary 1977, NOAA, NMFS, CFS, No. 7522.

[2]Equivalent to 95-mm TL (distance from tip of rostrum to tip of telson); conversion factor from Fontaine and Neal (1968).

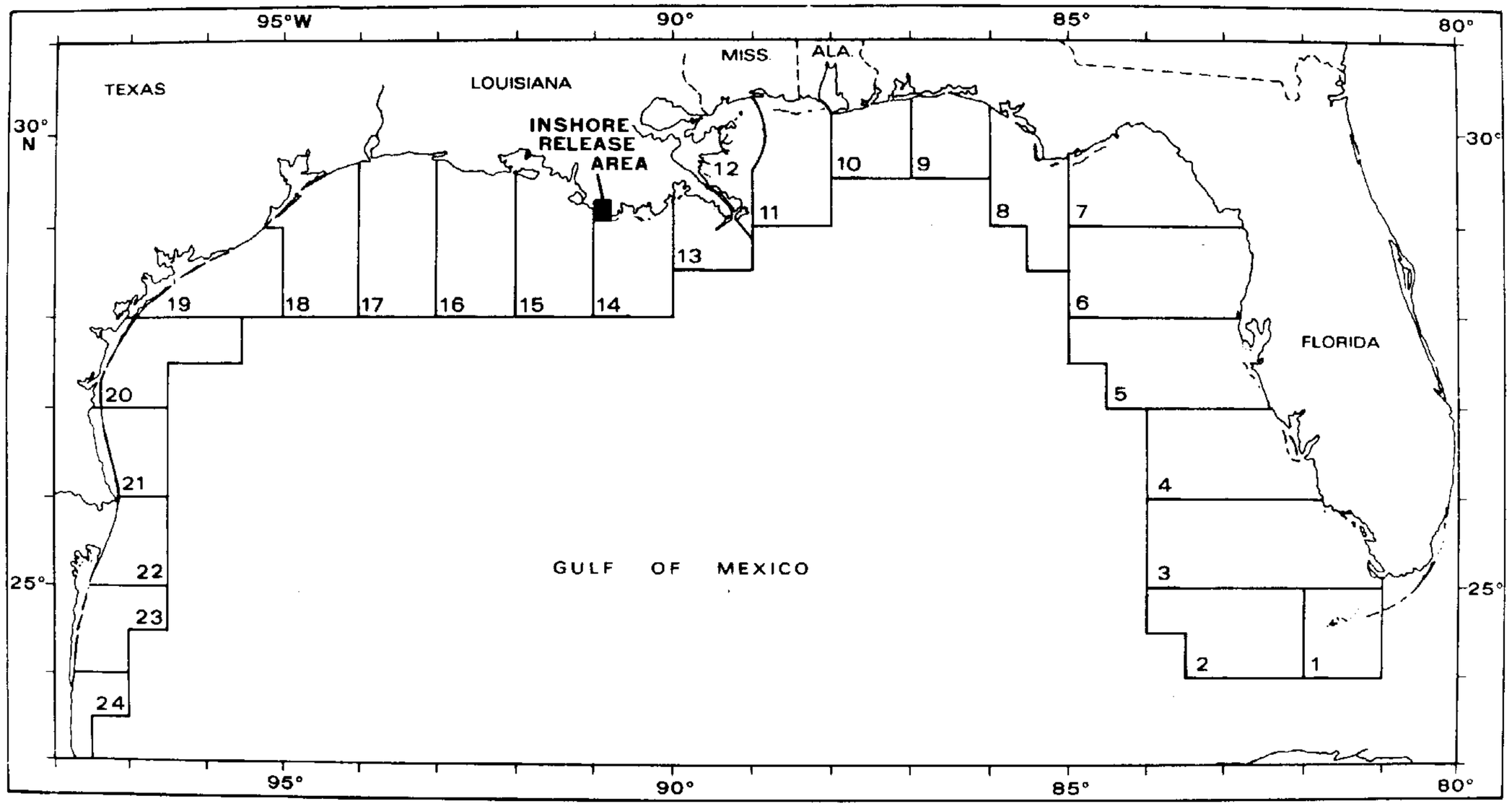

Figure 1. National Marine Fisheries Service statistical subareas 1 through 24 in the Gulf of Mexico from the Florida Keys to the 24th geographic latitude parallel off Mexico as designed by Kutkuhn (1962). The inshore release area is shown in subarea 14.

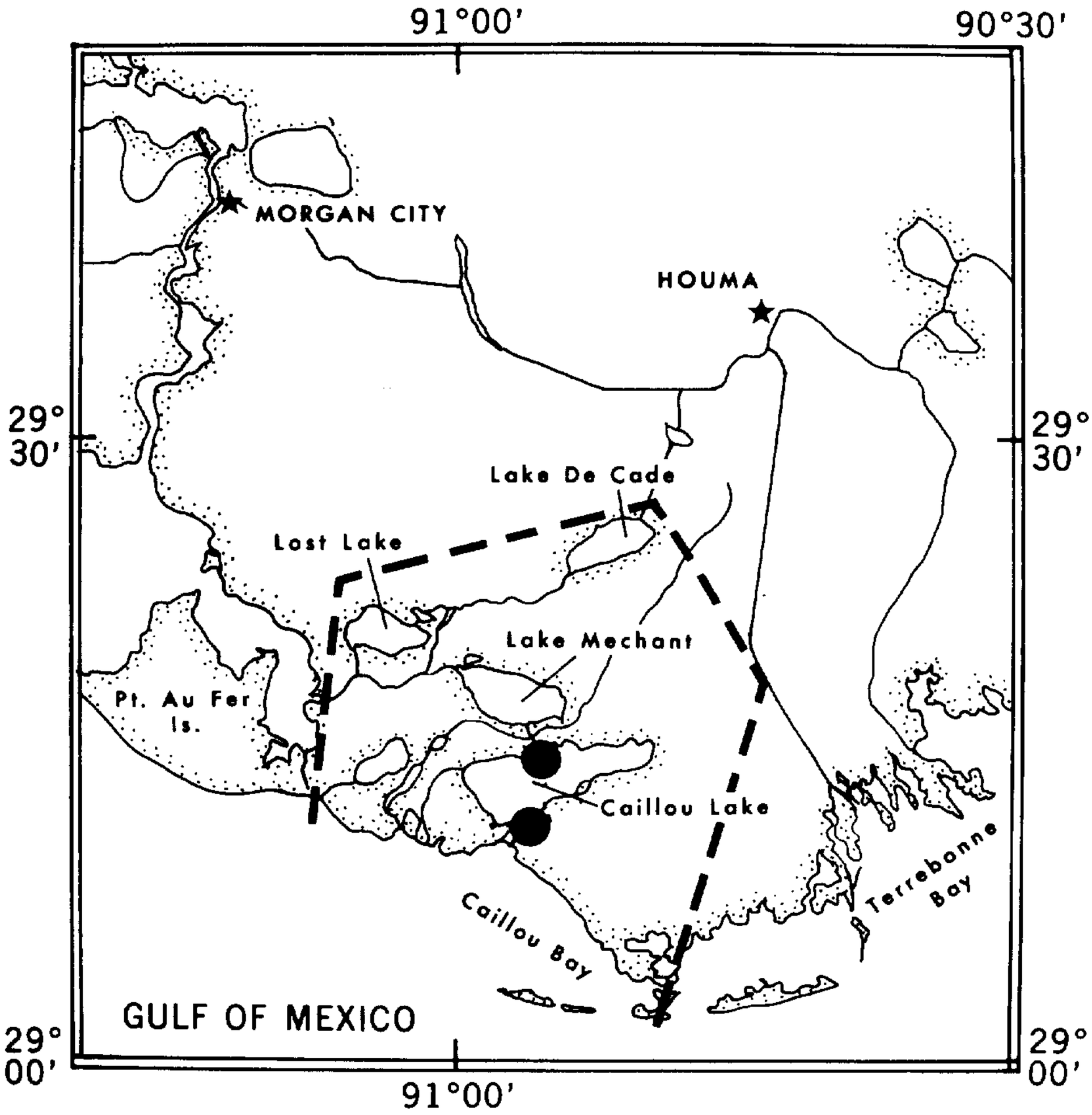

Figure 2. The inshore release area with the two release sites represented by solid circles. For purposes of this study the dashed lines indicate in general the Caillou Lake estuarine system.

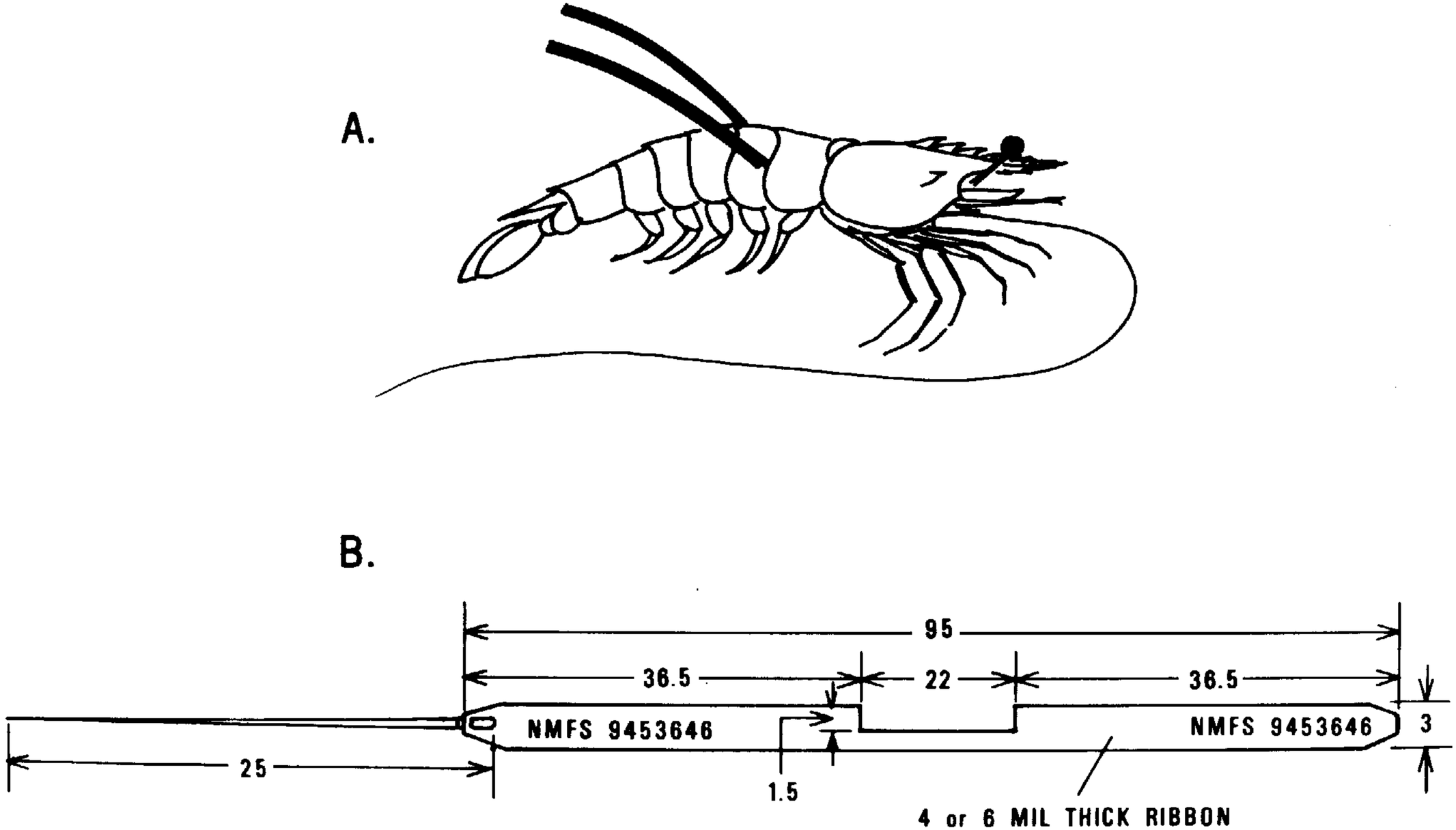

Figure 3.
A. Shrimp with tag in place.
B. Tag with slotted needle attached. Measurements are in mm.

in the shrimp; then the needle is released from the tag. After tagging, the shrimp is measured for tail length and placed in the holding tank. The date, species, tail length, sex of adult shrimp tagged offshore, and tag number are recorded.

Laboratory studies with the mini-ribbon tag have demonstrated its efficiency with regard to shrimp survival and tag retention. In short-term experiments Hold (unpublished MS.) found no mortality due to tagging. Moreover, tagged shrimp held in aquaria at the Southeast Fisheries Center's Galveston Laboratory (unpublished data) successfully completed ecdysis, and tags remained in place during the 59-day experiment.

The inshore studies were conducted by the Louisiana Department of Wildlife and Fisheries (LDW&F) through a contract[3] with NMFS for tagging and releasing of shrimp in the Caillou Lake estuary. Offshore experiments were accomplished by NMFS personnel aboard National Ocean Survey R/V OREGON II and a contracted commercial shrimp trawler. Through another NMFS agreement[4], Louisiana State University Sea Grant Center for Wetland Resources publicized the study by means of news releases in newspapers, radio and television in addition to posters and magazine articles, and presented cash awards for returned shrimp selected as winners in sweepstakes contests. Every three months, four winning tag numbers were selected randomly by computer. Awards of $500, $200, $100 and $50 were presented to the four individuals that returned the tagged shrimp with the selected tag numbers. This incentive program stimulated workers on shore as well as fishermen to return tagged shrimp.

All shrimp tagged and released inshore were caught by 16-ft (4.9 m) or 20-ft (6.1 m) shrimp trawls towed by outboard skiffs as near the tagging area as possible to reduce hauling distance. Depending on the abundance of shrimp, towing time varied from 2 to 5 minutes. Following capture, shrimp were kept in aerated tanks for at least 30 minutes before tagging to provide a resting period and permit the culling of damage or moribund individuals. The remaining shrimp were tagged and kept in aerated tanks on barges for 1 to 12 hours to detect individuals that may have been damaged during tagging.

Retention time varied according to shrimp availability, time required in tagging, and preferred time of release. Dead and moribund shrimp were removed before tagged shrimp were released. Releases were made at the onset of night to reduce the possibility of bird predation. Tagged shrimp were released in or adjacent to grass areas and channel edges by means of dipnets, allowing the released shrimp to be reestablished in their natural environment as quickly as possible.

A total of 36,639 tagged white shrimp were released in the Caillou Lake estuary from July 18 through October 20, 1977. The number of shrimp released by month are shown in Table 1. Shrimp tagged in July and August 1977 were released in or adjacent to Grand Bayou du Large (Figure 2). Since inside waters were opened to shrimp fishing on the third Monday in August through December 20, 1977, the release location was changed to prevent immediate recapture of tagged shrimp. In September and October, tagged shrimp were released in a cove where shrimp fishing was prohibited. A representative sample of approximately 200 undamaged specimens was collected throughout the day from the group of shrimp used for tagging. Tail length, total length, tail weight, total weight, and sex of each shrimp in the sample were determined each day.

Procedures for offshore studies were similar to those used inshore except shrimp were caught with 10- to 15-minute tows of a 40-ft (12.2 m) trawl, sex was determined and recorded when the shrimp were tagged (offshore shrimp were larger then those tagged inshore), and releases were in a different manner. Tagged shrimp were placed in weighted canisters that sank to the bottom, then sprang open approximately 8 to 12 minutes after release (Emiliani, 1971). Fifty to 100 shrimp were placed in each canister. Canisters generally were released one-quarter to one-half nmi apart. A total of 14,224 individuals were released offshore, 8,336 in 1977 and 5,888 in January 1979. For numbers released per month, see Table 1 and for location of releases, see Appendices A, B, and C.

A network of fishery reporting specialists maintained along the Gulf coast by the Statistics Division of the Technical and Information Management Services of the NMFS Southeast Fisheries Center, Miami, Florida, facilitated the return of tagged shrimp and the collection of associated data. Moreover, these specialists obtained data regarding fishery effort in the study area.

Tag recovery data that appeared questionable or exceptional were verified by recontacting the person who caught the tagged shrimp. Moreover, unverified information was deleted from the return record in question. Although both date and location were requested, a "valid" return is one for which either the location or date of capture is known. All returns regardless of information accompanying them, are retained in the computer data bank. The number of returns that indicate location of recapture and time at large may be different, due to missing information, such as either date or location of capture.

Recapture locations were grouped in "blocks" of 6 minutes longitude (5.5 nmi) by 6 minutes latitude (6 nmi) for determining the location of returns in relation to release points. In this report, blocks of these dimensions are used to indicate the location of returns for the 1979 offshore studies, whereas the recapture locations for the 1977 inshore and offshore studies are presented in 12-minute blocks (11 nmi longitudinally by 12 nmi latitudinally).

The manner of presenting time at large differs from the 1977 and 1979 studies. Time at large for the 1977 studies is presented in incremental 10-day intervals. On the other hand, the returns for the 1979 offshore releases are separated into two groups: 1) those at large for 50 days or less and 2) those at large for more than 50 days. This procedure was adopted in order to compare the movement of tagged shrimp during winter (January and February) with that during the warming period of early spring. Tagged shrimp were released on 9 days (January 7-13 and 15-16) in 1979. The first 50 days at large for all 1979 releases falls within

[3]NMFS contract 03-7-042-2512
[4]NMFS contract 03-7-042-24123

Table 1. **A summary of release and recapture data for all inshore and offshore studies. Returns without date of recapture could not be used for time at large computation, whereas those without location of recapture could not be used to access movement. Number of "valid" returns equals the difference between total number of returns and number of returns with both date and location of recapture missing.**

Release Information	Number Released	Size Range[1] at Release	Number Recaptured	Size Range[1] at Recapture	Recapture Rate (%)	Recapture Location Missing	Recapture Date Missing	Number[2] "Valid" Returns
1977 Inshore								
July	9,572	31-88	645	52-155	6.7	29	66	219
August	8,705	35-104	1,787	40-110	20.5	35	110	1,758
September	9,448	28-95	921	34-115	9.7	67	74	862
October	8,914	30-86	509	40-88	5.7	30	30	486
TOTAL	36,639		3,862			161	280	3,730
1977 Offshore								
September	5,537	36-120	276	62-116	5.0	31	41	252
October	1,104	60-119	68	77-115	6.2	10	8	60
December	1,695	55-115	62	69-106	3.7	4	12	58
TOTAL	8,336		406			45	61	370
1979 Offshore January								
11-13 (East Zone)	2,174	61-125	121	71-118	5.6	1	7	120
7-10 (Central Zone)	2,755	58-124	225	61-120	8.2	4	19	224
15-16 (West Zone)	959	66-120	44	83-120	4.6	3	11	41
TOTAL	5,888		390			8	37	385

[1]Size is tail length in mm.
[2]"Valid" return is one for which either date or location or recapture or both were obtained.

the period of January 7 through March 7, 1979.

In this report, "movement" means travel from point of release to point of recapture without implications as to route traveled. The "block" in which shrimp were released will be referred to as the "release block." Shrimp returned from the block in which released are considered to have shown very little movement.

RESULTS

A summary of release and recapture data for both inshore and offshore studies is presented in Table 1. The overall recapture rate for 1977 inshore release was 10% (3,862 of 36,639), whereas the return rate for offshore releases was considerably less than that of inshore releases. The rates for the 1977 and 1979 offshore releases were 4% (404 of 8,336) and 6% (391 of 5,888), respectively. Recapture rates varied from a high of 20% for the August 1977 inshore release to a low of 3% for the December 1977 offshore release. The results of the inshore and offshore releases of tagged white shrimp will be treated separately.

INSHORE RELEASES

Tagged white shrimp were released inshore in the Caillou Lake estuary on 23 dates from July 18 through October 20, 1977. Shrimp were recaptured throughout this estuarine system and at or near all passes between the estuary and the open Gulf. Approximately 71% of the shrimp returned from inshore releases were taken at inshore locations. Moreover, a majority of the recaptured shrimp from inshore releases were caught near the release point. Many of them were at large for only a few days; more than one-half were recaptured within 20 days and about three-fourths within 30 days (Table 2).

A few individuals were returned from inshore after entering other estuaries (Terrebonne, Timbalier, Vermilion and Galveston Bays). Furthermore, 92% (867 of 943) of those recaptured within 10 days after release appeared to have moved only 11 nmi (one 12-minute longitudinal block) or less in an east-west direction. During the 31- to 40-day-at-large period, 60% (231 of 382) of the returns were caught within 11 nmi alongshore (east-west) distance of the release area with 38% (146 of 382) leaving the estuary. During the 51- to 60-day-at-large period, 31% (31 of 101) of the returns were taken within 11 nmi along shore distance of the release area and 59% (60 of 101) left the estuary. Of those at large for more than 60 days, only 21% (31 of 150) were returned from within the 11 nmi along shore distance and only 17% (26 of 150) were recaptured inshore.

With regard to offshore movement of white shrimp released inshore, an examination of Tables 2 and 3 shows that about 29% (958 of 3324) of the returns came from offshore. Also, the data clearly show that the percentage of tagged shrimp recaptured offshore was directly related to time at large. The percentage of tagged shrimp recaptured offshore progressively increased with each subsequent 10-day period of freedom. For example, during the 0- to 10-day period, 15% (139 of 943) of the returns were from offshore, whereas during the 51- to 60-day period, 59% (60 of 101) were taken offshore.

Of the 29% (958) recaptured offshore a majority (96%) moved west of the release point and only 4% showed movement to the east. Furthermore, as shown in Table 2, the trend for westward movement was directly related to time at large. Two months after release the geographic range of returns extended from near the Mississippi River Delta south of Grand Isle to East Bay of the Galveston Bay, Texas estuarine system, a distance of 250 nmi.

White shrimp emigration rates to offshore, as shown by the offshore recapture rate within each time-at-large interval, differed according to month of release (Table 3). Although the recapture rates during the first 10 days of freedom were similar for August (13%) and September (10%), offshore recapture of inshore releases for comparable time at large (0-10 days) were quite different for July (0%) and October (31%). The early offshore appearance of large numbers of tagged shrimp from the October release was most likely due to strong, cold, northerly winds that occurred after the October release. "Northers" often lower water level and temperature in an estuary and could trigger a mass offshore migration.

As noted in Table 3, shrimp released in July appeared to remain in the estuary longer than those released in August, September and October. After 60 days of freedom, 67% of the returns for the July releases were from offshore compared to 90 to 100% for the other three inshore releases. Thus, including the July release, the majority of the shrimp had moved offshore by the end of 60 days of freedom.

Returns from 1977 inshore releases indicate no difference in migration or movement according to sex. Computer plots of location according to sex (1,982 females and 1,396 males) for all returns for which both sex and location of recapture are known are presented in Figure 1, Appendix A. An examination of Figure 1, shows the distribution of returns of females and males to be quite similar.

Data obtained from daily samples of juvenile white shrimp used for the four inshore tagging studies show a progressive seasonal increase in ratio of females to males. The sex ratio for the composite of all samples (3,619 specimens) was 1.81 females to 1 male. On a monthly basis, however, the sex ratios were: July - 1.21:1, August - 1.40:1, September - 2.06:1 and October - 2.47:1. These data suggest that the ratio of females to males approximately doubled in the 3 month period between July and October.

OFFSHORE RELEASES

Shrimp were tagged and released in offshore Louisiana waters in September, October and December 1977 and January 1979. Overall dispersal and distance traveled by shrimp released in 1977 are shown in Tables 4 and 5. Release areas and recapture locations are designated by blocks measuring 12 minutes longitude (11 nmi) by 12 minutes latitude (12 nmi) for determination of movement. Seventy-two percent of the valid recapture locations for all 1977 offshore releases were within 22 nmi of the release area. The results of the 1979 experiments will be presented later

Table 2. Recapture data for four inshore releases of tagged white shrimp in Caillou Lake in 1977. Returns are tabulated to show number of shrimp recaptured in 12-minute (11 nmi) longitudinal blocks for each 10-day period at large. The percentage of tagged shrimp recaptured offshore per 10-day period at large for all inshore releases combined may be ascertained by subtracting the percentage recaptured inshore from 100%.

Days at Large	95° 48	36	24	12	94° 48	36	24	12	93° 48	36	24	12	DEGREES MINUTES 92° 48	36	24	12	91° 48	36	24	12	90° 48	Number Recaptured	Number Recaptured Inshore	Recapture Rate (%) Inshore
0-10													1		1	2	71	867	1				943	804	85
11-20												1		5	3	2	13	117	856	4		1		1002	756	75
21-30					1					1			1	2	4	6	12	13	93	455	8		1	1	598	431	72
31-40				1		1			1	1			4	5	4	8	12	26	85	231	2	1			382	236	62
41-50										1		2	3	7	7	2	13	12	29	70	2				148	72	49
51-60									1				3	13	4	2	13	13	20	31	1				101	41	41
>60[1]		1					3		1	3	1	3	3	18	10	9	2	20	21	18	31	4			150	26	17
TOTAL# RECAPTURED		1		1	1	1	3		1	5	4	3	5	30	36	34	23	73	100	433	2541	22	1	2	1	3324	2366	

COASTAL REFERENCES:	Entrance Galveston Bay	Sabine Pass	Mermantau River	Vermilion Bay	Caillou Lake Release sites (90°54'-56')	Grand Isle
STATISTICAL SUBAREAS:	18	17	16	15	14	13

[1]The longest time at large for the inshore releases is 348 days.

Table 3. Offshore recapture data for tagged white shrimp released in Caillou Lake in 1977. The data are tabulated to show number and percentage recaptured offshore in each 10-day period at large.

	July 18-21		August 1-10		September 12-28		October 11-20			
Days at Large	Number Recap-tured	Recapture Rate Offshore (%)	Number Recap-tured	Recapture Rate Offshore (%)	Number Recap-tured	Recapture Rate Offshore (%)	Number Recap-tured	Recapture Rate Offshore (%)	Number Recap-tured	Recapture Rate Offshore (%)
0-10	9	0	399	13	286	10	249	31	943	15
11-20	29	31	696	21	186	34	91	50	1,002	25
21-30	225	16	190	27	143	40	40	78	598	28
31-40	165	32	107	38	90	48	20	95	382	38
41-50	25	48	89	48	22	41	12	100	148	49
51-60	44	52	44	66	10	60	3	100	101	59
60[1]	51	67	71	90	13	100	15	93	150	83
TOTAL NO. RECAP-TURED	548		1,596		750		430		3,324	

[1]The longest time at large for the inshore releases is 348 days.

Table 4. Recapture date for tagged white shrimp offshore September 18-26, 1977. Returns are tabulated to show number of shrimp recaptured in 12-minute (11 nmi) longitudinal blocks for each 10-day period.

	95°				94°				93°				92°				91°				90°					
Days at Large	48	36	24	12	48	36	24	12	48	36	24	12	48	36	24	12	48	36	24	12			Number Recaptured
1-10													1	1	2	6	13	19	39							81
11-20												1	4	2	7	9	14	37	3							77
21-30													4	1	4	7	8	2								26
31-40											1		1		6	1	1									10
41-50													1			2										3
51-60															1	1										2
>60[1]					1							2		2		8	1									14
TOTAL NO. RECAP-TURED					1						3	1	13	4	27	25	39	48	42							213[2]

RELEASE AREA (91°00')

STATISTICAL SUBAREAS: 18 17 16 15 14 13

[1]The longest time at large for the September release was 225 days.

[2]A total of 276 tagged shrimp were returned. Location is known for 235 and both date and location of recapture are known for only 213.

Table 5. Recapture data for tagged white shrimp released offshore in October and December 1977. Returns are tabulated to show number of shrimp recaptured in 12-minute (11 nmi) longitudinal blocks. Blocks containing "+" indicate release sites. Time at large is not indicated since the recaptures were relatively few and most of them occurred less than 1 month after release. The longest time at large for these releases were: October 27, 77 days; October 28 and 30, 272 days and December 3-4, 84 days.

Release Dates	95° W 48	36	24	12	94° 48	36	24	12	93° Degrees 48	36	24	12	92° 48	36	24	12	91° 48	36	24	12	90° 48	Number Return
Oct. 27											1		1			+ 10	3	1				16
Oct. 28									1			+ 4	1	2	2	1	3	1	1	1		17
Oct. 30						7		1	4	2	+ 5	1	3		1		1		2			27
Dec. 3-4							1	1		3	1	1	+ 22	5	1	2	7	3	2	1		50
STATISTICAL SUBAREAS:	18				17				16				15				14				13	

[1]Number of returns with known location of recapture.

in this section.

A total of 276 tagged shrimp were recaptured from the September release. Of these returns, however, location is known for 235 and both location and date of recapture are known for only 213. Eighty-six percent (184 of 213) of the recaptured shrimp from the September release were caught within 27 days after release and 65% (139 of 213) were taken within 11 nmi of the release block. The primary movement as indicated by the returns from 11 nmi or more beyond the release block was to the west. Of the 38% (91 of 235) that moved either east or west, 85 moved to the west and 6 moved to the east. Furthermore, with regard to inshore-offshore movement beyond the release block, the movement was predominantly inshore. Eighty-seven percent (204 of 235) were recaptured in areas with depths less than the release block and 27% (63 of 235) were recaptured in the shallow waters of the Atchafalaya-Vermilion Bay estuarine system immediately west of the release area, whereas only 1% (3 of 235) were taken in deeper waters offshore of the release block. The greatest distance traveled was 155 nmi westward by a female shrimp taken near the Sabine Lake estuary (longitude 93°50' West) in statistical subarea 17.

In October, tagged shrimp were released at three locations, but because of the proximity of the releases on October 28 and 30 (adjacent blocks) and the low number of valid returns (17 and 27, respectively) these two releases are treated as one. From the first release, October 27, 13 of 16 tagged shrimp were recaptured within 11 nm of the release area. Of the three shrimp taken more than 11 nmi beyond the release block, two moved to the west and one moved eastward. Among the 44 returns for the October 28 and 30 releases, only nine were taken within the release block. Moreover, this group showed a greater along shore (longitudinal) movement than the October 27 release; 19 were recaptured east of the release block and 15 were taken west of it. In considering all returns for three October releases, 55% (33 of 60) moved in either an easterly or westerly direction. With regard to inshore-offshore movement, there was greater movement offshore (18 of 60-30%) than inshore (9 of 60-15%) of the release block. Also, 90% (54 of 60) of the recaptures of the October releases* extended to the east from off Caillou Lake (statistical subarea 14) to near Sabine Lake (statistical subarea 17) on the west, a distance of about 155 nmi.

Results of the December offshore release differed from those generally obtained in these studies in that more shrimp were recaptured east of the release ares (longitude 92°18' West) than west of it. As indicated in Table 5, 44% (22 of 50) of the returns were taken within the release area, and of the 28 individuals recaptured beyond the release area, 42% (21 of 50) were taken east of it. The east-west extent of the returns was from an area off Caillou Bay (longitude 90°52' West) to an area off Grand Lake (longitude 92°48' West). Moreover, there appeared to be more movement to the offshore than noted for October releases. Forty-six percent (23 of 50) were taken offshore of the release block in comparison with 30% (18 of 60) for the October releases. Furthermore, 70% (35 of 50) of the returns from the December release were at large 14 days or less.

*Occurred within 23 days. The return for these releases.

In summary, predominant movement of the tagged shrimp released offshore in 1977 was (1) to the west and inshore for September releases, (2) about equal east-west movement with some movement inshore and offshore for October releases and (3) more movement to the east and offshore for the December releases than noted for the other 1977 offshore releases. Additionally, most (90%) of the recaptures from 1977 offshore releases occurred within 1 month. Furthermore, the returns indicated no difference in direction or distance of movement with regard to sex (Figures 1, 2 and 3, Appendix B). The sex ratios of the returns for these three 1977 offshore releases were similar (52% females - 48% males).

As previously indicated, the returns of tagged white shrimp released offshore in January 1979 were separated into two groups: 1) those at large for 50 days or less (winter recaptures) and 2) those at large for more than 50 days (spring-summer recaptures). This procedure was adopted to permit the comparison of movement of tagged shrimp during the cold period of late winter and the warming period of early spring. The locations of recapture as well as time of recapture (winter or spring-summer returns) are presented in Figures 4-8. Data for the returns from 1979 offshore releases presented in this report do not extend beyond July 7, 1979.

The recapture rate for the January 1979 releases (Table 1) was 5.6% (121 of 2,174) for the east zone, 8.2% (225 of 2,755) for the central zone, and 4.6% (44 of 959) for the west zone. Fishing effort data for the general area encompassed by these offshore releases were not available at the time this report was being prepared. During the tagging operation, the investigators noted more trawlers in the central zone than in either the east or west zone. Only a few trawlers were noted during tagging in the east zone.

The majority (88%-107 of 121) of the recaptures from the east zone releases were taken within the first 50 days and only seven of these winter returns showed appreciable movement beyond the release area (Figure 4). One individual was recaptured near the Mississippi River Delta and the other six had moved westward with the greatest distance being 150 nmi. Although nine of the 13 shrimp known to be at large for more than 50 days showed considerable westward movement, one was taken near the Mississippi River Delta (Figure 4). Furthermore, two of the westerly migrants comprising the spring-summer returns had moved into estuaries. One shrimp was recaptured in Vermilion Bay and the other in Caillou Lake.

The location and time at large of the returns of shrimp released in the central zone are presented in Figures 5 and 6. The winter returns indicated that the predominant movement was offshore of the release sites. Moreover, with regard to longitudinal movement, the returns extended from as far east as Belle Pass (longitude 90°10' West) to as far west as south of White Lake (longitude 92°30' West), a distance of about 140 nmi. Although 61% (73 of 120) of the winter returns showed some offshore movement, 30% (36 of 120) were recaptured near the release sites.

Contrary to the general offshore movement shown by winter returns, the spring-summer recaptures indicated more migration inshore of the release sites with some being

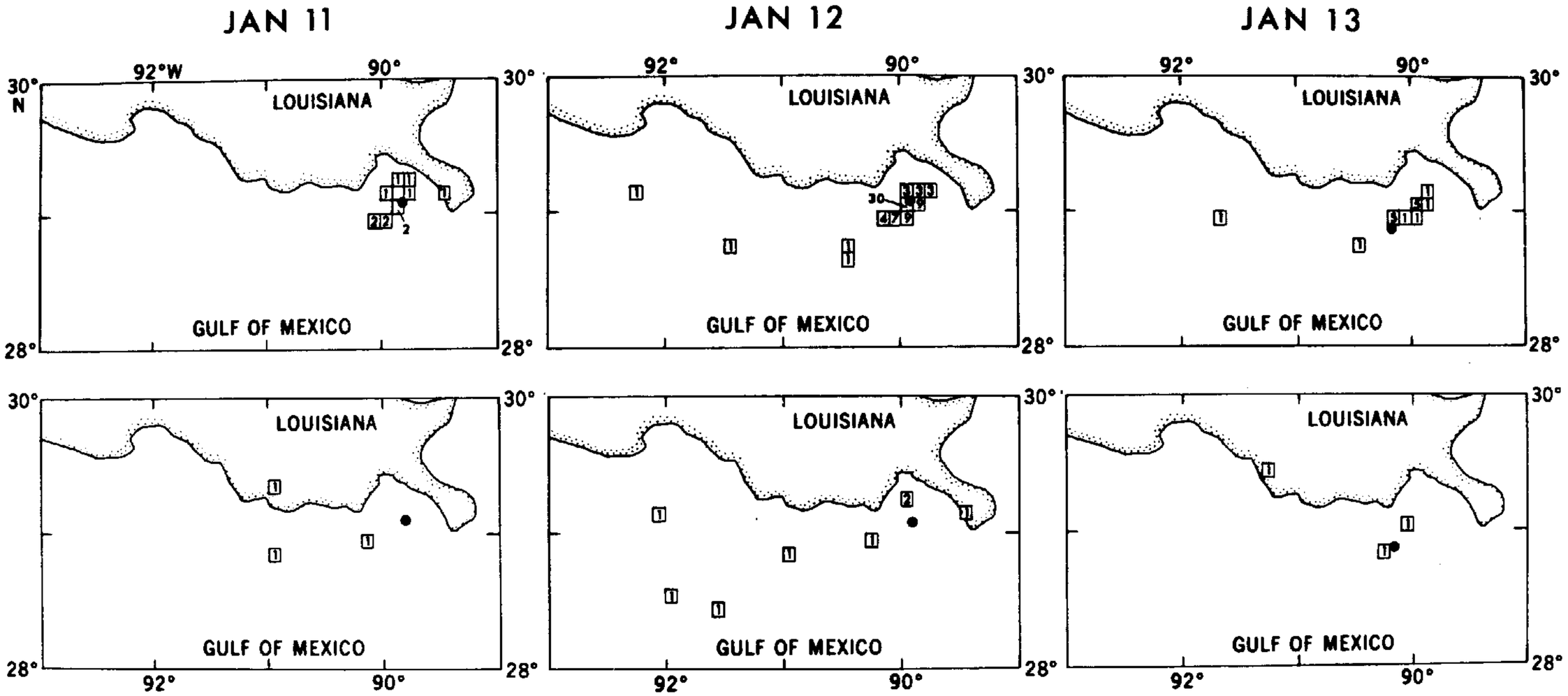

Figure 4. Computer plots of location of returns of tagged white shrimp released offshore in east zone on January 11, 12, and 13, 1979. Time at large shown as "within 50 days of freedom" (top graphs) and "after 50 days of freedom" (bottom graphs). The number within the blocks (12 minutes longitude — 11 nmi by 12 minutes latitude — 12 nmi) represents the number of individuals recaptured within a particular block. Location of release sites indicated by solid cirles.

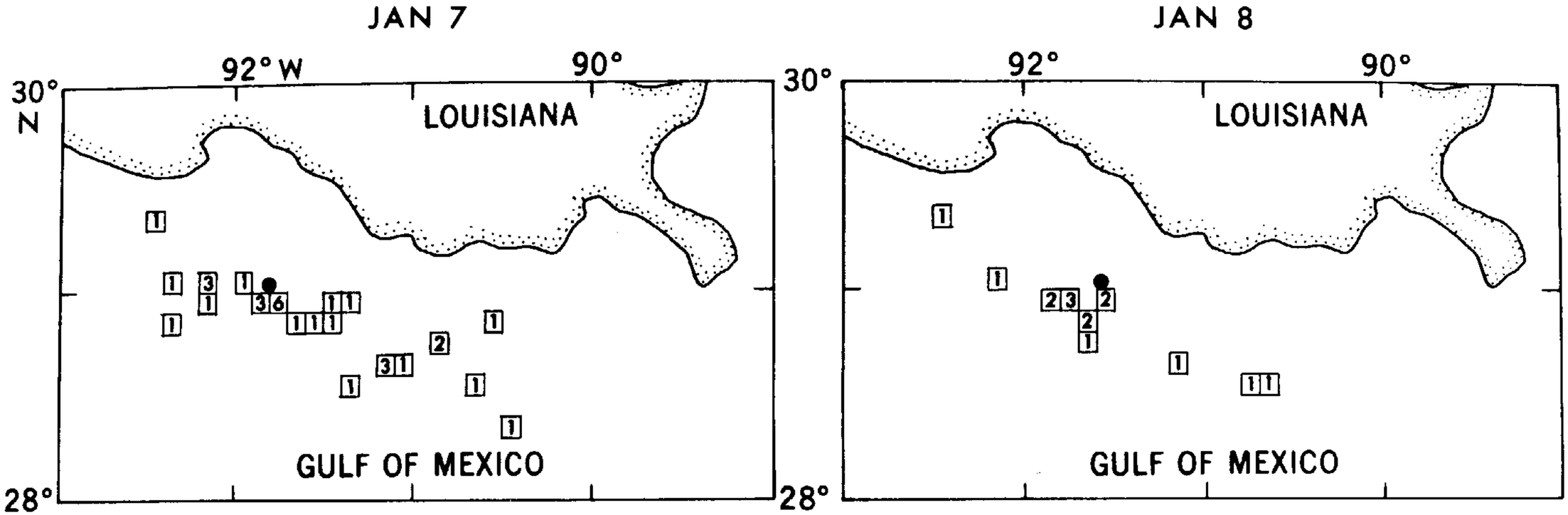

Figure 5. Computer plots of location of returns of tagged white shrimp released offshore in central zone on January 7 and 8, 1979. Time at large shown as "within 50 days of freedom" (top graphs) and "after 50 days of freedom" (bottom graphs). The number within the blocks (12 minutes longitude — 11 nmi by 12 minutes latitude — 12 nmi) represents the number of individuals recaptured within a particular block. Location of release sites indicated by solid circles.

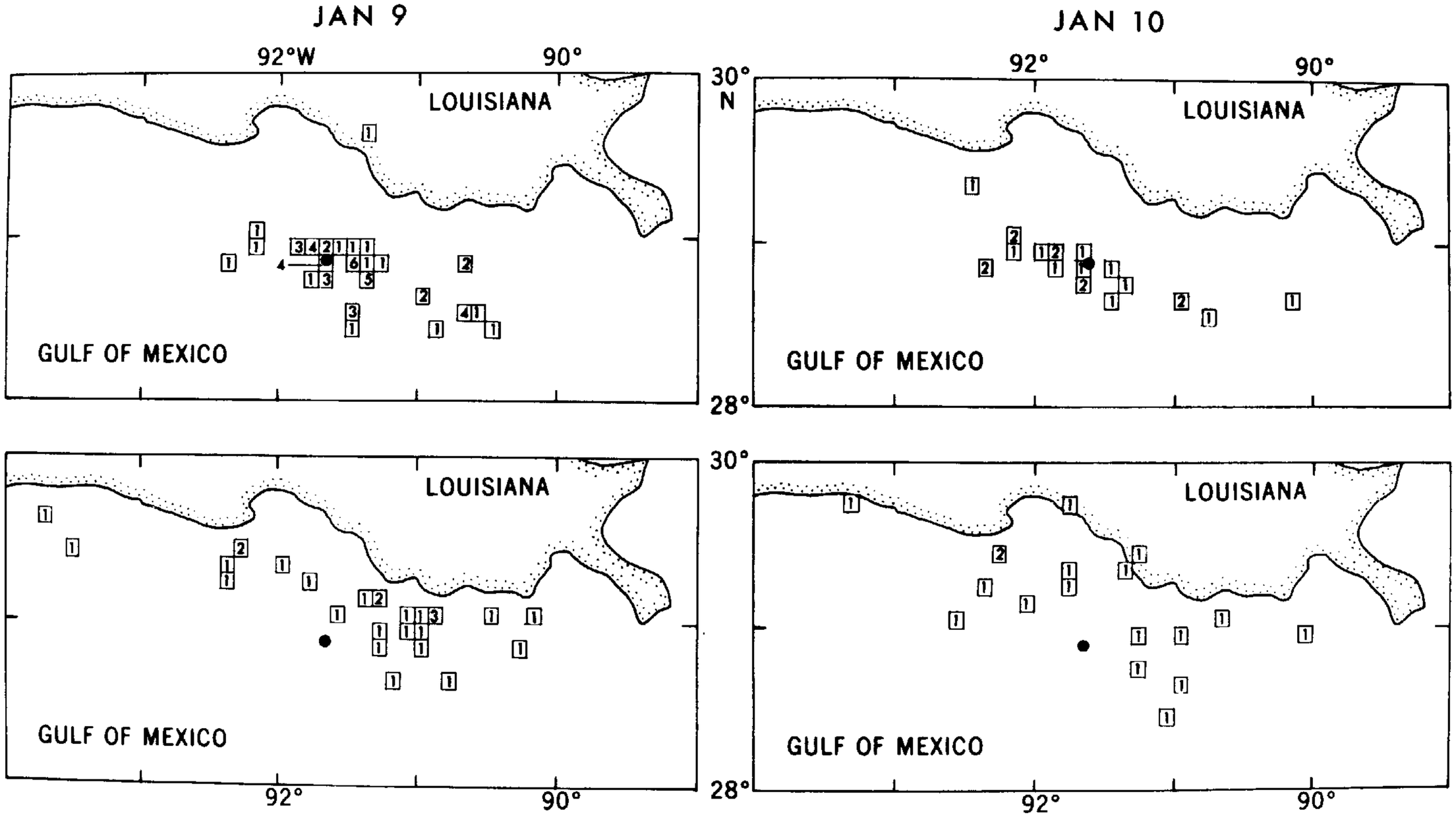

Figure 6. Computer plots of location of returns of tagged white shrimp released offshore in central zone on January 9 and 10, 1979. Time at large shown as "within 50 days of freedom" (top graphs) and "after 50 days of freedom" (bottom graphs). The number within the blocks (12 minutes longitude — 11 nmi by 12 minutes latitude — 12 nmi) represents the number of individuals recaptured within a particular block. Location of release sites indicated by solid circles.

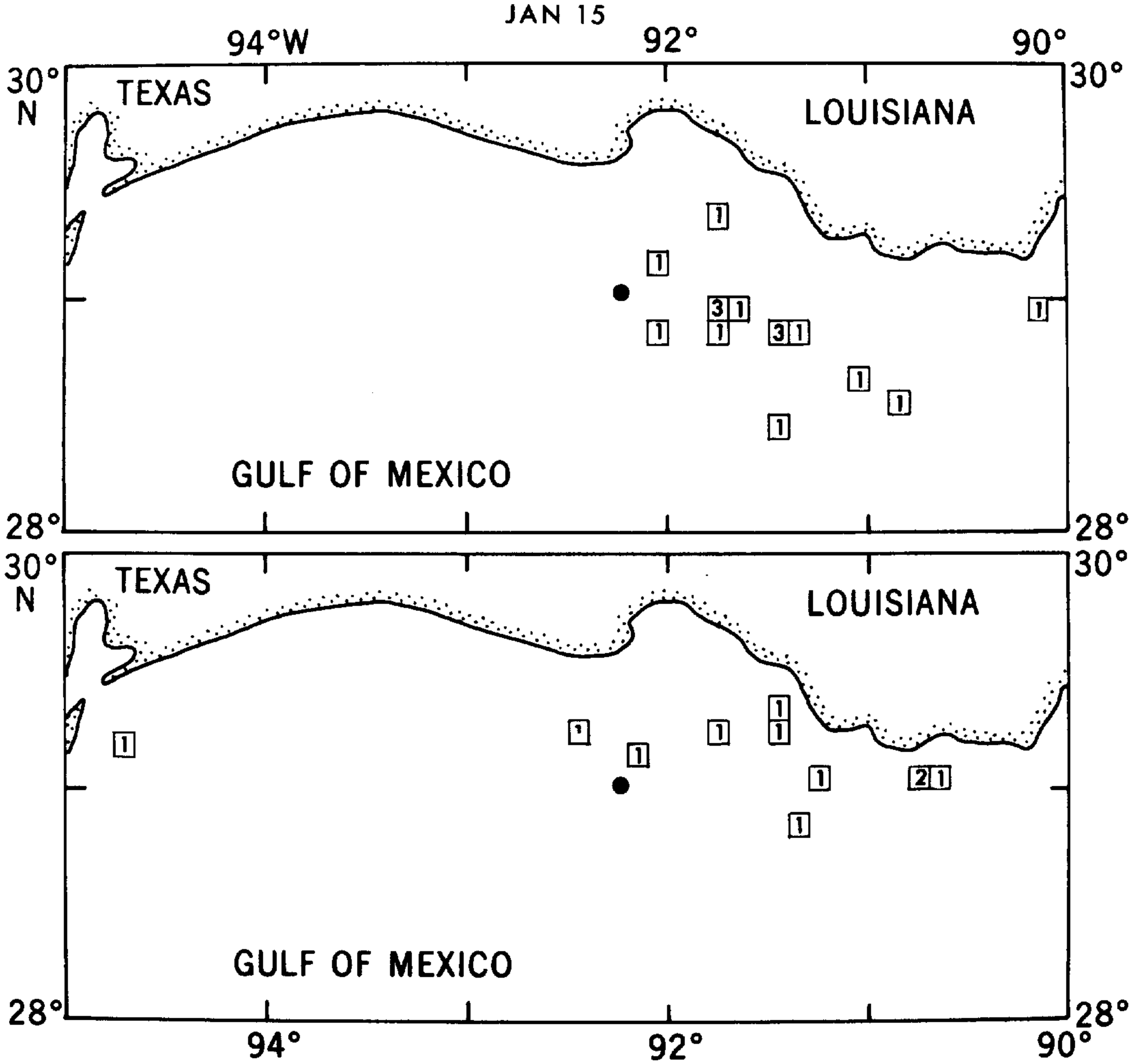

Figure 7. Computer plots of location of returns of tagged white shrimp released offshore in west zone on January 15, 1979. Time at large shown as "within 50 days of freedom" (top graph) and "after 50 days of freedom" (bottom graph). The number within the blocks (12 minutes longitude — 11 nmi by 12 minutes latitude — 12 nmi) represents the number of individuals recaptured within a particular block. Location of release sites indicated by solid circles.

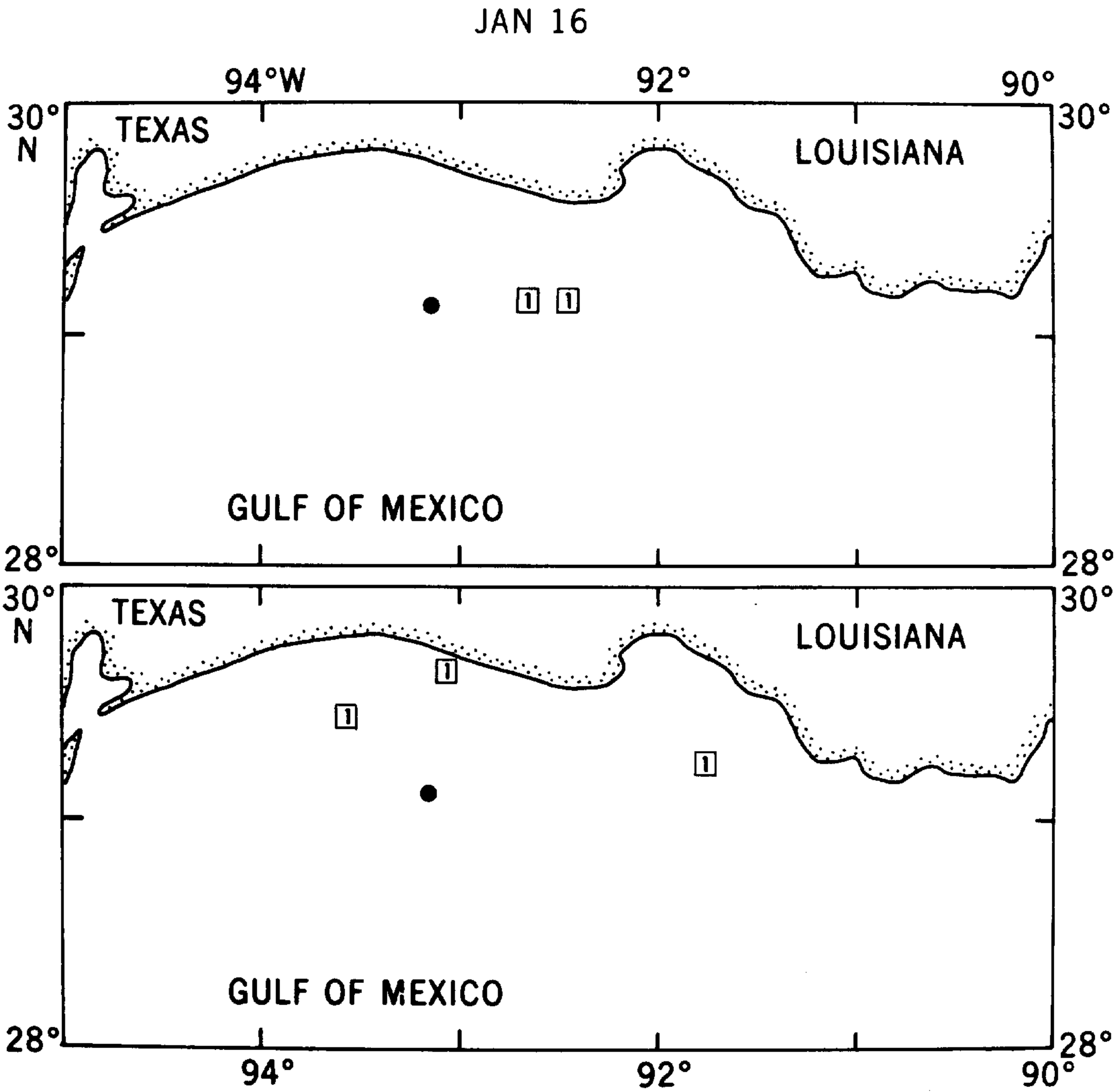

Figure 8. Computer plots of location of returns of tagged white shrimp released offshore in west zone on January 16, 1979. Time at large shown as "within 50 days of freedom" (top graph) and "after 50 days of freedom" (bottom graph). The number within the blocks (12 minutes longitude — 11 nmi by 12 minutes latitude — 12 nmi) represents the number of individuals recaptured within a particular block. Location of release sites indicated by solid circles.

returned from estuaries and off the coastline from Barataria Bay (longitude 89°50' West) to Freshwater Bayou (longitude 92°15' West). Moreover, the returns from the January releases in the central zone generally showed more eastward than westward movement. Also, the eastward movement appeared to be more pronounced among spring-summer returns than winter returns. Sixty-eight percent (54 of 79) of the spring-summer returns were taken more than 11 nmi east of the release sites compared with 42% (51 of 120) for the winter returns.

Although 44 shrimp released in the west zone were recaptured during the period covered by this report (Table 1), both data and location of recapture are known for only 32 (Figures 7 and 8). These returns were about equally distributed among winter (18) and spring-summer (14) returns. Only four of the 32 were recaptured within 22 nm of the release sites. All but two of the remaining 28 returns were taken east of the release sites and one of these was taken off of Belle Pass, which is 110 nm from the release site. One individual that moved westward was recaptured off Calcasieu Lake and another was taken off Galveston Bay. All but one of the 14 spring-summer returns were taken inshore of the release sites.

It is noteworthy that seven shrimp released offshore in January were recaptured within estuaries. Except for one female recaptured 29 days after release on January 11, the time at large for those returning to inside waters varied from 65 to 147 days. The size (tail length) of these seven shrimp ranged from 88 mm to 99 mm when released and 85 mm to 115 mm when recaptured. The poor condition (dehydration and poor preservation) of some returned specimens as well as the precision of measurement (51 mm) probably account for the minimum length on recapture being a little less than when released. With regard to sex, six were females and one was a male.

Except for the limited data showing that more females than males were recaptured in estuaries, computer plots (Figures 1,2 and 3, Appendix C) of location of returns for 1979 offshore releases by sex (187 females and 126 males) do not indicate a noticeable difference in movement according to sex. The proportion of female returns (60%) for the 1979 offshore releases was somewhat greater than that (52%) for the 1977 offshore releases.

A complete summary of results for the 1977 inshore and offshore tagging experiments, including location of release and recapture sites, length (tail) at release and recapture as well as direction and distance traveled for each returned tagged shrimp is available (Baxter and Hollaway, 1981).

DISCUSSION

INSHORE RELEASES

Recapture rates for 1977 (4%) and 1979 (6%) offshore releases were approximately one-half of the 1977 Caillou Lake releases (10%). Similar rates were reported by Hollaway and Baxter (1981) for 1978 releases of brown shrimp in Caillou Lake (9%) and offshore Louisiana (3%). This difference is not surprising since the inshore waters of Louisiana probably receive much greater fishing pressure per unit of area than the adjacent offshore waters. Recapture rates are directly related to level and timing of fishing effort in the general area of release. Another important factor influencing recapture rates is predation, which is affected by the condition of tagged shrimp at release. Furthermore, the fishing regulations, such as legal seasons, legal fishing areas, and fishing gear restrictions, influence recapture rates. Among the Gulf states such regulations are most liberal in Louisiana.

Generally, recapture rates for mark-recapture studies with shrimp show great variability. This variability appears to apply to all three of the commercial penaeid shrimp of the Gulf of Mexico. Results of numerous recent (1979 through 1981) studies show the magnitude of the variability of recapture rates for inshore and offshore studies conducted with penaeid (white, brown and pink) shrimp in the Gulf of Mexico, including the coasts of Alabama, Mississippi, Louisiana, Texas and Mexico. The return rates for some of the studies in various Gulf states and Mexico are presented in Table 6.

The reliability of mark-recapture data is greatly improved by availability of information on fishing effort in the study area. Data obtained by fishery reporting agents of TIMS during these studies provide information on effort in offshore areas that can be directly related to fishing for white shrimp. The major offshore catch of white shrimp in Louisiana occurs at depths of 5 fm (9 m) or less, whereas the offshore harvest of brown shrimp predominately takes place farther offshore in depths of 10 to 25 fm (18 to 46 m).

Shrimp-trawling effort for white shrimp at 5 fm (9 m) or less by statistical subareas (13 through 17) is presented in Figure 9 for the last six months (July through December) of 1977[5]. Before considering fishing effort for the various subareas it may be helpful to point out that Caillou Lake, the release area for inshore studies (see Figure 1), is near the northwest corner of subarea 14 and that the last inshore release of tagged shrimp occurred October 20, 1977.

Subarea 15, which is adjacent and immediately west of subarea 14, consistently received the highest level of fishing effort throughout the season. Level of effort in subarea 15 exceeded 1000 days (24-hour day) for each of the six months. Effort in September and November amounted to about 2000 days per month. The greatest effort in subarea 15, nearly 3000 days, occurred in October.

During the entire 6 month period the greatest effort, approximately 4000 days, was expended in subarea 14 in November and subarea 16 in September. On the other hand, except for a previously mentioned extremely high level of subarea 14 in November 1977, fishing effort in the eastern portion of the study area, subareas 13 and 14, was consistently low (less than 500 days) from July through December because of low catch rates by the fleet. Thus, data presented in Figure 9 suggest that there was sufficient effort in the offshore area in the immediate vicinity offshore from the inshore release area to provide a reasonable return of

[5]Data source is Gulf Coast Shrimp Data Annual Summary 1977, D.O.C., N.O.A.A., N.M.F.S. Current Fishery Statistics No. 7523.

Table 6. Return Rates for Mark-Recapture Studies Conducted in the Gulf of Mexico[1]

	Inshore		Offshore	
Brown Shrimp				
Mexico	2	0.31-0.71	2	13.40-21.13
Texas	5	0.01-7.90	7	0.83-26.78
Louisiana	4	0.11-7.26	3	0.46—7.26
Mississippi			1	2.66
Alabama			1	1.73
White Shrimp				
Mexico	2	3.45-5.24		
Texas	3	0.88-6.87	2	2.61-13.09
Louisiana	5	0.20-9.64	5	2.86-8.13
Mississippi			1	8.45
Alabama			1	7.18
Pink Shrimp				
Mexico	1	0.55	3	2.64-15.64
Texas	2	4.41-13.72	2	8.40-27.70

[1]Unpublished data, National Marine Fisheries Service, Galveston Laboratory.

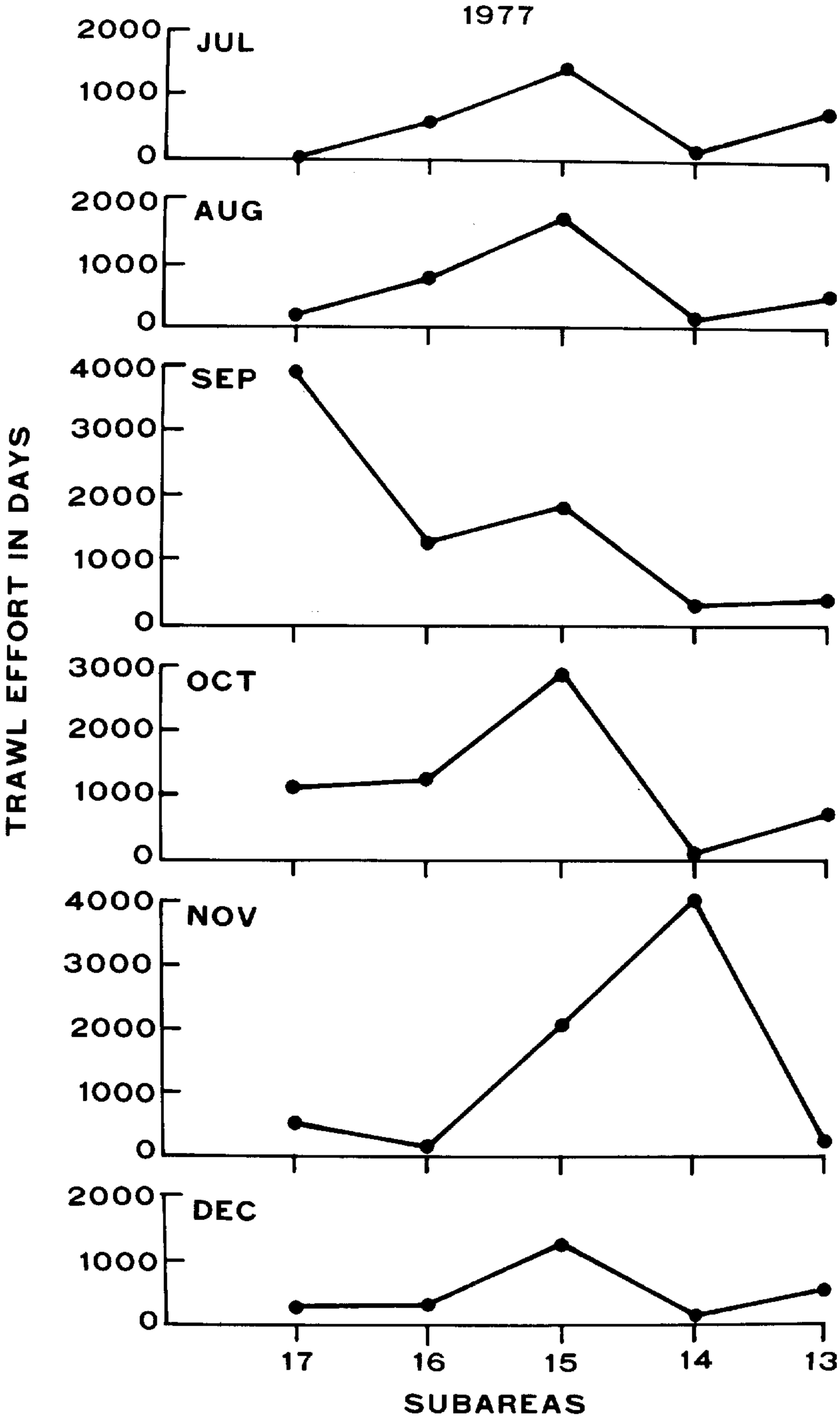

Figure 9. Trawling effort in days (24-hour day) for white shrimp in statistical subareas 13 through 17, offshore from the beach to a depth of 5 fm (9 m), for July through December 1977.

tagged shrimp by the shrimp fishing fleet. Data on fishing effort in the area of offshore releases in January 1979 were not available when this report was prepared.

Returns of tagged juvenile white shrimp released in the Caillou Lake estuary in 1977 showed a marked alongshore movement to the west of the release site. Similar results were obtained by Perret and Boudreaux (1976) who also released tagged white shrimp in this estuary during summer. Other mark-recapture studies conducted along the northern Gulf coast corroborate the predominately westerly movement noted in our studies. Lindner and Anderson (1956) released tagged white shrimp during summer and winter in Barataria Bay and along the east and west sides of the Mississippi River Delta. Shrimp released west of the delta in the Barataria Bay area moved either west or along the delta and those released east of the delta moved both east and west as well as along the delta. These investigators found no evidence that tagged shrimp moved from one side to the other of the Mississippi River Delta; they considered the delta to be a "natural barrier." The same investigators released shrimp in August in Timbalier Bay, the next estuarine system to the west of Barataria Bay. The returns from this release showed a predominantly westward movement with little movement toward the delta. In offshore studies conducted along the western coast of Louisiana (Klima, 1964), the returns of tagged white shrimp indicated alongshore movement in both directions.

Limited inshore releases of tagged white shrimp have been made in Texas bays. McRae (1952) in late spring and early summer released white shrimp (385) tagged with Peterson discs near Port Arkansas both in the Gulf and in the bay. The author did not indicate the numbers released offshore and inshore. However, all but one of the 12 returns had been released in the Gulf. Nine of the 11 returns showed southerly along-shore movement and two had moved along-shore to the north. None of the shrimp were recaptured outside of statistical subarea 20 (Corpus Christi area).

In another Texas study, tagged white shrimp released in September 1975[6] in Galveston Bay showed movement in both directions along the coast. The releases in this study were confined to one area, Moses Lake, a secondary bay on the western shore of Galveston Bay about 12 nmi from the Gulf. As in the 1977 Caillou Lake studies, tagged shrimp were returned from throughout the Galveston Bay estuarine system. These results corroborate our findings that white shrimp released in a discrete area may spread throughout the entire estuarine system prior to emigrating to the Gulf. Offshore returns ranged from near the Colorado River mouth in Texas (subarea 19) to near the Calcasieu River entrance in Louisiana (subarea 17).

OFFSHORE MOVEMENT

The extent and rapidity that shrimp tagged in 1977 in Caillou Lake emigrated to the offshore region appeared to be influenced by the time (month) of release and meteorological conditions following release. Offshore returns (Table 3) indicate that shrimp released in July remained in the estuary longer than those released in August, September and October. No offshore returns were obtained for the July releases during the first 10 days of freedom compared with 13, 10 and 31% respectively, for August, September and October releases. Moreover, even after more than 60 days of freedom, only 67% (34 of 51) of the returns for July releases was taken offshore compared to 90 to 100% for August, September and October releases.

The lack of offshore returns, especially during the first 10 days of freedom, cannot be attributed to excessive early recapture of tagged shrimp since inshore shrimping season did not open until August 15, 1977. Moreover, the offshore fishing effort in statistical subarea 15, which is just to the west of the release area, of more than 1000 days in July should have been sufficient for recapture of some tagged shrimp if they were in the area. Admittedly, the fishing effort was weak (between 100 and 200 days) in subarea 14 in July. However, one should keep in mind that the release area is in the northwest corner of subarea 14 and also that once shrimp reached the offshore waters the majority moved westward, i.e., towards subarea 15.

A comparison by month of release for inshore studies shows that the proportion of returns made during the first 30 days following release was considerably less for July (45%) than for the other three months (August, 81%, September, 82% and October, 88%). This marked difference in early return rates for the four inshore releases is most likely due to a difference in inshore fishing effort and the apparent tendency for the tagged shrimp to remain within the estuary during early days after release. The shrimp released in July were at large for 3 weeks prior to opening of the inshore season for white shrimp, whereas the August releases were completed only 6 days before opening of the season. The magnitude of the shrimp fishing fleet in coastal waters of Louisiana as indicated by Gaidry and White (1973) may be as great as 12,000 licensed trawl boats. Thus the likelihood of early recapture of tagged white shrimp during the legal shrimping season is great.

The high proportion of early offshore returns for the October releases appears to be related to rapid reduction of water temperature. During the first (0-10 days) and second (11-20 days) 10-day periods of freedom, 31% and 50% of the recaptures, respectively, of the October releases were taken offshore. On the other hand, the offshore recapture levels for releases of the prior 3 months did not equal or exceed 50% until after approximately 2 months (51-60 days) of freedom.

Documentation of temperature regime of the estuarine system utilized for the inshore releases is provided by hourly recordings of subsurface water temperatures at the pier of the Louisiana Department of Wildlife and Fisheries Headquarters at Caillou Lake. The mean daily water temperatures (mean of hourly readings for each calendar day from July 1 through December 31, 1977) are presented in Figure 10. The mean daily temperature ranged from a low of 27°C and a high of 33°C until October. During October, two "northers" moved through the area and sharply reduced the water temperature. As may be noted from Figure

[6]Unpublished data. National Marine Fisheries Service, Galveston Laboratory.

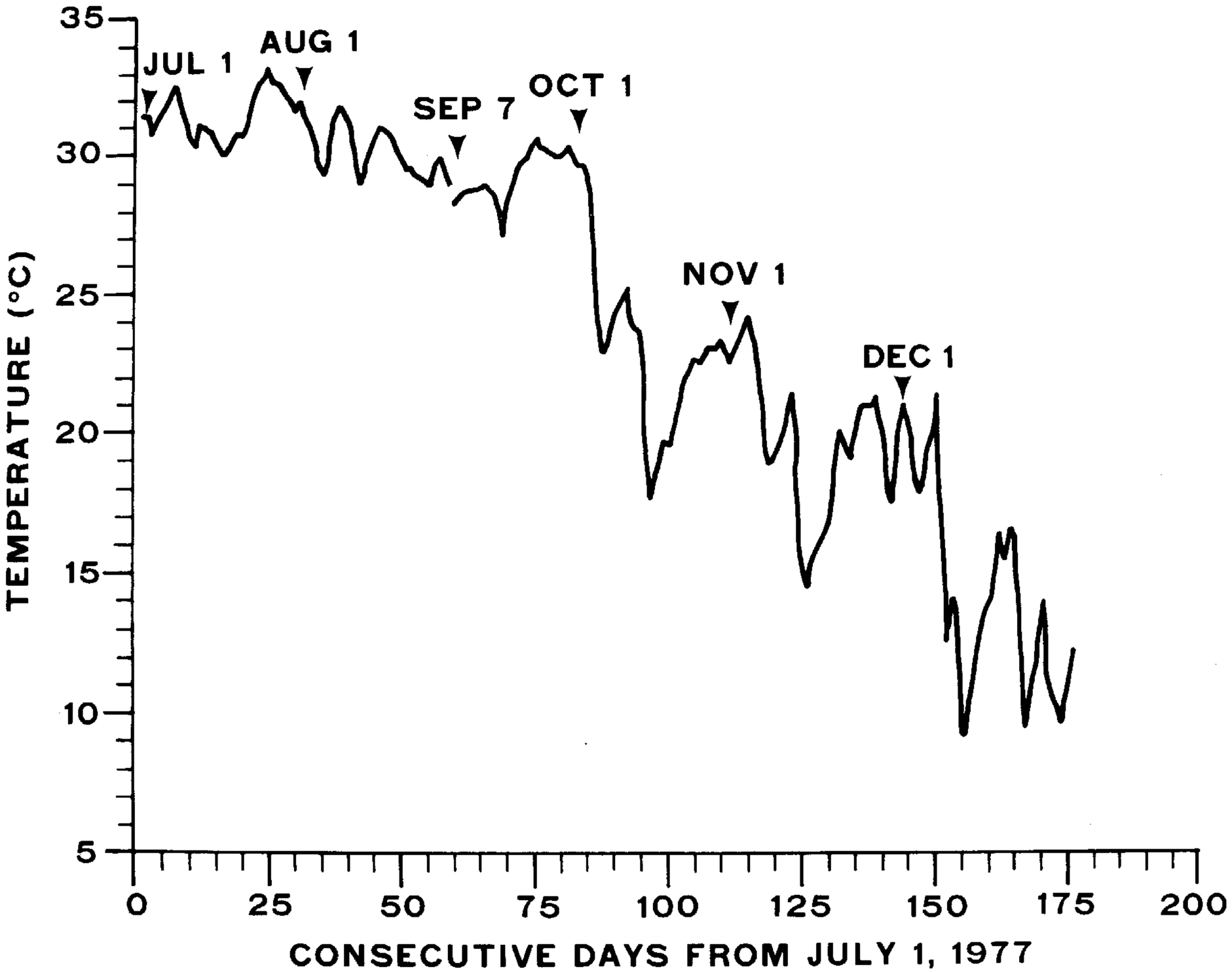

Figure 10. Averaged daily water temperatures at Caillou Lake July 1, 1977 through December 31, 1977.
***No temperatures recorded August 30 through September 6.**

10, the passage of the first norther, which occurred during the first half of the month, dropped the mean daily temperature 7°C from 30°C to 23°C. Shortly after the final inshore release of tagged shrimp on October 20, passage of the second norther later that day dropped the water temperature 8°C, from 26°C to 18°C.

Undoubtedly, the rapid reduction of water temperature accounted for the early offshore recovery of large numbers of shrimp for the October inshore releases. Other investigators, Pullen and Trent (1969) and Gaidry and White (1973), also have noted a rapid emigration of white shrimp from inshore to offshore areas after the passage of norther. Pullen and Trent (1969) reported that peak emigration from Galveston Bay coincided with water temperatures between 19°C and 8°C in the tidal pass.

With regard to movement within Caillou Lake, the returns showed that shrimp had dispersed throughout this estuarine system within 30 days. As previously mentioned, these results demonstrate that white shrimp released in one area of an estuary may utilize the entire estuary rather than a portion before eventual emigration to the Gulf.

Offshore Releases

Although the recapture rate for offshore releases was only approximately one-half that of the inshore releases in Caillou Lake, the results were similar in some respects. The predominant direction of movement appeared to be more variable for offshore than for inshore releases. Moreover, an examination of the results obtained for offshore releases by month (September, October and December 1977 and January 1979) of release suggest that the predominant direction of movement is related to month of release.

With regard to along-shore (east-west) movement, the westward movement that characterized the inshore releases was more predominant for the September offshore releases than for the other 3 months. Beginning with the October releases, the predominant along-shore movement shifted from west to east. A comparison by month of release of recaptures that showed appreciable along-shore movement supports this interpretation. According to month of release, percentages of returns showing westward movement were: September, 93% (85 of 91); October, 46% (17 of 37); December 25% (7 of 28), and January, 1979 (all releases combined), 33% (51 of 156).

The returns for January 1979 releases indicated a predominantly eastward movement for releases for all except the east zone, which is nearest to the Mississippi River Delta. Despite the small number of returns, westward movement predominated among both the winter (6 of 7-86%) and spring-summer (9 of 10-90%) recaptures for the east zone. On the other hand, the predominant movement showed by the returns for central and west zones was east of the release areas. Moreover, as in the case of east zone releases, no appreciable difference was noted in along-shore movement between winter and spring-summer returns for both central and west zone releases. For the central zone, 64% (32 of 50) of the winter returns and 76% (46 of 62) of spring-summer returns and for the west zone, 100% (16 of 16) of the winter returns and 82% (9 of 11) of spring-summer returns were taken east of the release sites.

The apparent difference in along-shore movement for east zone releases and central and west zone releases probably is related to fishing effort. The release areas for the central and west zones were near longitude 92° West and that of the east zone was near longitude 90° West. Thus, the release areas for the central and west zones are roughly 2° longitude (110nmi) west of the release areas for the east zone. Possibly the primary fishing effort in this region in January may occur in the area between longitude 90° West and longitude 92° West. If this is actually the case, then the area of primary fishing effort would generally be west of the east zone release sites and east of the central and west zone release sites. Also, the proximity of the east zone release site to the Mississippi River Delta may influence either the movement of tagged shrimp and/or fishing effort.

Inshore-Offshore Movement

These offshore studies contributed important information regarding another dimension of directional movement, i.e., inshore-offshore movement. The returns for the 1977 offshore releases indicated a progressively increasing offshore movement with the advance of winter. For the September release, 87% (204 of 235) of the returns was taken inshore of the release block and 1% (3 of 235) was recaptured offshore of the release block. Returns for both the October (18 of 60-30%) and December (23 of 50-46%) releases showed considerably more offshore movement than the September release. The above data suggest that declining water temperatures stimulated the offshore movement indicated by the returns of October and December releases.

Likewise, the winter returns (at large for 50 days or less) of the January 1979 releases, except for east zone releases, showed a marked offshore movement. On the other hand, the spring-summer returns (at large for more than 50 days) showed a predominantly inshore movement. The inshore-offshore movement was similar for both winter and spring-summer returns for the east zone release. For the central and west zones, however, the predominant latitudinal movement for the winter returns was offshore and that of the spring-summer returns was inshore. For the central zone releases, 61% (73 of 120) of the winter returns had moved offshore in contrast to 6% (73 of 120) that moved inshore. Contrarily, the predominant inshore-offshore movement was reversed for spring-summer recaptures; about twice as many (47 of 79-59%) returns were taken inshore as were taken offshore (21 of 79-27%) of the release sites. Similar results were obtained with the west zone releases. All but four of 18 winter releases showed some offshore movement, whereas all but one of the 14 spring-summer returns were taken inshore of the release area.

Many of the spring-summer recaptures showed a decided inshore movement and several were taken near the shoreline and in estuaries.

The pronounced offshore movement indicated by winter returns and the contrasting predominant inshore movement

of the spring-summer recaptures are probably due to effects of water temperature. As one might expect, colder temperatures tend to stimulate offshore movement and warmer temperatures favor inshore movement. The mean surface water temperature in the release area in mid-January 1979 was 14.7°C.

Documentation of the temperature regime in lower Barataria Bay, Louisiana is provided by hourly recordings of subsurface water temperatures at the pier of the LDW&F Marine Laboratory at Grand Terre Isle, Louisiana. Although the water temperature of lower Barataria Bay is subject to greater short-term fluctuations than the waters of the offshore study areas, these temperatures indicate the general warming trend that prevailed 50 days or more after the releases of January 1979. We have reviewed these mean daily water temperatures (mean of hourly readings for each calendar day) from January 1 through May 31, 1979. The mean water temperature in lower Barataria Bay fluctuated between approximately 16°C and 18°C between February 26 and March 7 (50 days after release) and temperature fluctuations between about 15°C and 22°C continued until about March 26. After this date the water temperature in lower Barataria Bay exceeded 20°C.

Gaidry (1974) reported that offshore (between Ship Shoal and Trinity Shoal) overwintering shrimp populations correlated mathematically to the spring inshore white shrimp commercial landings for Louisiana. From these data, Gaidry concluded that a significant portion of the white shrimp population that overwintered offshore returned inshore in spring and contributed to the highly valuable spring offshore white shrimp fishery of Louisiana. The results of our offshore tagging experiments confirm Gaidry's conclusion and probably provide the first direct evidence that overwintering adult white shrimp contribute to the fishery for a second year.

In reviewing the tagging data, we conclude that white shrimp recruit to both the inshore and offshore fisheries from July through November. These young-of-the-year generally move offshore during the summer and fall; by December and January they are located within the 10-20 fm depth off Louisiana. This population then moves inshore during late winter and forms the basis of the spring white shrimp fishery. This overwintering stock is a source for recruits of the following summer and fall fishery, which is exploited from July through November in the inshore and offshore waters of Louisiana.

The high percentage of early recaptures as well as the relatively short distance traveled by the majority of the recaptures suggest that there was sustained commercial shrimp fishing in the release areas during and immediately following our 1977 offshore experiments (Figure 9). The results of the 1979 offshore experiments show that some of the tagged white shrimp traveled considerable distances coastwise, both to the east as well as west of the release sites.

Comparison With Other Studies

It is of interest to compare the results of our experiments with those of other investigators who have conducted mark-recapture studies with white shrimp in northern Gulf of Mexico, specifically those studies conducted west of the Mississippi River Delta. We have attempted to do this in Figure 11, in which the sites of release and recapture are related to statistical subareas. Tagged white shrimp have been released in all statistical subareas between the mouths of the Mississippi and Rio Grande Rivers, except subareas 19 and 21.

Thus, in comparing the results of our studies with those of other experiments conducted with white shrimp in the northwestern Gulf of Mexico, our returns showed greater distances of movement, both to the east and west of the sites, than those of prior investigations. This extension of the known distances traveled by white shrimp is probably due to four factors:

1) Our release of more tagged individuals than in previous investigations.
2) The increase in commercial fishing effort that has occurred in the northwestern Gulf of Mexico since prior investigations were conducted.
3) Our use of the modified mini-ribbon tag, which is superior to either the Peterson disc or stains and organic dyes used in some of the earlier investigations.
4) The publicity and reward incentives associated with our studies were greater than those employed in earlier investigations.

CONCLUSIONS

1. White shrimp released in an estuarine system will disperse throughout the system within 30 days and prior to emigration to offshore areas. Furthermore, juvenile shrimp released in one estuarine system may enter another.
2. Shrimp released inshore predominantly show a westward movement after emigration to offshore areas with some easterly movement in fall and winter.
3. Some shrimp remain in the estuary throughout the summer and early fall, and they may quickly emigrate offshore in response to sudden water temperature reduction caused by cold fronts.
4. Returns indicate that some shrimp (both inshore and offshore releases) traveled more than 100 nmi longitudinally, either westward or eastward prior to recapture. Shrimp populations of a particular statistical subarea may contribute brood stock to several subareas to either side of the one in question.
5. Although shrimp were released in all statistical subareas between the Mississippi River Delta (subarea 13) and western boundary of Louisiana (subarea 17), no returns were obtained from either east of the Mississippi River Delta or west of Galveston, Texas.
6. Generally, shrimp release offshore in September and October showed little movement and no particular direction of movement prevailed as for the inshore releases.
7. Shrimp released offshore in December showed appreciable movement to the east as well as offshore of the release sites.
8. Shrimp released offshore in January showed a predominantly offshore movement within 50 days of re-

lease, whereas those at large for more than 50 days predominantly moved inshore during late winter and spring. Some returned to estuaries either east or west of the release longitudes.

9. Shrimp overwintering in the offshore area contributed to the spring inshore white shrimp fishery. Moreover, this overwintering population is a brood stock that provides recruits for the next years fishery.
10. Both sexes show similar patterns of movement.

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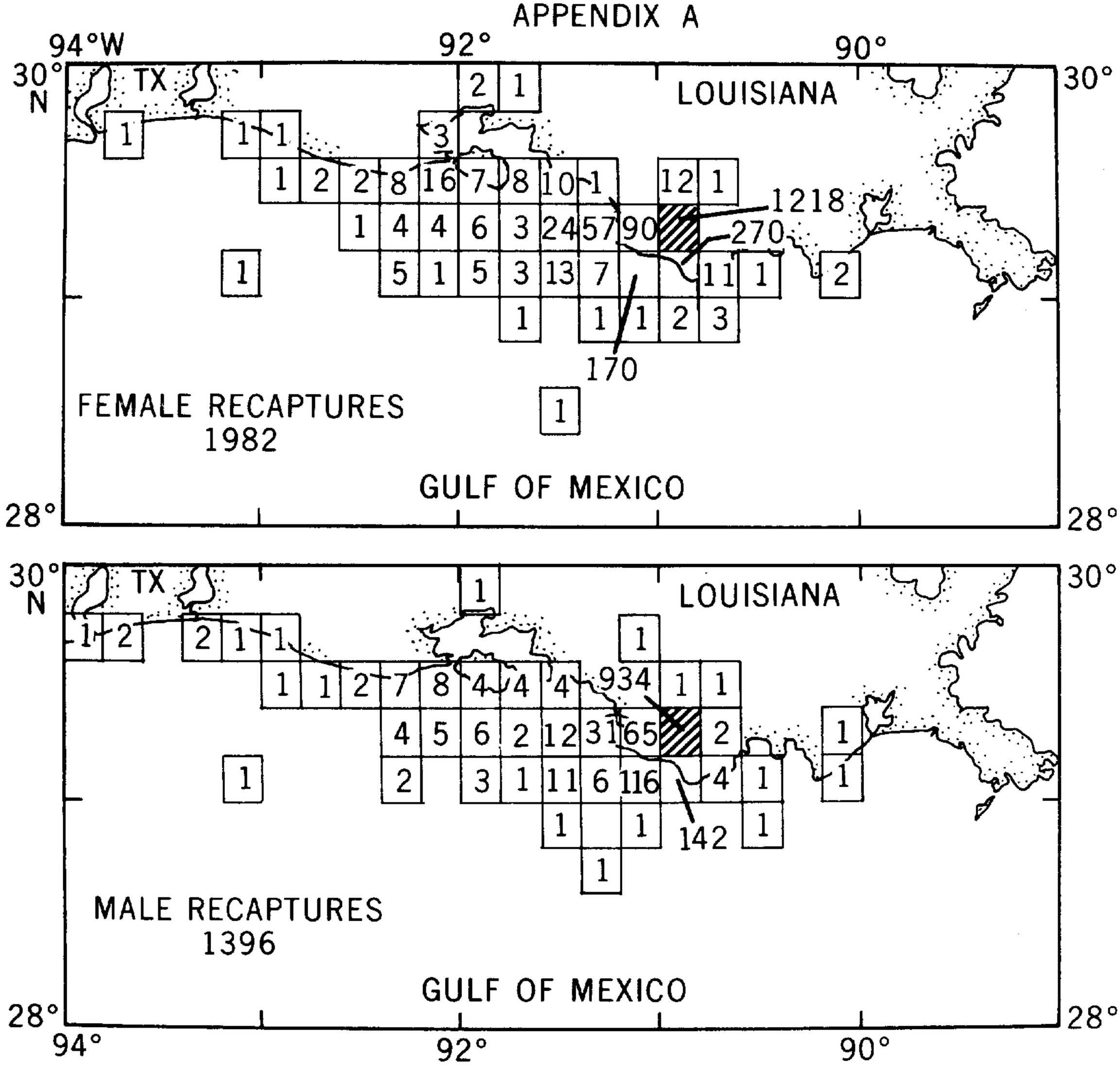
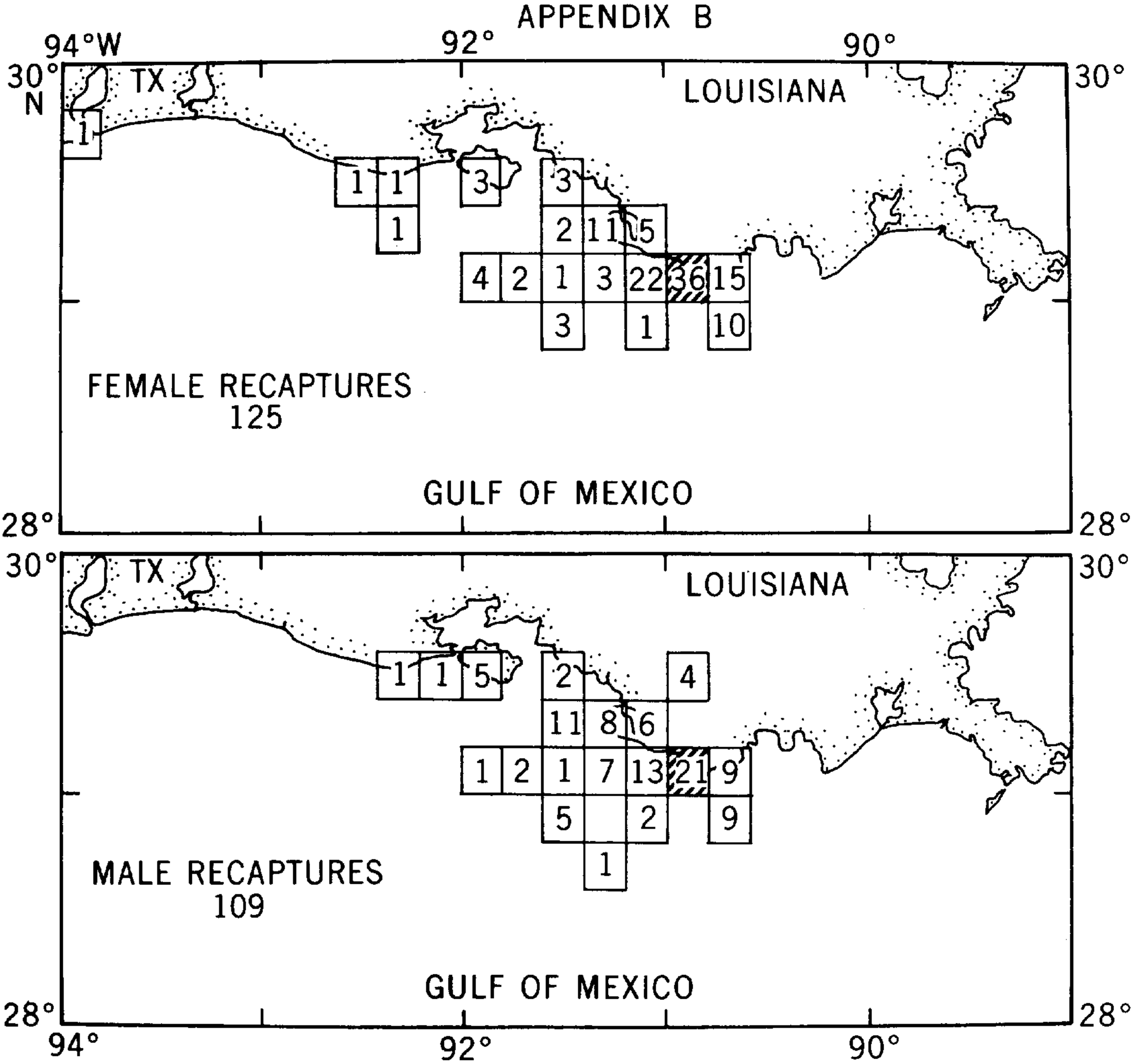


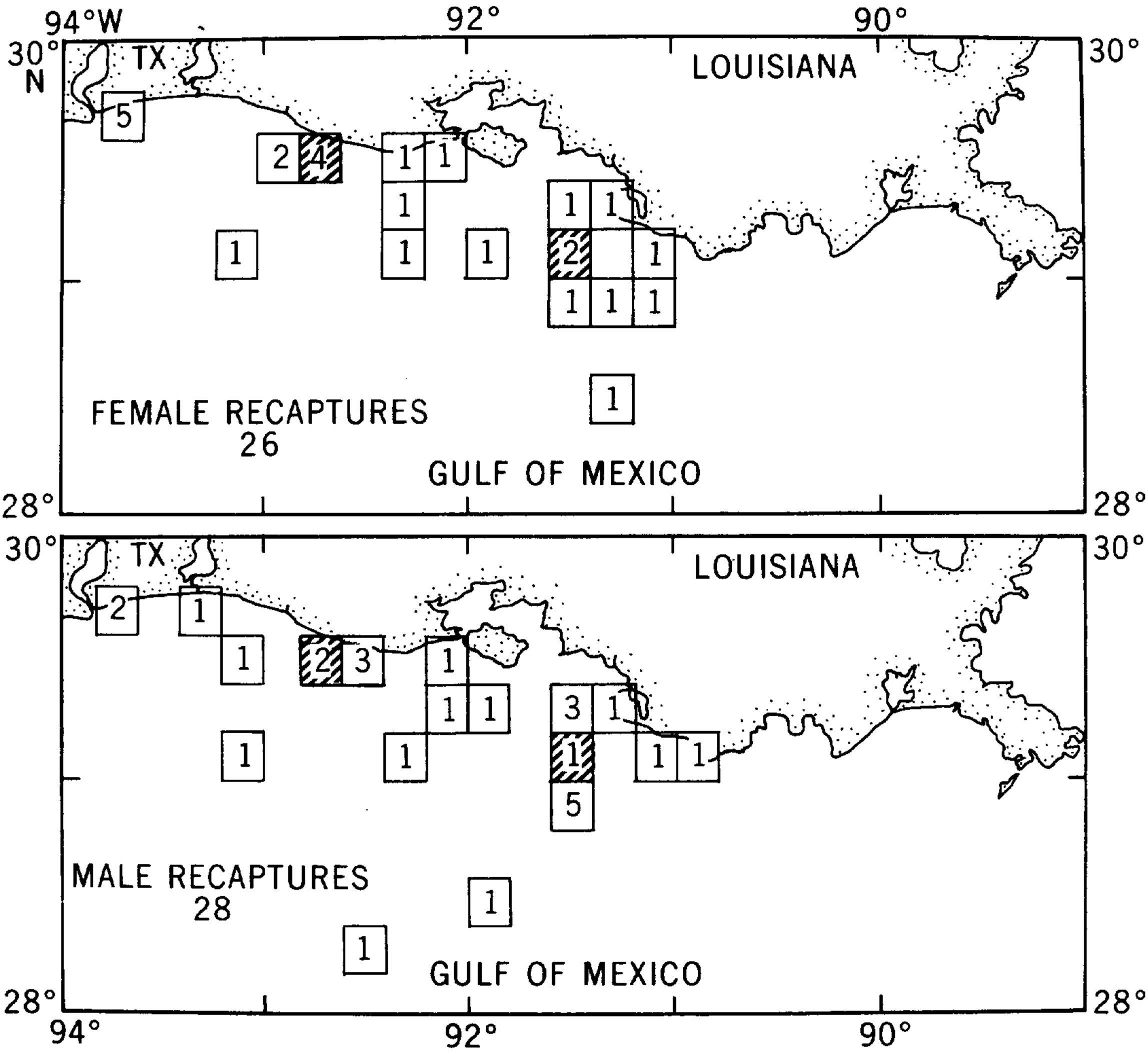
Appendix A

Figure 1. Computer plots of location of returns by sex for tagged white shrimp released in Caillou Lake in 1977. The number within the blocks (12 minutes longitude — 11 nmi by 12 minutes latitude — 12 nmi) represents the number of either females or males recaptured within a particular block. Location of release sites indicated by slash lines.



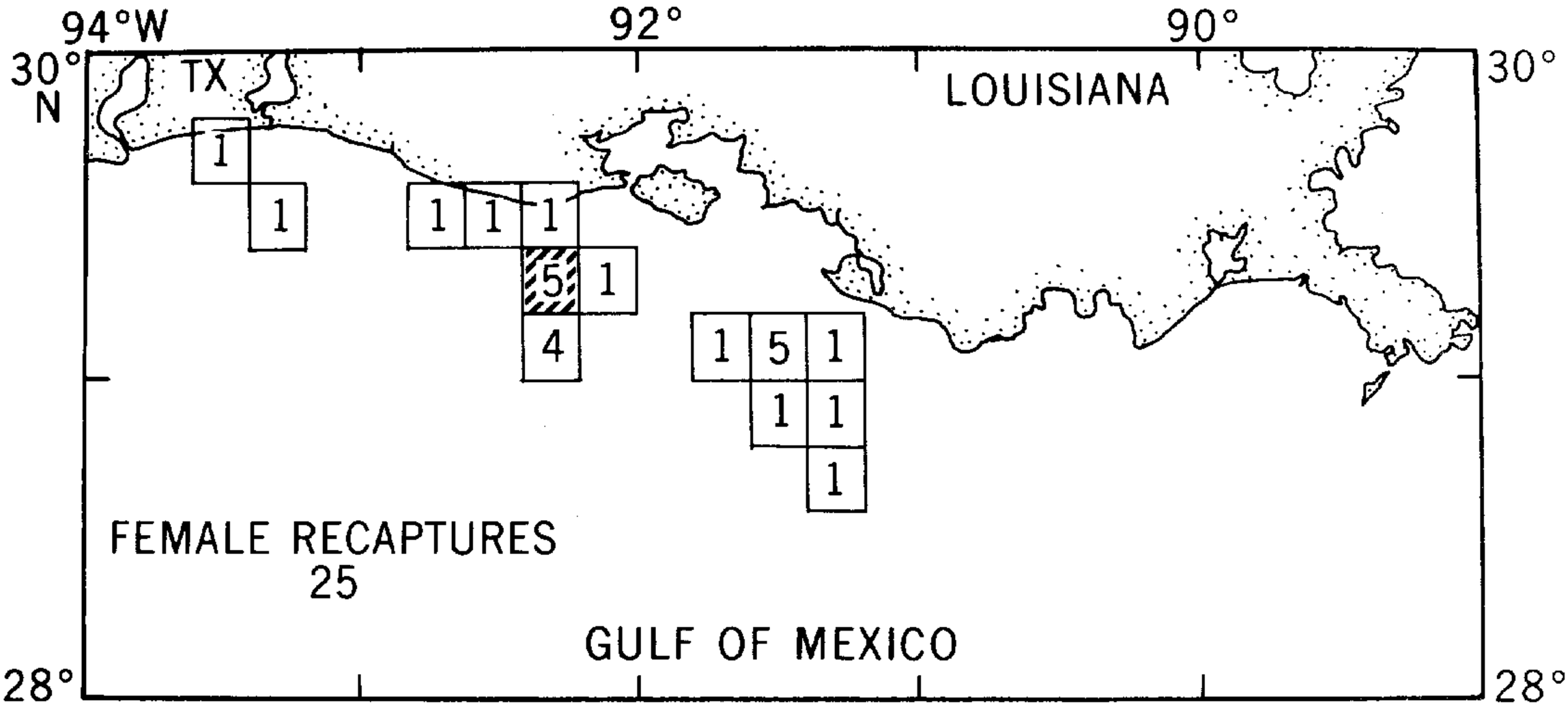
Appendix B

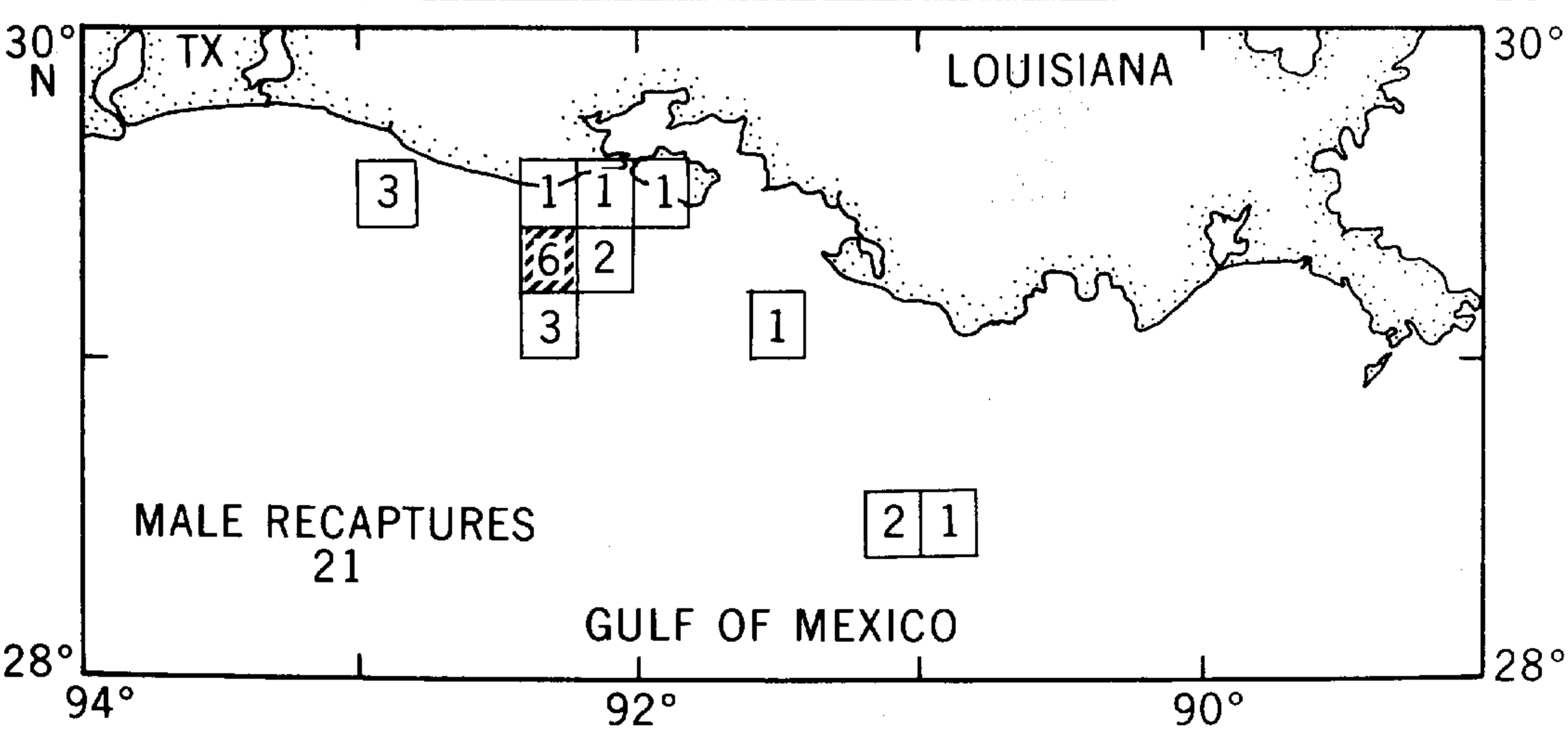
Figure 1. Computer plots of location of returns by sex for tagged white shrimp released offshore in September 1977. The number within the blocks (11 minutes longitude — 11 nmi by 12 minutes latitude — 12 nmi) represents the number of either females or males recaptured within a particular block. Location of release sites indicated by slash lines.



Appendix B

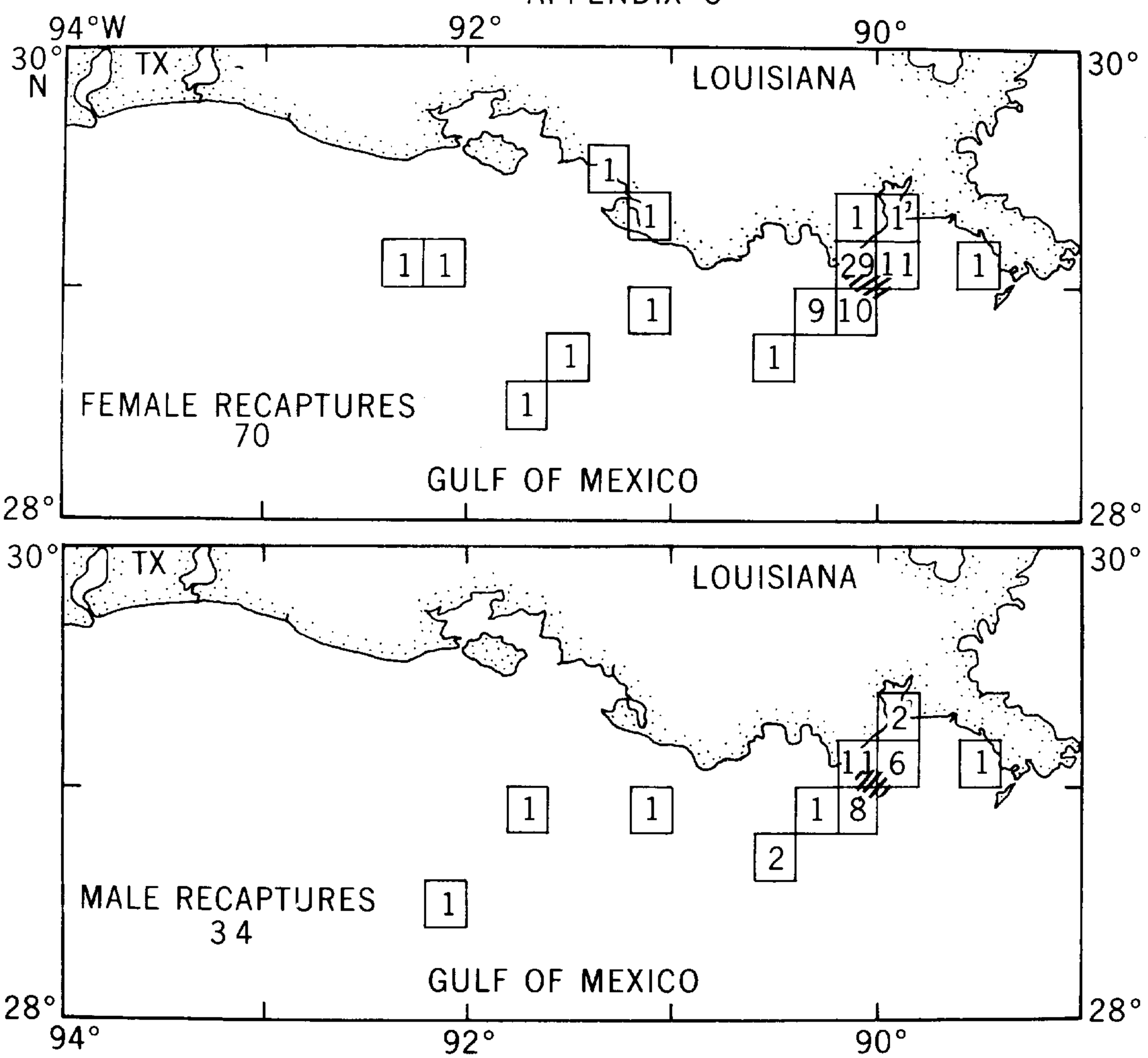
Figure 2. Computer plots of location of returns by sex for tagged white shrimp released offshore in October 1977. The number within the blocks (11 minutes longitude — 11 nmi by 12 minutes latitude — 12 nmi) represents the number of either females or males recaptured within a particular block. Location of release sites indicated by slash lines.





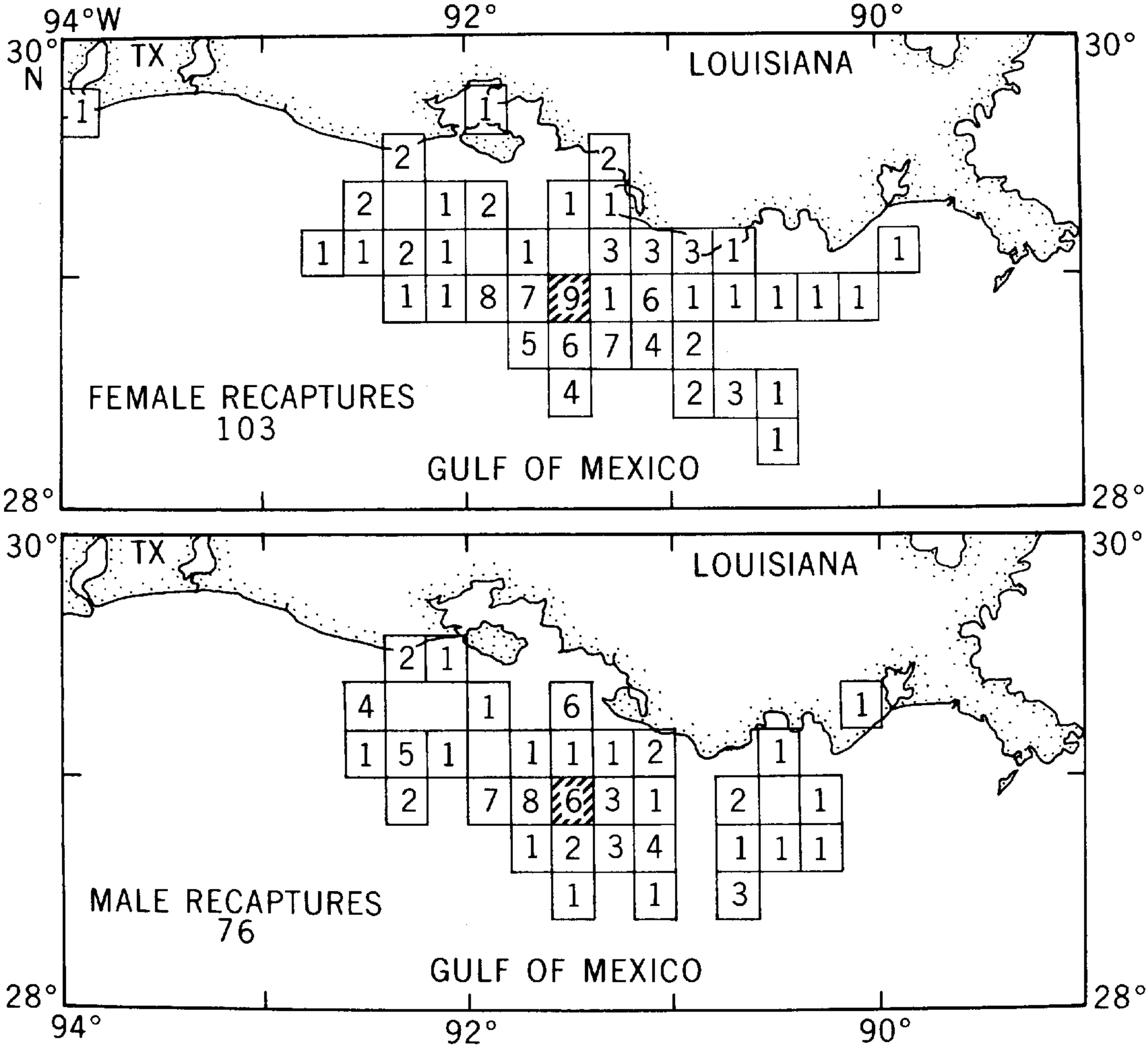
Appendix B

Figure 3. Computer plots of location of returns by sex for tagged white shrimp released offshore in December 1977. The number within the blocks (11 minutes longitude — 11 nmi by 12 minutes latitude — 12 nmi) represents the number of either females or males recaptured within a particular block. Location of release sites indicated by slash lines.



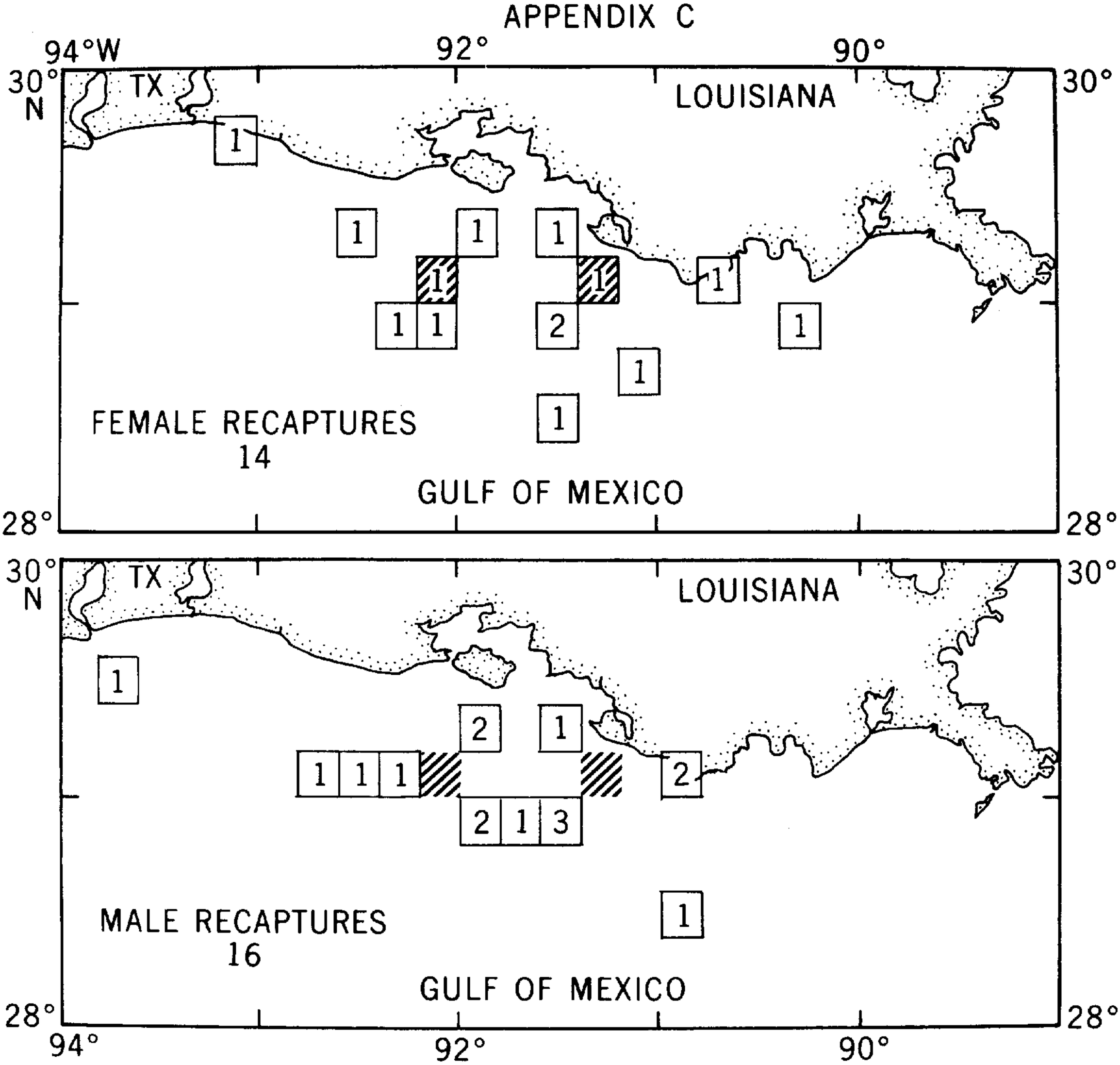
Appendix C

Figure 1. Computer plots of location of returns by sex for tagged white shrimp released offshore in east zone on January 11, 12 and 13, 1979. The number within the blocks (11 minutes longitude — 11 nmi by 12 minutes latitude — 12 nmi) represents the number of either females or males recaptured within a particular block. Location of release sites indicated by slash lines.



Appendix C

Figure 2. Computer plots of location of returns by sex for tagged white shrimp released offshore in central zone on January 7, 8, 9 and 10, 1979. The number within the blocks (11 minutes longitude — 11 nmi by 12 minutes latitude — 12 nmi) represents the number of either females or males recaptured within a particular block. Location of release sites indicated by slash lines.



Appendix C

Figure 3. Computer plots of location of returns by sex for tagged white shrimp released offshore in west zone on January 15 and 16, 1979. The number within the blocks (11 minutes longitude — 11 nmi by 12 minutes latitude — 12 nmi) represents the number of either females or males recaptured within a particular block. Location of release sites indicated by slash lines.