Movements of Brown Shrimp, *Penaeus aztecus*, and Pink Shrimp, *P. duorarum*, Relative to the U.S.-Mexico Border in the Western Gulf of Mexico

PETER F. SHERIDAN, FRANK J. PATELLA, Jr., NEAL BAXTER, and DENNIS A. EMILIANI

ABSTRACT—Seasonal movement patterns of marked brown shrimp, Penaeus aztecus, *and pink shrimp,* P. duorarum, *relative to the U.S.-Mexico border in the western Gulf of Mexico are described from recaptures of shrimp tagged during 1978-80. The intent was to determine the degree to which coastal shrimp movements would affect commercial catches after implementation of new fishing regulations off Texas and Mexico. Shrimp were collected by trawl, marked with polyethylene streamer tags, and released during March-November at sites between Galveston, Tex., and Tampico, Tamaulipas, Mexico. Movements were examined by vector analysis and by recaptures per unit commercial landings. Over 121,500 shrimp were marked during seven releases in estuaries, of which 1,827 (1.5 percent) were recaptured. Only 72 brown shrimp and 126 pink shrimp were recaptured offshore, but southerly movement patterns were indicated after five of those seven releases. Offshore releases of 71,485 brown shrimp and 19,185 pink shrimp resulted in 12.4 percent and 19.7 percent recapture proportions, respectively. Tagged brown shrimp moved up to 620 km from release sites and remained free up to 430 days. Tagged pink shrimp moved a maximum 428 km and were free up to 446 days. Recaptures were higher south of release sites after 20 of 30 releases of brown shrimp off Texas and Tamaulipas. In contrast, recaptures of pink shrimp were higher south of release sites after only 7 of 13 releases. The effectiveness of the Gulf of Mexico shrimp fishery management plan, enacted in 1981 to increase brown shrimp yield by seasonal prohibition of fishing, could be diminished by the tendency for brown shrimp to migrate south.*

Introduction

The major fishery for brown shrimp, *Penaeus aztecus*, occurs in the western Gulf of Mexico. Annual U.S. landings of brown shrimp off Texas averaged 13,800 metric tons (t) between 1970 and 1980, approximately 50 percent of the entire northern Gulf of Mexico catch (Klima et al., 1982). Annual catches off Tamaulipas and upper Veracruz, Mexico (lat. 21°-26°N) averaged 2,000 t in 1974-79 by Mexican vessels (Castro[1]) and 2,800 t in 1970-75 by U.S. vessels prior to the U.S. withdrawal from that fishery (NMFS, 1971-76). Pink shrimp, *Penaeus duorarum*, are caught by the brown shrimp fishery off Texas and Tamaulipas but are not separated by processors because they form 10 percent or less of the total catch (Klima et al., 1982).

Tagged brown shrimp and pink shrimp have been reported to move up to 435 km before recapture (Klima, 1963; Costello and Allen, 1966; Cody and Fuls, 1981; Castro et al.[2]). These longshore movements represent a potential loss of yield from the U.S. fishery due to management regulations in the United States and Mexico. By 1976 treaty, U.S. vessels were to withdraw from Mexico's shrimp fishery by January 1980 (GMFMC, 1981). Reported U.S. shrimp catches from the Tamaulipas coast declined from 534 t in 1976 to zero in 1979 (NMFS, 1977, 1978, and unpubl. data). During the same period, the U.S. Gulf of Mexico shrimp fishery management plan was being developed for implementation in 1981. The plan's objective was to increase yield of brown shrimp recruiting to the offshore fishery by delaying harvest of small shrimp until a larger, preferred size was reached (GMFMC, 1981). A 45- to 60-day prohibition of shrimping in the Texas territorial sea and the Federal Fishery Conservation Zone (FCZ) during peak emigration of brown shrimp from Texas estuaries was instituted in 1981. An effective management plan would depend in part upon detailed knowledge of shrimp movement patterns. The National Marine Fisheries Service, the Texas Parks and Wildlife Department, and the Instituto Nacional de la Pesca of Mexico tagged brown shrimp and pink shrimp along the Texas and Tamaulipas coasts during 1978-80 as a means of studying movement, growth, and mortality. To date, only the results of tagging off Texas have been published, and these articles did not relate recaptures to fishing pressure (Cody and Avent, 1980; Cody and Fuls, 1981; Castro et al.[2]). This paper documents shrimp movements on the continental shelf adjacent to Texas and Tamaulipas as influenced by fishing pressure, with particular reference to the Texas closed shrimp season.

Materials and Methods

We hypothesized that net longshore movements of shrimp populations, as measured by recapture of tagged shrimp

[1]Castro, Refugio G. Fundamentos y consideraciones para definir la temporada de veda en altamar y Laguna Madre en las costas de Tamaulipas en el noroeste del Golfo de Mexico. Unpubl. manuscr., 35 p. Departmento de Pesca, Instituto Nacional de la Pesca, Tampico, Tamaulipas, Mexico.

[2]Castro, Refugio G., Esteban Rosas, and Rolando Orta. Investigaciones conjuntas de camaron Mexico-E.U.A. en el Golfo de Mexico. Programo de marcado-recaptura de camaron en las costas de Tamaulipas, Mexico de 1978-1981. Unpubl. manuscr., 63 p. Instituto Nacional de la Pesca, Centro de Investigaciones Pesqueras, Tampico, Tamaulipas, Mexico.

The authors are with the Galveston Laboratory, Southeast Fisheries Center, National Marine Fisheries Service, NOAA, 4700 Avenue U, Galveston, TX 77551-5997.

by commercial and recreational fishermen, were random with respect to both month and location of release. Tagged shrimp were released during May-November over 3 years (1978-80) although releases were not made in each month each year. Release locations were National Marine Fisheries Service statistical subareas 18-25 between Galveston, Tex., and Tampico, Tamaulipas (Fig. 1). Release sites within these locations were either localized inshore sites near estuary passes or dispersed offshore sites where adequate supplies of shrimp for tagging could be located. Offshore releases were made in many combinations of month, year, and location, but inshore releases were limited.

All shrimp were collected by trawl and marked with colored, numbered polyethylene streamer tags as described by Marullo et al. (1976). Shrimp were released by dipnet or chute (10 cm diameter hose) in shallow inshore waters and by expendable release canister offshore. Each canister was weighted, loaded with 50-75 shrimp, and sealed with a salt block that dissolved and freed the shrimp after 10-15 minutes on the sea floor (Emiliani, 1971). Periodic lottery rewards of up to $500 were offered as an incentive to fishermen who caught tagged shrimp and provided information on locations and dates of recaptures (Cody and Fuls, 1981).

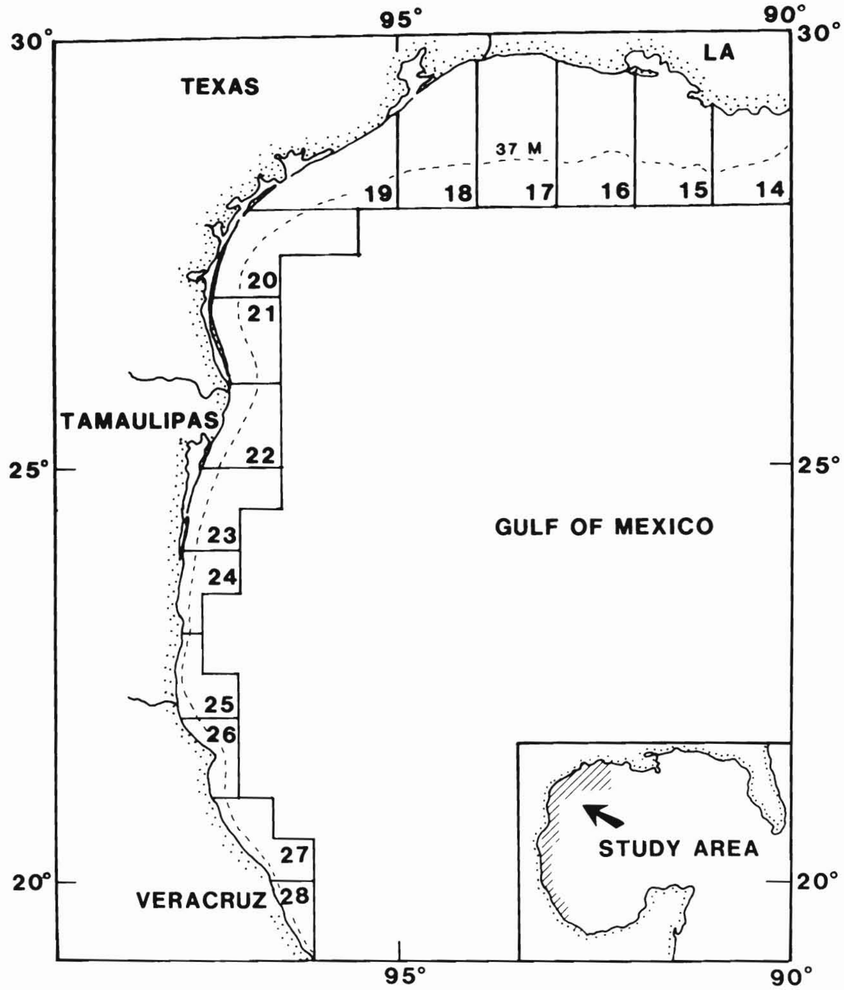

Figure 1.—Statistical subareas of the Gulf of Mexico in which marked shrimp were released (18-25) and later recaptured (14-28).

Tagged shrimp were identified before release with the exception of September 1978 releases off Tamaulipas. Cody and Fuls (1981) reported that the proportion of pink shrimp among all recaptures after release off Texas in October 1978 was similar to the proportion of pink shrimp among all shrimp released at that time (4.6 vs. 5.2 percent). Thus, numbers stated for brown shrimp and pink shrimp released in September 1978 off Tamaulipas were estimated from the total number released multiplied by the proportion of each species among recaptures.

Evaluation of directional movement employed two methods: Vector analysis of recaptures (Cody and Avent, 1980; Cody and Fuls, 1981) and recaptures per 10^3 t of commercial landings. Vector analysis assumed uniform catch in time and space and straight line movement from release site to recapture site. To determine longshore movements of shrimp in each statistical subarea, the 360° compass configuration was divided into octants with midpoints corresponding to the compass points N, NE, E, SE, S, SW, W, and NW. The approximate orientation of the 37 m isobath in each statistical subarea (NOS Chart 411) was matched to an opposing pair of these octants to determine longshore (parallel to coastline) and onshore-offshore (perpendicular to coastline) directions as well as compass heading ranges for these directions. Three octants were assigned to each longshore direction while one octant each was assigned to onshore and offshore (Table 1). Longshore movement toward the Mississippi River was termed "north" while longshore movement toward Veracruz, Mexico, was termed "south". The vector heading (in degrees) and the distance traveled for each recaptured shrimp were calculated from tag return data, and each recapture was then assigned to one of the four coastwise categories. It was hypothesized that after each release dispersal was random, and significant departures from the expected 1:1 north-south ratio in the numbers of recaptures was tested by chi-square analysis ($P<0.05$). Onshore and offshore recaptures were excluded because they did not address longshore movement.

Recaptures per 10^3 t of commercial

landings (R/L) corrects for variation in shrimp landings among statistical subareas. Shrimp were recaptured either in the statistical subarea of release ("within"), in subareas between that of release and the Mississippi River ("north"), or in subareas between that of release and Veracruz ("south"). Monthly brown shrimp landings data for statistical subareas 14-21 and 22-26 were collected by the Economics and Statistics Office, National Marine Fisheries Service, Miami, Fla., and the Centro de Investigaciones Pesqueras, Instituto Nacional de la Pesca, Tampico, Tamaulipas. These landings included pink shrimp. For each release, R/L was calculated by: 1) Tabulating the number of recaptures within the subarea of release and in subareas north and south of the release site, where north was defined as up to and including the subarea of northernmost recapture and south was defined as down to and including the subarea of southernmost recapture, then 2) dividing those values by the commercial landings in those subareas recorded from the month of release through the month of last recapture.

Some of the shrimp recaptures were not appropriate for either analysis. Recaptures with incomplete return data, such as no species identification or inaccurate location or date, were omitted. Only offshore recaptures following inshore releases were analyzed. Recaptures within 9 km of the offshore release sites were excluded from vector analysis because a minor error in recapture location could have led to a major error in apparent movement direction over such a short distance.

Table 1.—Compass points and heading ranges (degrees) corresponding to shrimp movements relative to shore by statistical subareas of release. Headings are based on the approximate orientation of the 37 m isobath on NOS Chart 411. North = toward the Mississippi River; south = toward Veracruz, Mexico; SS = statistical subarea.

		North		Offshore		South		Onshore	
Area	SS	Points	Headings	Points	Headings	Points	Headings	Points	Headings
Texas	18	NE, E, SE	022.5-157.4	S	157.5-202.4	SW, W, NW	202.5-337.4	N	337.5-022.4
	19	N, NE, E	337.5-112.4	SE	112.5-157.4	S, SW, W	157.5-292.4	NW	292.5-337.4
	20	N, NE, E	337.5-112.4	SE	112.5-157.4	S, SW, W	157.5-292.4	NW	292.5-337.4
	21	NW, N, NE	292.5-067.4	E	067.5-112.4	SE, S, SW	112.5-247.4	W	247.5-292.4
Tamaulipas	22-25	NW, N, NE	292.5-067.4	E	067.5-112.4	SE, S, SW	112.5-247.4	W	247.5-292.4

Table 2.—Directional movements of tagged brown shrimp and pink shrimp released in Texas and Tamaulipas estuaries as determined by vector analysis of offshore recaptures north and south of release sites and by recaptures per 10^3 t of commercial landings north, within, and south of the statistical subarea (SS) of release. N = number of offshore recaptures, * = significant difference in expected 1:1 north-south ratio as indicated by chi-square analysis ($P<0.05$).

Releases					Vector analysis[1]			Recaptures per 10^3 t			
Year	SS	Months	Number	Total recaptures	N	North	South	N	North	Within	South
				Brown shrimp							
1978	20	May-July	42,180	7	0			0			
1979	20	June-July	9,598	0	0			0			
	21	April-June	15,776	84	18	2	4	18	0.0	11.6	42.2
	23	April-May	10,083	31	2	1	1	2	0.0	1.9	2.8
1980	18	June-July	11,350	1	0			0			
	19	May, July	10,218	10	0			0			
	21	March-April	2,912	229	11	4	7	11	0.0	1.6	48.0
	23	March-June	4,362	31	5	1	4	5	8.4	9.0	0.0
Total			106,479	393	36			36			
				Pink shrimp							
1979	21	April-June	2,778	123	35	12	6	35	0.5	11.1	27.4
	23	April-May	384	2	0			0			
1980	21	March-April	9,548	1,296	82	23	59*	82	0.5	13.8	21.9
	23	March-June	2,374	13	2	1	1	2	18.9	4.8	0.0
Total			15,084	1,434	119			119			

[1] N − (North + South) = number of onshore/offshore recaptures.

Results

The available evidence indicates that net population movement of tagged brown shrimp along the Texas-Tamaulipas coast was southward after 1978-80 releases. Three of four inshore releases and 20 of 30 offshore brown shrimp releases resulted in higher R/L values south of release sites. Southerly movement was not consistent, however, as the remaining 10 releases had higher R/L values to the north. Pink shrimp had a more variable movement pattern since two of three inshore releases and only 7 of 13 primary offshore releases resulted in higher R/L values to the south.

Over 121,500 brown shrimp and pink shrimp were marked and released in estuarine waters but, with three exceptions, recaptures after inshore releases were <1 percent of those released (Table 2). Poor recoveries were probably due to stress by handling, high water temperature, predation, or attacks of tagged shrimp by untagged shrimp (Cody and Avent, 1980; Howe and Hoyt, 1982). Twelve inshore releases were conducted but only one was followed by directional movement as indicated by vector analysis. Pink shrimp recaptured after release during March-April 1980 in statistical subarea 21 demonstrated significant southward movement. R/L values for the seven inshore releases with subsequent offshore recaptures, however, indicated southward movement after three brown shrimp releases and two pink shrimp releases. All trans-border recaptures (7 brown shrimp, 31 pink shrimp) were made from shrimp released in the Laguna Madre of Texas, most likely because the Brazos-Santiago Pass from the Laguna Madre of Texas is only 15 km from the border while Boca de Catan, near the tagging site in the Laguna Madre of Tamaulipas, is 175 km from the border.

Vector analysis of brown shrimp recaptures (Table 3) generally indicated significant southward migration. Southerly movements occurred spring through fall while northerly movements

Table 3.—Directional movements of tagged brown shrimp released off Texas and Tamaulipas as determined by vector analysis of recaptures north and south of release sites and by recaptures per 10^3 t of commercial landings north, within, and south of the statistical subarea (SS) of release. N = number of recaptures appropriate for analysis, * = significant difference in expected 1:1 north-south ratio as indicated by chi-square analysis ($P<0.05$).

Releases					Vector analysis[1]			Recaptures per 10^3 t			
Year	SS	Months	Number	Total recaptures	N	North	South	N	North	Within	South
1978	20	August	2,832	193	73	45*	24	171	4.0	63.6	2.4
		October	1,430	153	101	30	64*	127	1.5	41.7	4.6
	22	September	2,011	336	264	42	222*	264	0.3	242.7	65.8
	23	September	5,859	1,416	1,205	297	889*	1,250	10.9	388.2	421.8
	24	September	539	62	46	20	26	61	10.6	171.1	27.6
	25	September	503	64	59	21	36	62	10.4	265.8	58.6
1979	18	September	771	120	66	5	57*	86	0.5	105.0	18.5
	19	September	1,760	158	89	19	65*	121	3.3	114.1	6.7
		October	8,270	1,039	796	53	607*	811	13.4	155.3	4.4
		November	2,569	109	80	44	30	95	25.9	74.4	3.4
	20	May	978	139	95	21	47*	115	0.0	18.5	35.0
		September	349	37	30	18	11	33	6.7	16.3	8.7
		October	1,106	225	156	28	104*	196	3.0	50.3	10.6
	21	May	1,620	444	141	59	78	191	3.7	51.4	3.9
	22	May	519	132	92	25	46*	98	3.2	445.5	14.2
		June	1,509	183	112	8	90*	167	0.5	573.0	70.0
		September	168	12	10	1	9*	10	0.0	110.6	23.1
	23	May	549	121	86	34	52	86	175.8	75.1	17.9
		June	1,224	193	110	36	66*	176	239.9	243.3	69.1
	24	June	2,618	459	357	235*	118	423	34.2	768.3	16.1
1980	19	June	11,677	882	437	177	241*	653	16.4	156.5	7.4
		July	10,545	873	336	34	277*	598	5.0	98.0	28.3
	20	June	2,013	67	47	12	20	52	2.8	12.8	2.4
		July	4,362	229	163	7	150*	220	0.3	30.4	40.4
	21	May	423	113	83	28	46*	101	2.4	34.3	15.1
		June	298	15	14	6	6	14	0.7	2.6	8.5
	22	May	883	106	100	44	40	105	4.5	214.4	11.9
	23	May	974	129	93	37	53	121	152.5	73.5	25.0
	24	May	1,062	152	71	35	28	143	25.6	328.6	33.4
	25	May	2,064	666	536	367*	169	641	105.2	779.6	0.0
Total			71,485	8,827	5,848			7,191			

[1]N − (North + South) = number of onshore/offshore recaptures.

Table 4.—Percentage of brown shrimp recaptures by days free, state, and months of release, 1978-80. N = total number recaptured.

			Days free						
State	Release months	N	1-10	11-20	21-30	31-40	41-60	61-100	101+
Texas	May	696	36	18	12	8	16	5	6
	June-August	2,259	44	17	18	9	7	3	1
	September-November	1,841	28	22	18	8	13	7	4
	Total	4,796	36	19	17	8	11	5	3
Tamaulipas	May	1,306	16	32	19	14	10	6	4
	June-August	835	27	22	26	9	9	7	1
	September-November	1,890	15	29	25	13	9	7	4
	Total	4,031	17	28	23	12	9	7	3

were noted in spring and summer. R/L values also indicated that brown shrimp moved south more frequently than north. Eleven of 16 Texas releases and 9 of 14 Tamaulipas releases resulted in higher R/L values in statistical subareas south of the release sites. Five Texas releases and five Tamaulipas releases resulted in higher R/L values north of the release sites. Both southerly and northerly movements of brown shrimp occurred spring through fall, as indicated by R/L values. Of the 19 vector analyses indicating significant movement of brown shrimp, 16 of the corresponding R/L values agreed on direction of movement.

An examination of tag returns over time (Table 4) indicated that about 70 percent of all tagged brown shrimp were returned within 30 days of Texas and Tamaulipas release. Recaptures after 1-10 days free were higher in Texas than in Tamaulipas (36 vs. 17 percent of the respective total numbers returned), but the reverse was true after 11-30 days free (36 vs. 52 percent, respectively). On a seasonal basis, tag returns occurred more rapidly after June-August releases (the main shrimping season) than after spring or fall releases off each state.

Maximum long distance movements by marked brown shrimp included 620 km within U.S. waters, 596 km from Texas to Tamaulipas, 528 km from Tamaulipas to Texas, and 526 km within Mexican waters. Maximum days at large were 390 days within U.S. waters, 430 days for a Texas release-Tamaulipas recapture, 400 days for the reverse, and 353 days within Mexican waters.

Vector analysis of pink shrimp recaptures (Table 5) indicated no overall movement pattern. R/L values for pink shrimp recaptures indicated southward movement after seven primary releases and northward movement after the remaining six releases. Of the seven vector analyses indicating significant directional movement, six of the corresponding R/L values agreed on direction of movement.

The time course of pink shrimp recaptures after primary releases in May-June (Table 6) differed between the two release states. Only 40 percent of the returns after Texas releases had been recorded within 30 days, compared with 67 percent of the Tamaulipas releases. A comparatively large proportion (34 percent) of the recaptures after Texas releases came after 41-60 days free. Some 50 percent of the recaptures after incidental releases were made within 30 days. The maximum distances traveled by marked pink shrimp were 428 km from Texas to Tamaulipas, 380 km from Tamaulipas to Texas, 400 km within U.S. waters, and 398 km within Mexican waters. Maximum days at large for these same spatial areas were 391, 446, 436, and 344 days, respectively.

Transborder movements of tagged brown shrimp and pink shrimp were recorded each year (Table 7). Transborder recaptures primarily followed releases in subareas 21 and 22 adjoining the U.S.-Mexico border. However, one pink shrimp traveled from subarea 20 and five brown shrimp traveled from subarea 19 into Tamaulipas waters, while two pink shrimp from subarea 23 and one brown shrimp from subarea 24 were recaptured in Texas waters.

Discussion

R/L values are the preferred of our two indicators of shrimp movement because R/L depends on marked shrimp that move completely out of the subarea of release and thus are exhibiting long-range, directed movement. R/L values also compensate for nonuniform commercial shrimp landings among statistical subareas. Vector analysis is useful as a secondary indicator of shrimp movement because it reflects primarily short-range movements (usually within the subarea of release), but it assumes a uniform pattern in landings which rarely occurs. Our definition of longshore movement for the vector analyses is also liberal in that 75 percent of all recaptures are assumed to be showing longshore movement. Perhaps a better indicator of shrimp movement would be recaptures per unit effort, but these data were not available for the complete study period on both sides of the border.

Brown shrimp and pink shrimp migrations may be related to food, substrate, or currents. The offshore diets of these species have not been investigated, but if infaunal organisms are a primary food as they are inshore (Williams, 1955; Eldred et al., 1961; Sastrakusumah, 1971), then brown shrimp and pink shrimp might be attracted to the areas of densest infaunal assemblages (Williams, 1958). Along the south Texas coast, these areas are found on the relict Rio Grande Delta (Hill et al., 1982) in statistical subarea 21. This is also an area of unique sedimentary characteristics along the Texas coast (Shideler, 1978), but the offshore sediment preferences of penaeid shrimps have not been examined directly (Grady, 1971). Experiments with juvenile shrimp indicate that pink shrimp may seek coarse substrates (Williams, 1958) or be competitively displaced from fine-grained substrates by the more numerous brown shrimp (Rulifson, 1981), both factors that may influence shrimp recapture patterns. Statistical subarea 19 has traditionally yielded the largest catches of brown shrimp, most likely because it contains 26-85 percent more bottom area in the most productive depth stratum (20-46 m) than is contained in statistical subareas 18, 20, or 21 (Patella, 1975; Klima et al., 1982). Infaunal and sedimentary patterns on the Tamaulipas shelf are not known, although highest shrimp catches in statistical subareas 22-24 are also made in 20-46 m waters (Griffin and Beattie, 1977).

Prevailing bottom currents may also influence the observed patterns in recaptures of tagged shrimp. Upcurrent migration have been reported for king prawn moving to spawning areas on the

Table 5.—Directional movements of tagged pink shrimp released off Texas and Tamaulipas as determined by vector analysis of recaptures north and south of release sites and by recaptures per 10^3 t of commercial landings north, within, and south of the statistical subarea (SS) of release. N = number of recaptures appropriate for analysis, * = significant difference in expected 1:1 north-south ratio as indicated by chi-square analysis ($P<0.05$).

Releases				Total	Vector analysis[1]			Recaptures per 10^3 t			
Year	SS	Months	Number	recaptures	N	North	South	N	North	Within	South
1978	20	October	68	7	5	2	3	6	0.9	3.9	1.6
	22	September	23	4	3	2	1	3	1.2	5.6	1.6
	23	September	24	5	5	0	5	5	0.0	0.0	77.4
	24	September	65	9	6	2	4	8	3.6	12.1	5.7
	25	September	77	12	9	2	7	10	6.6	45.2	0.0
1979	18	September	4	1	1	1	0	1	0.0	6.0	0.0
	19	September	86	3	2	1	1	2	6.0	0.0	1.8
	20	May	361	49	31	7	20*	39	0.0	6.3	9.4
		September	34	1	1	0	1	0	0.0	2.1	0.0
		October	17	1	0	0	0	0	0.0	0.0	0.0
	21	May	8,463	1,793	1,068	454	585*	1,688	16.4	359.1	26.1
	22	May	846	195	164	54	75	182	2.8	382.7	10.8
		June	68	6	2	0	2	5	0.0	23.3	4.3
		September	26	0	0	0	0	0	0.0	0.0	0.0
	23	May	819	120	111	47	64	111	169.6	64.2	6.6
		June	367	32	16	1	13*	17	0.0	13.6	22.9
	24	June	421	77	68	34	34	73	19.5	133.0	16.1
1980	20	June	235	17	12	6	4	14	5.5	9.9	2.1
		July	15	4	4	1	3	4	0.3	0.0	1.0
	21	May	2,885	812	549	399*	138	778	13.7	207.2	11.8
		June	386	93	68	39*	17	87	7.2	38.7	0.0
	22	May	1,035	102	95	53	36	99	6.0	178.0	6.4
	23	May	1,203	202	125	53	68	189	14.3	139.6	17.0
	24	May	1,134	166	70	38*	21	163	17.7	317.2	22.3
	25	May	523	59	47	36*	11	58	16.4	54.0	4.7
Total			19,185	3,770	2,462			3,538			

[1]N − (North + South) = number of onshore/offshore recaptures.

Table 6.—Percentage of pink shrimp recaptures by days free, state, and months of release, 1978-80. N = total number recaptured.

			Days free						
State	Release months	N	1-10	11-20	21-30	31-40	41-60	61-100	101+
Texas	May-June	2,768	31	4	5	10	34	11	4
	September-October	13	23	15	8	8	31	15	0
	Total	2,781	31	4	5	10	34	11	4
Tamaulipas	May-June	959	27	23	17	9	14	6	4
	September-October	30	20	23	7	7	10	17	17
	Total	989	27	23	17	9	14	6	4

Table 7.—Total number of recaptures and number and percentage of transborder recaptures (in parentheses) from all brown shrimp and pink shrimp releases by statistical subareas of release.

	Brown shrimp recaptures		Pink shrimp recaptures	
Release subarea	Total	Transborder	Total	Transborder
18	120	0 (0.0)	1	0 (0.0)
19	3,060	5 (0.2)	3	0 (0.0
20	1,043	10 (1.0)	79	1 (1.3)
21	572	12 (2.1)	2,698	82 (3.0)
22	769	46 (6.0)	307	72 (23.5)
23	1,859	2 (0.1)	359	2 (0.6)
24	673	1 (0.1)	252	0 (0.0)
25	730	0 (0.0)	72	0 (0.0)

Australian continental shelf (Ruello, 1975). Bottom currents in statistical subareas 18-21 are generally southerly in spring and fall and variable to northerly in summer (Armstrong, 1980; Smith, 1980; Lewis, 1982; McGrail, 1983). The only published measurements off Tamaulipas indicate southerly bottom currents in summer in waters >100 m deep (Vazquez de la Cerda, 1975). Thus, adult shrimp marked in spring and fall may drift south with the currents, while shrimp tagged in summer would have to swim actively against the northerly currents, at least in Texas waters, to have a southerly dispersal.

The results of these shrimp mark-recapture experiments bear upon the present U.S. shrimp fishery management plan and any future U.S.-Mexico agreements to exploit the fisheries. Peak emigration of brown shrimp from the Laguna Madre of Tamaulipas (statistical subarea 23) occurs in mid-to-late May with a subsequent acceleration in offshore catches in June (Castro[1]). Peaks in brown shrimp emigration from Texas estuaries typically occur in late May-early June in statistical subareas 20 and 21 and later in statistical subareas 18 and 19 (Benefield and Baker, 1980; Matthews, 1982). The shrimp fishery management plan mandates a 45- to 60-day closed season beginning about 1 June each year. During the ensuing 3 months, the present study indicates that the degree of success in achieving the shrimp management plan's objective (increasing yield) may be influenced by the tendency of brown shrimp and pink shrimp to move south, particularly in the border area. All four inshore releases of tagged brown shrimp and pink shrimp between March and June in statistical subarea 21 resulted in greater southward movement than northward movement. Three offshore releases of brown shrimp and pink shrimp were conducted in each of subareas 21 and 22 during May through August. All brown shrimp recapture patterns described stronger southerly movement than northerly movement, while four of six pink shrimp releases had similar results. The Texas Closure delivered positive benefits to the fishery in its first four years (1981-84). Annual Gulf-wide yields attributed to the closure of the FCZ off Texas have ranged between 181 t in 1983 (1 percent increase in catch) and 1,905 t in 1981 (4 percent increase), with annual value increases ranging between $6.0 million (3 percent) in 1982 and $9.7 million (4 percent) in 1981 (Klima and Nichols[3]). Yields might be improved if the shrimp management plan considered the migratory behavior of brown shrimp and pink shrimp.

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