# MEXUS-Gulf Shrimp Research, 1978-84

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## Introduction

Mexico and the United States share shrimp and other marine resources in the Gulf of Mexico. As a result, in 1977 a cooperative research agreement was established between the Federal fisheries research organizations of the two countries—the Departmento de Pesca's Instituto Nacional de Pesca (INP) and the National Marine Fisheries Service's (NMFS) Southeast Fisheries Center—to develop joint marine research programs. At the first MEXUS-Gulf meeting in Campeche, Mex. (1977) a shrimp working group developed cooperative research plans to determine migration, growth and mortality rates of brown and pink shrimp, and to define the fishing characteristics of the U.S. and Mexican shrimp fleets. This report summarizes the first 7 years' results from this cooperative research and suggests the direction of the program for the next 2 years (1985-86).

## Background and the Fishery

Total shrimp production in the Gulf of Mexico in 1977 was about 148,000 metric tons (t), heads on, whereas in 1978 it decreased slightly to 139,000 t. The fishery originally consisted of both U.S. and Mexican vessels fishing Mexican waters and primarily U.S. boats fishing U.S. waters. Since 1979, however, U.S. vessels have not been allowed in Mexican waters.

The distribution and relative abundance of white shrimp, *Penaeus setiferus*; brown shrimp, *P. aztecus*; and pink shrimp, *P. duorarum*, have been described by Osborn et al. (1969) and are depicted in Figures 1, 2, and 3, respectively. The brown shrimp population is distributed throughout the northern and western Gulf of Mexico, with the center of abundance off Texas. White and pink shrimp are also distributed throughout the northern half of the Gulf, with the center of white shrimp abundance off Louisiana and that of pink shrimp off southern Florida, with highest concentrations around the Dry Tortugas and Campeche areas. There appear to be two separate stocks of pink shrimp, one on the Campeche Bank off Mexico and the other on the Tortugas and Sanibel grounds off south Florida. White shrimp are believed to have a continuous distribution throughout the northern half of the Gulf and south into Mexico.

Lindner and Anderson (1956) described the results of tagging studies which clearly indicated white shrimp moved across the U.S. -Mexico border. The species composition in the Tampico-Texas fishery is believed to be predominantly brown shrimp. Exact percentages are not available because all shrimp, regardless of species, landed are are recorded as brown shrimp by both the United States and Mexico. Further,

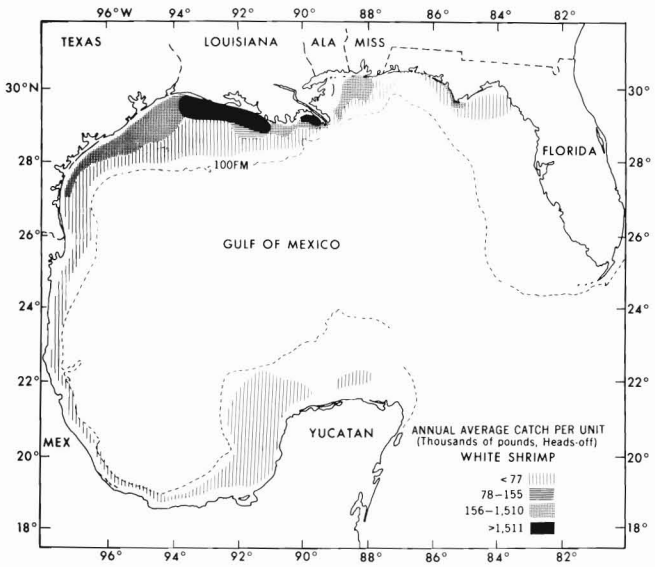


Figure 1.—Distribution of catch per unit (thousands of pounds) of white shrimp in the Gulf of Mexico.

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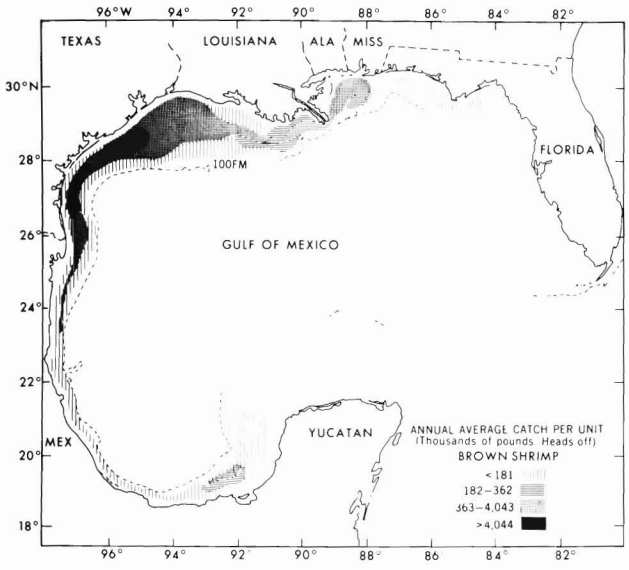


Figure 2.—Distribution of catch per unit (thousands of pounds) of brown shrimp in the Gulf of Mexico.

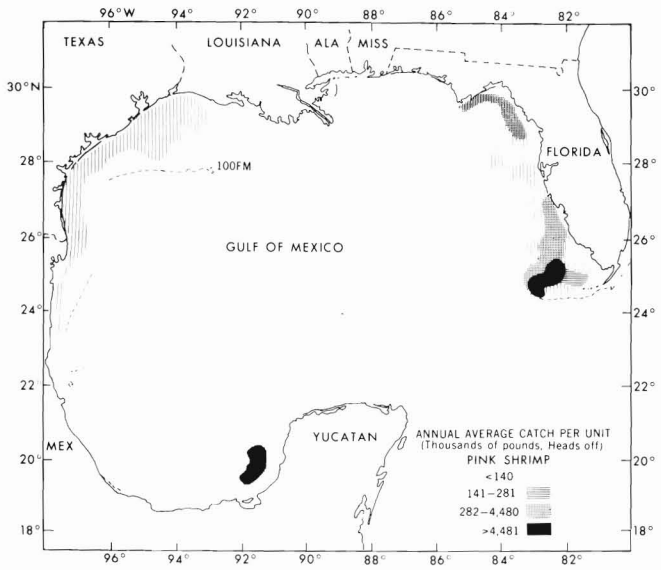


Figure 3.—Distribution of catch per unit (thousands of pounds) of pink shrimp in the Gulf of Mexico.

information concerning transboundary movement of the brown and pink shrimp stocks is also unknown and formulated the basis for a major study by the MEXUS-Gulf shrimp working group.

## Methods

### Shrimp Tagging

Shrimp stock assessment has been based largely on information obtained from tagging studies. Shrimp probably were first tagged in the Gulf of Mexico during the mid-1930's (Lindner and Anderson, 1956) with Petersen disc tags. Since that time, many investigators have used an assortment of tags and techniques to obtain information on growth, mortality, and movement. Neal (1969) reviewed the marks and marking procedures used up to that time.

Petersen disc tags were not completely suitable for these studies and as early as 1955, Menzel (1955) successfully marked white shrimp by injecting them with a solution of fast green biological stain. Costello (1959) and Costello and Allen (1962) perfected the use of biological stains for penaeid shrimp marking and evaluated the effectiveness of these stains and injection techniques. The stain injection technique was later used in the Gulf area by Klima (1964, 1974), Allen and Costello (1966), and Knight and Berry (1967), but was severely limited because only groups of shrimp and not individuals could be identified.

The next stage in the evolution of tags was the development of a ribbon tag by Marullo et al. (1976), which has been modified slightly for the cooperative tagging studies. The tag is now tapered at the end attached to the needle so that it is easily inserted between the muscular tissue of the shrimp. An Aureomycin[1] mixture is routinely used prior to tag insertion to retard infection and secondary bacterial growth. Tags 4 mils thick are used to tag juvenile shrimp (50-100 mm TL) and a thicker 6-mil tag is employed for larger shrimp.

### MEXUS-Gulf Tagging

Cooperative shrimp tagging efforts were conducted both inshore and offshore U.S. and Mexico waters from 1978 to 1981. Tagging procedures and methods have been described by Neal (1969), Emiliani (1971), and Baxter and Hollaway (1981). In the offshore studies, shrimp were caught by the FRS *Oregon II* or the *Marcep II*, with tows limited to 15 minutes to lessen stress on the shrimp. The animals were maintained in 500 L flow-through tanks fitted with aluminum baffles to reduce the effects of vessel roll. All shrimp were tagged with serially numbered ribbon tags.

Tagged animals were placed in an expendable canister (Emiliani, 1971) and released overboard while the vessel was underway. Within about 10 minutes after dropping to the bottom, the canister opened, allowing shrimp to escape. This presumably reduced mortality by predation at the release site and was a standard technique for this study.

### Shrimp Recovery and Awards

To increase the return of captured shrimp, a fishing contest was established in 1977. Fishing contests were held in both the United States and Mexico every 45 days during major recovery periods, with winners for each contest awarded first ($500), second ($200), third

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

($100), and fourth ($50) prizes (Fig. 4). This awards system was used until the September 1979 contest, when the number of winners in each contest was increased. Awards of $500 (one), $100 (one) and $50 (six) were given in the September 1979 and all subsequent drawings. Winning numbers were preselected by computer at the time of release by a priority system. If the first priority tag selected was not recovered, the second priority tag was selected and so on until four winners were identified. Tagged shrimp were returned to port agents located in the major ports. These agents collected catch and fishery effort statistics, handled the recovery of tagged shrimp, and had a major responsibility for obtaining and verifying pertinent information on area and date of recapture.

## Data Analysis

Growth in length of brown and pink shrimp during the April-August period was estimated from 1978-81 mark-capture data. These data included tail length (the distance from the first body segment to the posterior end of the telson) when released and recaptured, the dates of release and recapture, and the sex of each individual. Data entries with the same release and recapture data do not reflect growth and therefore were not included.

Parrack's (1979) methods were used to estimate the growth functions which he expressed in terms of the change in the age rather than absolute age. He noted that recaptured individuals were of some unknown age on the date marked and on the date recaptured so that the change in age is equivalent to the time at large. Parrack rearranged the von Bertalanffy equation from:

$$S_a = S_\infty (1 - be^{-ka}) \quad \text{to}$$

$$S_r = S_\infty - (S_\infty - S_m)e^{-K(\Delta a)}$$

where:

$S_a$ = size at age $a$,
$S_r$ = size at recapture,
$S$ = asymptotic size,
$b$ = an equation constant related to the size at birth, and
$S_m$ = size when marked.

We also used Parrack's technique to estimate the equation parameter $S$ by utilizing the Marquardt algorithm to minimize the residual sum of squares.

We calculated the growth function for sexes combined to provide a description of population growth rather than estimating growth for each sex. The ratio of males to females throughout the recovery period did not appear to change from 1:1; therefore, we concluded that the growth function was adequate to describe growth of sexes combined.

## Commercial Catch Data

Commercial catch statistics were collected by the INP in Mexico and the NMFS Southeast Fisheries Center in the United States. The catch statistics were reported by statistical subareas (Fig. 5) and were used to determine general population trends. NMFS commercial


Figure 4.—Poster advertising shrimp incentive award system.

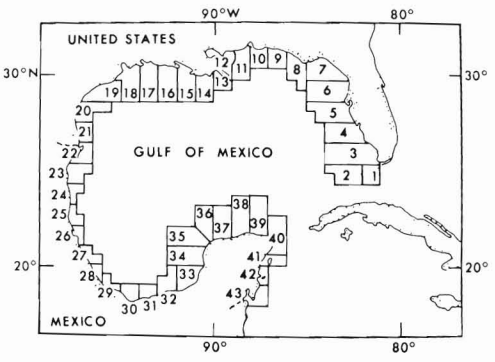


Figure 5.—NMFS grid system used to record shrimp statistics.

**Table 1.—Release (Rel.) and recapture (Rec.) summary for 1978 shrimp tagging studies (number of species released not recorded by species).**

| | Brown | | | Pink | | | White | | | Spp. unknown | | | Totals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Release area time | Rel. | Rec. | % | Rel. | Rec. | % | Rel. | Rec. | % | Rel. | Rec. | % | Rel. | Rec. | % |
| Texas | | | | | | | | | | | | | | | |
| Inshore | | | | | | | | | | | | | | | |
| Port Mansfield, May | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3,873 | 1 | 0 | 3,873 | 3 | 0.98 |
| Rockport, June/July | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 38,307 | 0 | 0 | 38,307 | 4 | 0.01 |
| Offshore | | | | | | | | | | | | | | | |
| Subarea 20, Aug./Sept. | 0 | 327 | 0 | 0 | 7 | 0 | 0 | 1 | 0 | 4,330 | 14 | 0 | 4,330 | 349 | 8.06 |
| Mexico | | | | | | | | | | | | | | | |
| Offshore | | | | | | | | | | | | | | | |
| Subareas 22-24, Sept./Oct. | 0 | 1,874 | 0 | 0 | 30 | 0 | 0 | 0 | 0 | 9,024 | 4 | 0 | 9,024 | 1,908 | 21.14 |
| Combined releases | 0 | 2,207 | 0 | 0 | 37 | 0 | 0 | 1 | 0 | 55,534 | 19 | 0 | 55,534 | 2,264 | 4.08 |

**Table 2.—Release and recapture summary for 1979 shrimp tagging studies (number of species released not recorded in all species).**

| | Brown | | | Pink | | | White | | | Spp. unknown | | | Totals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Release area time | Rel. | Rec. | % | Rel. | Rec. | % | Rel. | Rec. | % | Rel. | Rec. | % | Rel. | Rec. | % |
| Texas | | | | | | | | | | | | | | | |
| Inshore | | | | | | | | | | | | | | | |
| Port Isabel, April-June | 15,768 | 84 | 0.53 | 2,786 | 123 | 4.41 | 0 | 0 | 0 | 24 | 17 | 0.09 | 18,578 | 224 | 1.21 |
| Rockport, June/July | 9,598 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 9,606 | 0 | 0 |
| Port O'Connor, Sept./Oct. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 179 | 0 | 10,103 | 5 | 0 | 10,103 | 186 | 1.84 |
| San Luis Pass, Sept.-Nov. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 46 | 0 | 10,120 | 7 | 0 | 10,120 | 53 | 0.52 |
| Offshore | | | | | | | | | | | | | | | |
| Subareas 20-21, May/Sept./Oct. | 5,791 | 792 | 13.68 | 8,879 | 1,845 | 20.78 | 1,841 | 241 | 13.09 | 198 | 310 | 1.86 | 16,709 | 3,188 | 19.08 |
| Subarea 19, Sept.-Nov. | 0 | 1,189 | 0 | 0 | 0 | 0 | 0 | 689 | 0 | 28,021 | 75 | 0 | 28,021 | 1,955 | 6.78 |
| Mexico | | | | | | | | | | | | | | | |
| Inshore | | | | | | | | | | | | | | | |
| Laguna Madre, April-June | 10,083 | 31 | 0.31 | 384 | 2 | 0.52 | 208 | 11 | 5.29 | 4 | 0 | 0 | 10,679 | 44 | 0.41 |
| Offshore | | | | | | | | | | | | | | | |
| Subareas 22-24, May/Sept. | 1,493 | 230 | 15.41 | 2,022 | 345 | 17.06 | 1 | 110 | 0 | 10 | 51 | 1.45 | 3,526 | 627 | 17.78 |
| Subarea 24, June | 5,094 | 794 | 15.59 | 525 | 85 | 16.19 | 0 | 0 | 0 | 0 | 27 | 0 | 5,619 | 906 | 16.12 |
| Combined releases | 47,827 | 3,122 | 6.52 | 14,596 | 2,402 | 16.46 | 2,050 | 1,167 | 56.93 | 48,488 | 492 | 0 | 112,961 | 7,183 | 6.35 |

**Table 3.—Release and recapture summary for 1980 shrimp tagging studies.**

| | Brown | | | Pink | | | White | | | Spp. unknown | | | Totals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Release area time | Rel. | Rec. | % | Rel. | Rec. | % | Rel. | Rec. | % | Rel. | Rec. | % | Rel. | Rec. | % |
| Texas | | | | | | | | | | | | | | | |
| Inshore | | | | | | | | | | | | | | | |
| Port Isabel, Mar./April | 2,912 | 230 | 7.90 | 9,448 | 1,296 | 13.72 | 0 | 0 | 0 | 3 | 7 | 0.06 | 12,363 | 1,533 | 12.40 |
| Port O'Connor, May/July | 10,218 | 8 | 0.08 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 10,218 | 1 | 0.10 |
| San Luis Pass, June/July | 11,350 | 1 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11,350 | 1 | 0.01 |
| East Galv. Bay, Sept./Oct. | 0 | 2 | 0 | 0 | 0 | 0 | 5,141 | 355 | 6.94 | 0 | 0 | 0 | 5,141 | 359 | 6.98 |
| Offshore | | | | | | | | | | | | | | | |
| Subarea 20, June/July | 6,375 | 296 | 4.64 | 250 | 21 | 8.40 | 0 | 0 | 0 | 11 | 0 | 0 | 6,636 | 317 | 4.78 |
| Subarea 20, May | 721 | 128 | 17.79 | 3,271 | 906 | 27.70 | 0 | 1 | 0 | 11 | 0 | 0 | 4,003 | 1,035 | 25.86 |
| Subarea 19, June/July | 22,222 | 1,698 | 7.64 | 0 | 9 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 22,222 | 1,711 | 7.70 |
| Subarea 18, Oct. | 0 | 2 | 0 | 0 | 1 | 0 | 8,713 | 723 | 8.30 | 0 | 1 | 0 | 8,713 | 727 | 8.34 |
| Mexico | | | | | | | | | | | | | | | |
| Inshore | | | | | | | | | | | | | | | |
| Laguna Madre, Mar./Apr./June | 4,362 | 31 | 0.71 | 2,374 | 13 | 0.55 | 29 | 1 | 3.45 | 4 | 0 | 0 | 6,769 | 45 | 0.66 |
| Offshore | | | | | | | | | | | | | | | |
| Subareas 22-23-24, May | 4,983 | 1,053 | 21.13 | 3,895 | 529 | 13.58 | 0 | 0 | 0 | 21 | 0 | 0 | 8,899 | 1,582 | 17.78 |
| Combined releases | 63,143 | 3,449 | 5.46 | 19,238 | 2,775 | 14.42 | 13,883 | 1,088 | 7.84 | 50 | 8 | 0.01 | 96,314 | 7,320 | 7.60 |

catch statistics were also used to determine the proportion of pink shrimp in Texas commercial catches in the summer months.

## Results and Discussion

### Mark-Recapture

A total of 448,976 white, brown, and pink shrimp were released in U.S. and Mexican waters from 1978 to 1981, of which 28,505 were recaptured from 1978-81 (6.3 percent). Specific informa-

Table 4.—Release and recapture summary for 1981 shrimp tagging studies.

| Release area time | Brown | | | Pink | | | White | | | Spp. unknown | | | Totals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Rel. | Rec. | % | Rel. | Rec. | % | Rel. | Rec. | % | Rel. | Rec. | % | Rel. | Rec. | % |
| Texas | | | | | | | | | | | | | | | |
| Inshore | | | | | | | | | | | | | | | |
| Port O'Connor, Oct. | 0 | 0 | 0 | 0 | 0 | 0 | 10,027 | 174 | 1.74 | 0 | 0 | 0 | 10,027 | 174 | 1.74 |
| East Galv. Bay, May/June/Aug.-Oct. | 15,375 | 691 | 4.51 | 0 | 0 | 0 | 20,272 | 809 | 3.99 | 0 | 0 | 0 | 35,647 | 1,502 | 4.21 |
| Offshore | | | | | | | | | | | | | | | |
| Subarea 19, June-Oct. | 40,474 | 5,394 | 13.33 | 0 | 0 | 0 | 14,306 | 421 | 2.94 | 0 | 1 | 0 | 54,780 | 5,816 | 10.62 |
| Subarea 18, May/June/Oct./Nov. | 35,074 | 219 | 0.62 | 0 | 0 | 0 | 34,784 | 2,636 | 7.58 | 0 | 0 | 0 | 69,858 | 2,855 | 4.09 |
| Subarea 19, July | 4,189 | 1,152 | 27.50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4,189 | 1,152 | 27.50 |
| Mexico | | | | | | | | | | | | | | | |
| Offshore | | | | | | | | | | | | | | | |
| Subarea 34, March | 0 | 0 | 0 | 9,656 | 239 | 2.48 | 10 | 0 | 0 | 0 | 0 | 0 | 9,666 | 239 | 2.47 |
| Combined releases | 95,112 | 7,458 | 7.84 | 9,656 | 239 | 2.48 | 79,399 | 4,040 | 5.08 | 0 | 1 | 0 | 184,167 | 11,738 | 6.37 |

tion on release area and time and numbers recaptured are provided in Tables 1-4. Most shrimp releases from inshore sites resulted in poor recoveries of less than 1 percent. The only notable exception was in 1980 at Port Isabel, Tex., when more than 12 percent of the shrimp released in March-April were recovered. We believe the reason for poor recovery rates for inshore sites is that techniques are not yet developed to tag large quantities of live shrimp properly during the periods when temperatures are notably high (i.e., >30°C) and water is clear which may increase mortality of tagged shrimp due to predation by major inshore predators (Howe and Hoyt, 1982).

Comparative tagging studies conducted in coastal Louisiana waters in the summer showed recovery rates ranging from 5.7 percent to 20.5 percent (Hollaway and Baxter, 1981; Baxter and Hollaway, 1981). The turbid waters in Louisiana probably prevented predation on tagged shrimp by major inshore predators. The combination of clear coastal Texas waters and high temperatures may have resulted in poor survival of the tagged shrimp. Further, inshore areas are probably not exposed to intensive fishing immediately following the release; therefore, the opportunity for recovery is slight and depends on shrimp migration to offshore waters where intensive fishereis are located. The water temperature at Port Isabel in March-April, when an inshore study was conducted, was well below 25°C and the shrimp appeared to be in good condition. In all other inshore studies, water temperatures were >25°C and shrimp condition was poor to fair.

Offshore recovery rates ranged from 2.5 percent in March 1980 on the Campeche Banks to 26 percent in the offshore fishery (statistical subarea 20) in May 1980. The low 2.5 percent recovery was probably due to poor detection of the tags and poor return of recaptured tagged shrimp to the proper authorities. This was the first mark-recapture study conducted on the Campeche Banks and, as such, the fishermen probably were not aware of the tags even though publicity of the tagging program had been distributed to the Campeche fleet. The next lowest recovery rate (4.2 percent) occurred from the October-November 1981 release in statistical subarea 18, probably due to low fishing pressure exerted in the area. Overall, recovery rates from the offshore fisheries reflected the fishing pressure exerted on the marked population. The offshore tagging studies conducted in 1978, 1979, and 1980 in the Tampico fishery (subareas 22-24) yielded consistently high recovery rates of 16-21 percent. This indicated a fairly consistent high rate of exploitation. On the other hand, the offshore tagging studies conducted off Texas yielded variable fishing intensity in time and space.

## Shrimp Movement

### *Transboundary*

Cody and Avent (1980) reported on the 1978-79 tagging studies conducted in Texas and described generalized movements of the shrimp stocks. We do not attempt to repeat their analyses but concentrate on the aspect of transboundary migration of brown and pink shrimp stocks.

A total of 108 brown and 160 pink shrimp were recaptured which had migrated either from the United States to Mexico or from Mexico to the United States. Movement of tagged brown shrimp from Mexico to the United States centered in statistical subarea 21. However, several of these shrimp migrated northward up the coast, one as far as long. 94°W and into waters deeper than 20 fm (Fig. 6). Most of the brown shrimp which moved from U.S. waters into Mexican waters were recovered immediately south of the border; however, one shrimp was recovered almost off Tampico and four were recovered south of lat. 24°N (Fig. 7).

Pink shrimp which moved across the

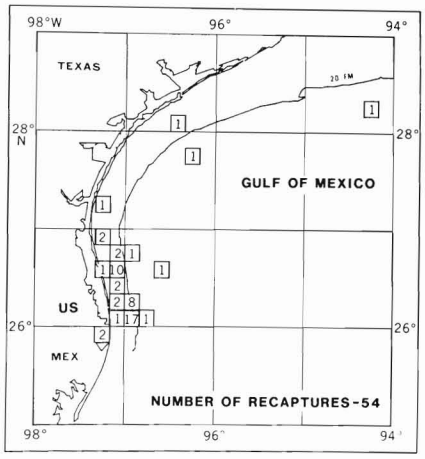


Figure 6.—Distribution of brown shrimp transboundary travelers, Mexico to Texas (number in grids 10 × 10 minutes).

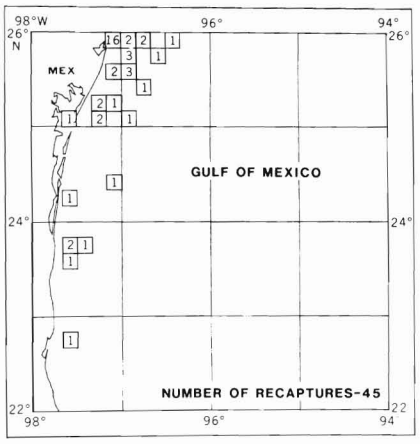


Figure 7.—Distribution of white shrimp transboundary travelers, Texas to Mexico (number in grids 10 × 10 minutes).

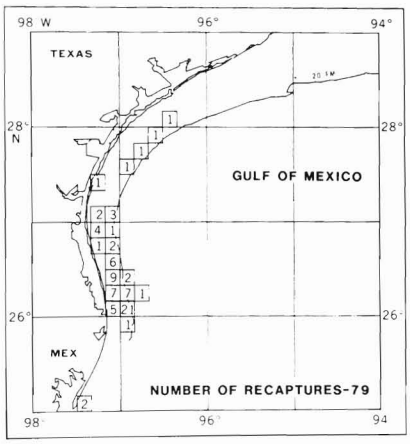


Figure 8.—Distribution of pink shrimp transboundary travelers, Mexico to Texas (number in grids 10 × 10 minutes).

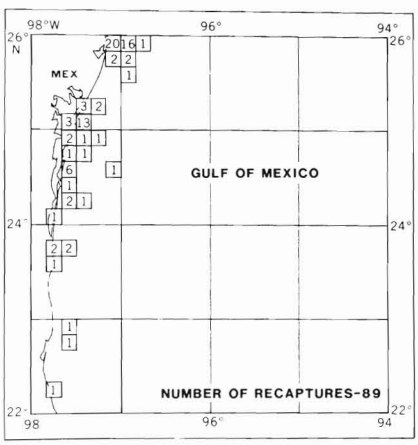


Figure 9.—Distribution of pink shimp transboundary travelers, Texas to Mexico (number in grids 10 × 10 minutes).

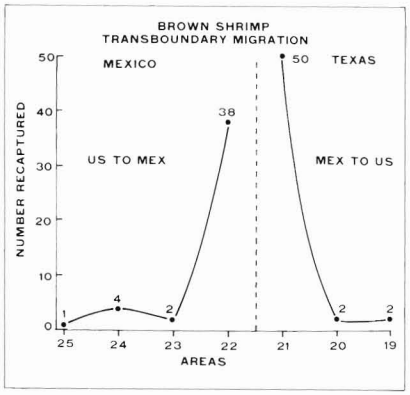


Figure 10.—Distribution of brown shrimp transboundary travelers by statistical subareas.

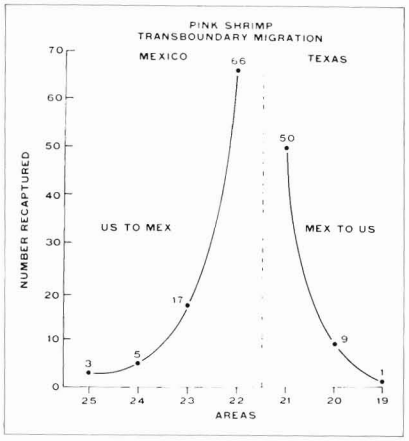


Figure 11.—Distribution of pink shrimp transboundary travelers by statistical subareas.

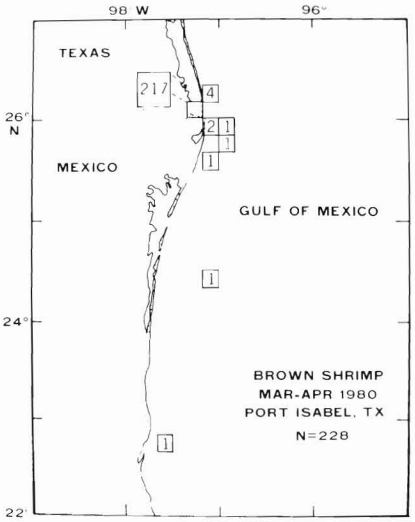


Figure 12.—Distribution of brown shrimp recoveries from Port Isabel, Texas shrimp tagging study, March-April 1980 (Grids are 10 × 10 minute intervals).

U.S. border from Mexico were clustered immediately north of the border, yet many of them migrated northward to the Aransas Pass area (Fig. 8). Pink shrimp migrating south were generally clustered around the border, but a large concentration was found south of lat. 25°N and an appreciable number moved south of lat. 24°N. Three were recovered just off Tampico (Fig. 9).

The longest distance traveled was 249 n.mi. (461 km) in 113 days by a brown shrimp released in August 1978. It had migrated from the U.S. statistical subarea 19 to statistical subarea 24 and had doubled its size. Eleven brown shrimp migrated over 200 n.mi. (370 km). Most recoveries of brown and pink shrimp were made in statistical subareas 21 and 22 (Fig. 10, 11) The longest time at large before recapture was 446 days for a pink shrimp which was released in Mexico and migrated only 27 n.mi. (50 km) northward across the U.S. border into statistical subarea 21. Forty-three shrimp were at large 100 days or longer. Most of the transborder migrants were released in offshore waters, but of 1,533 brown and pink shrimp recaptured from the Port Isabel tagging study (March-April 1980), 42 were recaptured in Mexico. Seven recaptured brown shrimp left the U.S. estuary and moved across the border, one as far as lat. 23°N (subarea 24, Fig. 12). None of the recaptured brown shrimp moved north. Pink shrimp migrated offshore to the north and south, with a large number being caught in the U.S. Laguna Madre

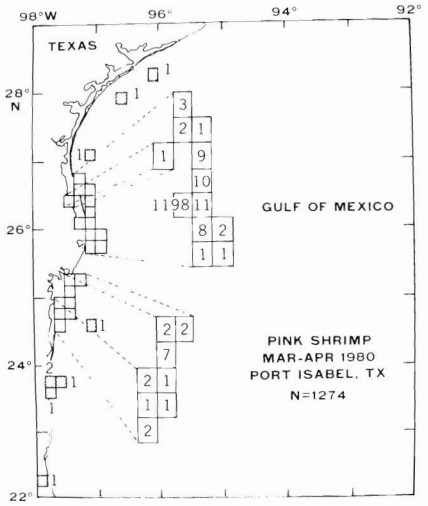


Figure 13.—Distribution of pink shrimp recoveries from Port Isabel, Texas shrimp tagging study, March-April 1980 (grids are 10 × 10 minute intervals).

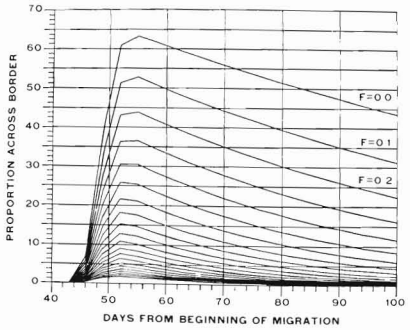


Figure 16.—Simulation of northward migration from Pass Jesus Maria, Mexico with F = 0.0-2.0 in increments of 0.1.

(Fig. 13). The farthest pink shrimp movement to the north was a recovery in statistical subarea 19 (1 shrimp), while 4 were recovered in statistical subarea 24. A total of 35 pink shrimp were recovered south of the U.S. border. Therefore, the Laguna Madre shrimp stock which utilized this nursery migrated offshore and into Mexican waters. Apparently brown shrimp move only southward, while pink shrimp move both north and south. The majority of the pink shrimp appeared to have moved south.

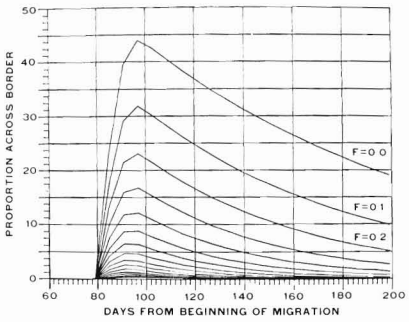


Figure 14.—Simulation of southward migration from Aransas Pass, Texas with F = 0.0-2.0 in increments of 0.1.

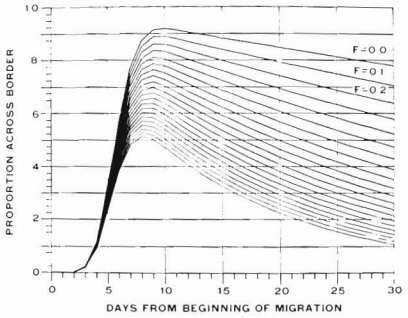


Figure 15.—Simulation of southward migration from Brazos Santiago Pass, Texas with F = 0.0-2.0 in increments of 0.1.


Figure 17.—Distribution of pink shrimp recoveries on the Campeche Bank (number in grids 10 × 10 minutes).

Brunenmeister's[2] model determined the proportion of the shrimp population which could cross the U.S.-Mexico border with assumed rates of fishing mortality. These data are presented in Figures 14, 15, and 16. She predicted that the shrimp population in Aransas Pass would take about 80 days to cross the border and, at fishing mortality rates of about 0.1, about 30 percent of the population would have crossed the border in 92 days (Fig. 15). For shrimp moving out of the Port Isabel area, assuming a fishing mortality rate of 0.1, about 90 percent of the population would move into Mexican waters in less than 10 days (Fig. 16). Northward migration from

[2]Brunenmeister, S. University of Maryland, Solomons, MD 20688; Personal commun.

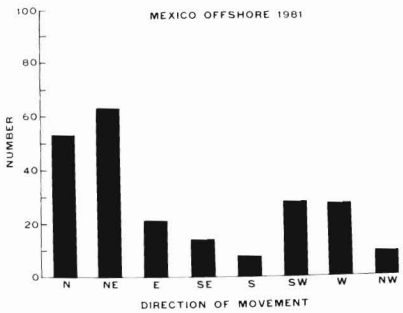


Figure 18.—Distribution of pink shrimp on the Campeche Bank by direction of movement.

Jesus Maria, Mex., would take half the population about 50 days to move across the U.S. border, assuming a fishing mortality rate of 0.1 (Fig. 16).

Mark-recapture data clearly show that the brown and pink shrimp stocks in the south Texas and north Tamaulipas, Mex., areas are migratory and cross the U.S.-Mexico border. One could assume that these stocks are continuous and therefore should be treated as one management entity.

*Campeche*

In March 1981, over 9,600 pink shrimp were released on the Campeche Banks with a recovery of only 238 (2.5 percent). The distribution of the recoveries is shown in Figure 17. Direction of movement was generally north-northeast with some movement to the south-south-west quadrants (Fig. 18). This was the first large-scale mark-recapture

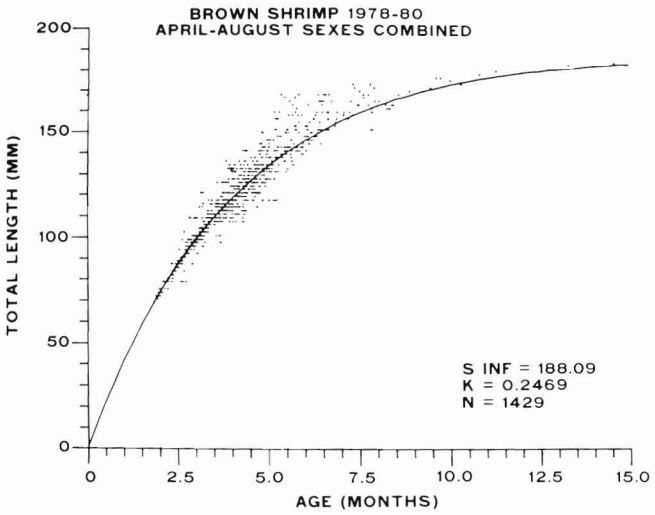


Figure 19.—Growth and length of brown shrimp, sexes combined, 1978-80.

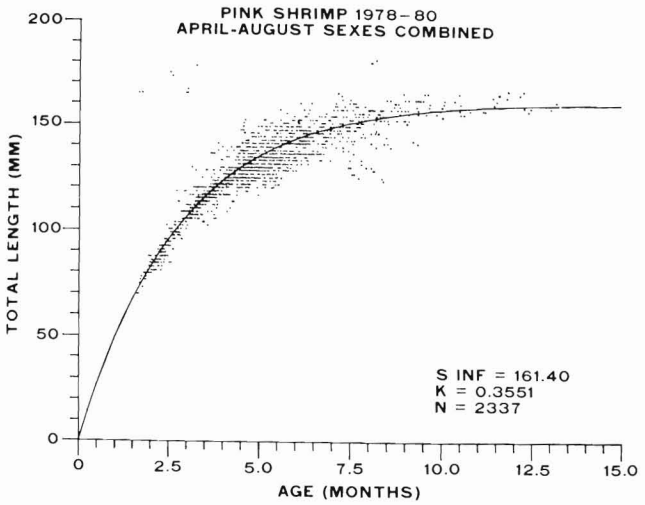


Figure 20.—Growth and length of pink shrimp, sexes combined, 1978-80.

study conducted on the Campeche Banks and basically indicated that the shrimp move in two directions. Insufficient information was available to determine growth rates of the pink shrimp stocks.

## Growth

Growth and length for both brown and pink shrimp were estimated from 1978-80 combined data. The brown shrimp growth for the April-August period indicated an asymptotic length of about 188 mm (Fig. 19), whereas pink shrimp had an asymptotic length of about 161 mm (Fig. 20). These values compare favorably with an asymptotic length of 169 mm and 193 mm for males and females, respectively, developed by Parrack (1979) for brown shrimp.

## Tampico Fishery

In 1979, U.S. and Mexican scientists agreed to a set of fishery statistics for the shrimp fishery in the Tampico area which included pounds landed and fishing effort (Table 5). These data formed a basis for evaluating the annual production for 23 years. Catches from 1974 to 1978 have been affected by limited U.S. fishing effort off Tampico. U.S. production decreased from 2,978 t in 1974 to 455 t in 1978. No fishing has been permitted since 1979. Total fishing effort decreased 66 percent from 1974 to 1978, resulting in a 50 percent decrease in the total catch (Fig. 21, 22). After detailed examination of these data, U.S. and Mexican scientists determined that conventional models, i.e., surplus production models, were not appropriate. Therefore, they felt the long-term average catch best represented a conservative approach to determine the available annual sustainable yield. Klima and Fuentes[3] concluded that the fishery

**Table 5.—Summary of shrimp catch in metric tons, effort in days fished, catch per unit effort (CPUE) in tons/days (24 hours) of the United States and Mexico for the Tampico fishery.**

| | Catch (t) | | | Effort | | | CPUE |
|---|---|---|---|---|---|---|---|
| Year | U.S | Mexico | Total | U.S | Mexico | Total | U.S.-Mexico |
| 1956 | 4,464 | 601 | 5,065 | 16,125 | 2,171 | 18,296 | 0.277 |
| 1957 | 6,456 | 631 | 7,087 | 19,292 | 1,886 | 21,178 | 0.335 |
| 1958 | 5,079 | 482 | 5,561 | 31,292 | 2,970 | 34,262 | 0.162 |
| 1959 | 5,099 | 503 | 5,602 | 28,083 | 2,770 | 30,853 | 0.182 |
| 1960 | 1,664 | 426 | 2,090 | 14,667 | 3,755 | 18,422 | 0.113 |
| 1961 | 3,665 | 561 | 4,226 | 18,833 | 2,883 | 21,716 | 0.195 |
| 1962 | 2,757 | 621 | 3,378 | 17,625 | 3,970 | 21,595 | 0.156 |
| 1963 | 1,897 | 754 | 2,651 | 14,167 | 5,631 | 19,798 | 0.134 |
| 1964 | 2,356 | 646 | 3,002 | 14,417 | 3,953 | 18,370 | 0.163 |
| 1965 | 2,297 | 979 | 3,276 | 14,583 | 6,215 | 20,798 | 0.158 |
| 1966 | 2,777 | 1,128 | 3,905 | 19,917 | 8,090 | 28,007 | 0.139 |
| 1967 | 2,333 | 1,581 | 3,914 | 15,250 | 14,776 | 25,584 | 0.107 |
| 1968 | 3,683 | 1,803 | 5,486 | 21,750 | 10,648 | 32,398 | 0.169 |
| 1969 | 1,875 | 1,537 | 3,412 | 19,208 | 15,745 | 34,953 | 0.098 |
| 1970 | 2,370 | 2,705 | 5,075 | 20,167 | 23,018 | 43,185 | 0.118 |
| 1971 | 2,946 | 2,238 | 5,184 | 20,458 | 15,541 | 35,999 | 0.144 |
| 1972 | 3,919 | 3,172 | 7,091 | 20,250 | 16,390 | 36,640 | 0.194 |
| 1973 | 2,593 | 2,922 | 5,515 | 21,083 | 21,758 | 44,841 | 0.123 |
| 1974 | 2,978 | 3,110 | 6,088 | 13,166 | 19,768 | 32,934 | 0.185 |
| 1975 | 2,561 | 2,899 | 5,460 | 10,184 | 19,372 | 29,556 | 0.185 |
| 1976 | 538 | 3,450 | 3,988 | 3,830 | 20,374 | 24,204 | 0.165 |
| 1977 | 708 | 3,547 | 4,255 | 3,954 | 20,196 | 23,602 | 0.180 |
| 1978 | 455 | 2,561 | 3,016 | 2,988 | 18,417 | 21,094 | 0.143 |

[3]Klima, E. F., and D. Fuentes. 1979. Joint analysis of U.S.-Mexican Tampico shrimp fishery. NMFS Southeast Fisheries Center, Galveston Laboratory, 4700 Avenue U, Galveston, TX 77551. Unpubl. rep., 16 p.

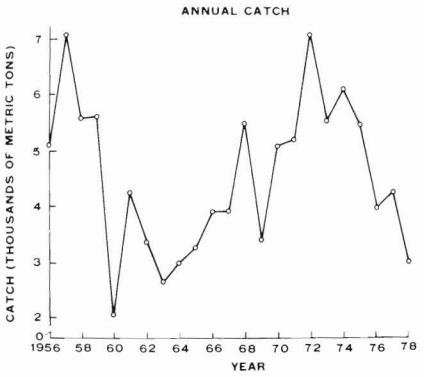


Figure 21.—Annual landings of shrimp in the Tampico fishery by the U.S. and Mexican fishing fleets, 1956-78.

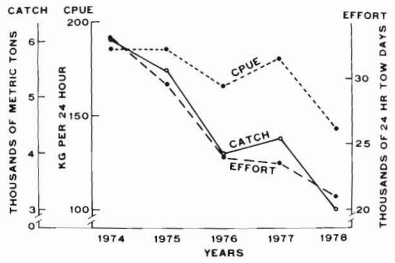


Figure 22.—Landings, effort and CPUE for the Tampico fishery, 1974-78.

could produce between 4,500 and 5,000 t per year, heads on, but that annual production fluctuates greatly, probably because of changes in fishing effort and recruitment. In times of good or exceptional recruitment (i.e., as in 1957, 1972, and 1974), the fishery should take advantage of this recruitment and optimize resource utilization, while fishing effort should be restricted during times of poor recruitment.

## Activities in 1983-85

For the 1983-85 period, the Shrimp Working Group agreed to pursue the following activities: 1) Determine the species composition of commercial shrimp catches in the western Gulf of Mexico, 2) compare juvenile shrimp abundance in vegetated areas of Galveston Bay with those in the Mexican Laguna Madre, 3) conduct cooperative coastal surveys of shrimp and finfish to determine sizes, species compositions, and abundances in summer, and 4) determine trophic relationships of selected coastal fishes in offshore waters.

A report[4] on the misclassification of pink shrimp as brown shrimp in Texas commercial catches during summer months was completed. Pink shrimp were detected in about half the sampling trips and constituted 7-8 percent of the overall catches. Maximum proportions of pink shrimp were 41 percent of those landed in Galveston and 22 percent of those landed in Port Isabel in July. Proportions declined rapidly in later months.

A simple drop sampler and sampling methodology were developed for equivalent comparison of juvenile shrimp densities in vegetated and nonvegetated habitats of shallow water marshes and lagoons. The fundamental elements of the design were acquisition of real as opposed to relative densities of fishing species, and paired sampling of habitats (Zimmerman et al., 1984).

Quantitative drop sampler comparisons of *Spartina alterniflora*, *S. patens*, and *Halodule wrightii* nursery habitats have been acquired in Texas and Louisiana. Brown shrimp, white shrimp, blue crab, *Callinectes sapidus*; and some fishes are more abundant in vegetated areas than elsewhere (Zimmerman and Minello, 1984a; Zimmerman et al., 1984). Brown shrimp are equally abundant in adjacent *Spartina* and *Halodule* stands. Brown shrimp grew faster in vegetated areas than over bare substrates, while white shrimp grew at equal rates (Zimmerman and Minello, 1984b). Carbon isotope analyses indicated that brown and white shrimp feed on different types of food (Zimmerman and Minello, 1984b). Laboratory results indicated white shrimp were herbivorous while brown shrimp needed a mixed plant-animal diet.

Mexican officials participated in a demonstration of this estuarine sampling methodology at the SEFC Galveston Laboratory in June 1983. Discussion was initiated concerning joint research to develop comparable data on shrimp densities for Mexican lagoons and Texas estuaries.

The U.S. coast from Louisiana to the Texas-Mexico border has been surveyed annually in June and July as part of the Southeast Area Monitoring and Assessment Program (SEAMAP) since 1982. Fish samples were collected for maturation and trophic studies, and shrimp samples were collected for size distribution, species composition, sex and abundance analyses.

Trophic relationships of eight fish species were determined from samples collected along the Texas coast in June and July[5]. The species and their primary foods were: *Synodus foetens* - fish; *Ancylopsetta quadrocellata* - fish and crabs; *Prionotus tribulus* - crabs; *Centropristis philadelphica* and *Menticirrhus americanus* - crabs and shrimp; *P. rubio* and *Diplectrum bivittatum* - shrimp; *Lutjanus campechanus* - fish, crabs, and shrimp. Only three *Penaeus* were found in 4,300 stomachs examined. Only *Diplectrum* had entered a major spawning cycle at this time.

## Future Direction

Since the implementation of the Shrimp Working Group in 1977, we have obtained good data on growth rates of both pink and brown shrimp, as well as preliminary information on the transboundary nature of the shrimp stocks. The 1977-81 large-scale tagging study called for releases of tagged shrimp dispersed in time and space. We now must estimate the flux of the brown shrimp stock across the Texas-Mexico border during the period peak migration, i.e., late May through mid-July. In the previous study, only 298 tagged shrimp were released off south Texas (statistical area 21) during this critical time period, with 14 recaptures from that release group (Sheridan et al., 1987).

The NMFS and INP will conduct cooperative mark-recapture experiments in south Texas and northern Mexico beginning in May 1985. Mexico will tag

[4]Slater, B. 1983. Report on misclassification of commercial pink shrimp as brown shrimp, July 16, 1982 to September 30, 1982. NMFS Southeast Fisheries Center, 75 Virginia Beach Dr., Miami, FL 33149. Unpubl. Rep., 33 p.

[5]Sheridan, P. F. NMFS Southeast Fisheries Center, Galveston Laboratory, 4700 Avenue U, Galveston, TX 77551; personal commun.

and release up to 20,000 shrimp off Tamaulipas, with assistance from NMFS personnel. Mexico will also collect tag returns and catch-effort statistics from the fishery. The NMFS will tag and release up to 100,000 shrimp at two Texas passes, Brazos-Santiago and Aransas; and offshore in subareas 20 and 21. Tag returns will be processed and catch-effort statistics will be collected and exchanged with Mexico.

The exchange of commercial catch statistics will continue between both countries. An effort will be made to obtain samples to simultaneously determine species composition of each country's commercial shrimp catch. U.S. and Mexican scientists will exchange collections of postlarval brown, white, and pink shrimps from Texas and Tamaulipas estuaries to verify identifications.

A major component of future studies will determine the importance of estuarine habitats, comparing those in Texas with the Mexican Laguna Madre. Specifically, we will examine the density of shrimp associated with the algae and marsh grasses, how density varies, and what factors may affect recruitment of juvenile shrimp to the estuaries and finally to the offshore fisheries.

## Summary

A cooperative marine science research program was initiated between Mexico's Instituto Nacional de Pesca and the U.S. National Marine Fisheries Service's Southeast Fisheries Center in 1977. As part of that program, a shrimp working group was established to investigate the transboundary aspects of shrimp stocks of the Gulf of Mexico. This group's activities for the past 7 years are reported. Information was obtained on the transboundary nature of brown shrimp, *Penaeus aztecus*, and pink shrimp, *P. duorarum*, stocks in the Texas-Tampico area. Specific information on the migratory patterns across the U.S.-Mexico border are described. Growth of brown and pink shrimp for the period April-August are also described and information is presented on the status of the Tampico fishery. Proposed plans for future research include a continued exchange of catch and effort statistics, studies to determine the importance and recruitment patterns of estuarine systems, both in the United States and Mexico, and a tagging experiment during peak brown shrimp emigration, May-July 1985.

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