shrimp. This was confirmed by recoveries in the fishery of shrimp tagged and stained in the estuaries. It is thus established that these estuaries, now included in the Everglades National Park, are the principal and perhaps the sole source of shrimp available to the commercial vessels fishing the Tortugas. The juvenile stage of the life history of the pink shrimp which is passed in these estuaries is not well understood. To sample shrimp moving in one of the principal canals leading out to Florida Bay, a large net of small mesh was used in this study. Data on shrimp and other animals caught in this net, which blocks the 60-foot wide canal, are recorded. Simultaneous environmental data are also collected. As was expected, the mean numbers of juvenile shrimp caught on flooding tides are low compared to the mean numbers caught on ebbing tides. There is a good inverse relationship between the tide height and the numbers of shrimp caught in the net. No shrimp were caught during full daylight. Estimates of numbers of shrimp moving seaward from this canal may provide index values which will permit prediction of the numbers of shrimp available subsequently on the fishing grounds.

---

# Mark-Recapture Experiments With Brown and White Shrimp in the Northern Gulf of Mexico[1]

EDWARD F. KLIMA
*Bureau of Commercial Fisheries*
*Galveston, Texas*

**Abstract**

Mark-recapture experiments with commercial shrimps were conducted in the northern Gulf of Mexico during 1962. Results provided information on movements of subadult and adult brown and white shrimp off Texas and Louisiana, on fishing and natural mortality in a stock of brown shrimp fished off Texas, and on growth as well as mortality in the white shrimp resource supporting a major fishery along the Louisiana coast.

## INTRODUCTION

A MAJOR GOAL of the Bureau of Commercial Fisheries shrimp research program is to determine optimum levels of exploitation for shrimp stocks in the Gulf of Mexico. To make these determinations, it is first necessary to measure average rates of growth and mortality for each of the stocks concerned. One direct means of estimating these parameters for a particular stock is through the release and subsequent recovery of marked specimens in the area it inhabits, and over which operates the fishery it supports.

Accordingly, a series of mark-recapture experiments was conducted in sections of the northern Gulf of Mexico during 1962 to obtain information on movements, growth, and mortality of brown shrimp, *Penaeus aztecus,* and white shrimp, *P. setiferus.* This paper discusses methods of marking shrimp as well as results obtained from the mark-recapture experiments, and deals only by implication with the general problem of establishing optimum levels of exploitation.

[1]Contribution No. 186, Bureau of Commercial Fisheries Biological Laboratory, Galveston, Texas.

## METHODS

### *Description of Marking Agents*

Investigations reported by Lindner and Anderson (1956) and by Costello (1959) demonstrated that Petersen disc tags and biological stains can be used to follow the movements and describe the growth of shrimp in their natural environment. Tags, however, appear to be somewhat less desirable marking agents than stains because of the possibility that they interfere with normal growth and movement. Costello (In press) found that certain biological stains do not fade, are therefore easily detectable over long periods of time, and do not seem to affect either the short- or the long-term survival of shrimp. The stain-injection method, because it evidently does not adversely affect marked shrimp, has greatly broadened the scope of research on shrimp population dynamics—particularly in the area of growth and mortality measurement.

Since the inception of the stain-injection technique, Trypan blue and fast green, classified as primary dyes because they concentrate in the gills and are thereby easily seen, have proved to be the only reliable stains for marking shrimp. To increase the technique's overall versatility, a series of laboratory experiments was recently conducted to find additional materials that might serve to provide the shrimp with a supplementary or secondary mark (Klima, MS). These experiments yielded five fluorescent pigments which provided suitable secondary marks when used in conjunction with one of the two biological (primary) stains. Such pigments, which remain at the site of injection and are not obvious to the casual observer, retain full color and are easily detected in the laboratory under ultraviolet light for at least 9 months after application. Their use increases from 2 to 12 the total number of colors, or combinations thereof, that can now be used to mark shrimp. There is no evidence that, when properly injected, the combination of a biological stain and a fluorescent pigment has any short- or long-term effect on survival.

### *Mark-Release Operations*

In areas where experiments were to take place, shrimp to be marked were caught with commercial shrimp trawls towed for less than 15 minutes to minimize injury. As soon as the trawls were emptied, the shrimp were placed in large tanks of circulating sea water to be sorted and marked.

Shrimp were marked with either fast green or Trypan blue stain alone, or in combination with a fluorescent pigment, following the methods described by Costello (In press) and Klima (MS), respectively. Aqueous solutions of 0.5% fast green or 0.25% Trypan blue provided the primary marks, while a 1.2% mixture of the fluorescent pigment blaze orange in petroleum jelly constituted the secondary mark. When double marks were applied, the shrimp were first injected with one of the biological stains and then immediately injected with the fluorescent pigment. Other shrimp were tagged with Petersen disc tags (5/16-inch diameter and 0.02-inch thickness) to acquire additional information on movements.

Estimation of growth rates from mark-recapture experiments requires that the release size of the experimental individuals be known. Since the identity of individual shrimp cannot be maintained when employing the stain-injection method of marking, shrimp to be stained were first sorted on the basis of uniform size into several narrowly defined length classes (±5mm total length). Each class was subsequently identified by means of a primary stain or a

combination of primary and secondary stains. In experiments where growth estimation was not an objective, shrimp were marked without being selected for uniformity of size.

After marking, the experimental shrimp were held from 12 to 24 hours before release. Just prior to release, all specimens in poor condition (i.e., overstained, injured, or disoriented) were discarded. All marked shrimp were liberated on the bottom in groups of 100 by means of a special release box. Underwater observations during earlier mark-recapture experiments on the Tortugas fishing grounds revealed that experimental shrimp so released immediately burrow into the substrate. Thus, predation during the process of liberation can, for most practical purposes, be assumed to have been nonexistent. Because of the care taken in their handling, the number of marked individuals liberated at the start of each experiment was considered to be a valid measure of the initial size of each experimental population.

In all experiments involving specimens marked with biological stains, the areas of release ranged in size from 30 to 210 square miles. It was therefore not possible, upon analyzing subsequent returns, to determine the exact distances moved by individual stained shrimp. To minimize this difficulty, the center of the release area was considered to be the specific site of release. This problem did not exist in the case of the tagged shrimp since the release position of every individual was known.

### *Recapture and Return of Marked Shrimp*

A reward of $2 was paid for the return of each marked shrimp accompanied by information regarding the date and the place where it was recaptured. All shrimp processing plants located in the study areas were provided with posters describing the program, and with bottles containing formalin in which recaptured shrimp could be held.

Estimates of the total fishing (recapture) effort expended in experimental areas were computed from *Gulf Coast Shrimp Data* published monthly by the Bureau of Commercial Fisheries, and from supplementary data collected by the Bureau's statistical agents. The average number of hours fished per vessel trip for either 14- or 30-day periods (depending on the experiment) was projected from data gathered through interviews with vessel crews.

## RESULTS

### *Brown Shrimp, April, 1962*

A total of 2,431 stained brown shrimp was released in a 100-square mile area southeast of Pass Cavallo, Texas, in water which ranged from 21 to 24 fathoms. Two groups of tagged shrimp, consisting of 976 and 716 individuals, respectively, were released—one on each side of the stained group—in statistical fishing areas 18 and 20 (Table 1, Fig. 1). Of the stained shrimp released, 153 (6%) were recovered through February, 1963, while 87 (5%) of the tagged shrimp were recovered through December, 1962.

Recoveries from the stained group were sufficient to estimate mortality rates for the period April-June, provided that certain assumptions could be satisfied. One of these was that the marked shrimp did not migrate out of the designated fishing area during this period.

MOVEMENTS: The pattern of recoveries from April through June indicated that the stained shrimp distributed themselves between the 16- and 30-fathom

TABLE 1

RELEASE AND RECOVERY INFORMATION ON MARK-RECAPTURE EXPERIMENTS WITH SHRIMP IN THE NORTHERN GULF OF MEXICO, 1962

| Species | | Release data | | | | Recapture data | |
|---|---|---|---|---|---|---|---|
| | Type of mark | Total length in mm. | Date | Area | Depth in fathoms | Number | Number | Percent |
| Brown | Fast green | 125-225 | 4/2-4/62 | SE Pass Cavallo, Tex., Stat. area 19 | 21-24 | 2,431 | 153 | 6.3 |
| Brown | Petersen disc tags | 115-220 | 4/6-7/62 | SE Port Aransas, Tex., Stat. area 20 | 20-27 | 716 | 69 | 9.6 |
| Brown | Petersen disc tags | 137-211 | 4/8/62 | SSE Freeport, Tex., Stat. area 18 | 21 | 976 | 18 | 1.8 |
| Brown | Fast green | 109-118 | 7/8-12/62 | S Grand Isle, La., | 13-16 | 1,554 | 437 | 28.1 |
| | Fast green and blaze orange | 124-133 | | Stat. area 13 | | 720 | 187 | 26.0 |
| Brown | Trypan blue | 90-154 | 7/17/62 | S Galveston, Tex., | 4-8 | 1,840 | 49 | 2.7 |
| | Trypan green and blaze orange | 98-107 | | Stat. area 18 | | 1,133 | 25 | 2.2 |
| White | Fast green | 147-156 | 9/23-26/62 | SW Vermillion Bay, | 3-5 | 1,071 | 65 | 6.1 |
| | Fast green and blaze orange | 147-156 | | La., Stat. area 16 | | 843 | 11 | 1.3 |
| White | Trypan green and blaze orange | 115-124 | 9/28-29/62 | Cameron, La., | 3-5 | 792 | 44 | 5.6 |
| | Trypan blue | 134-143 | | Stat. area 17 | | 1,499 | 158 | 10.5 |

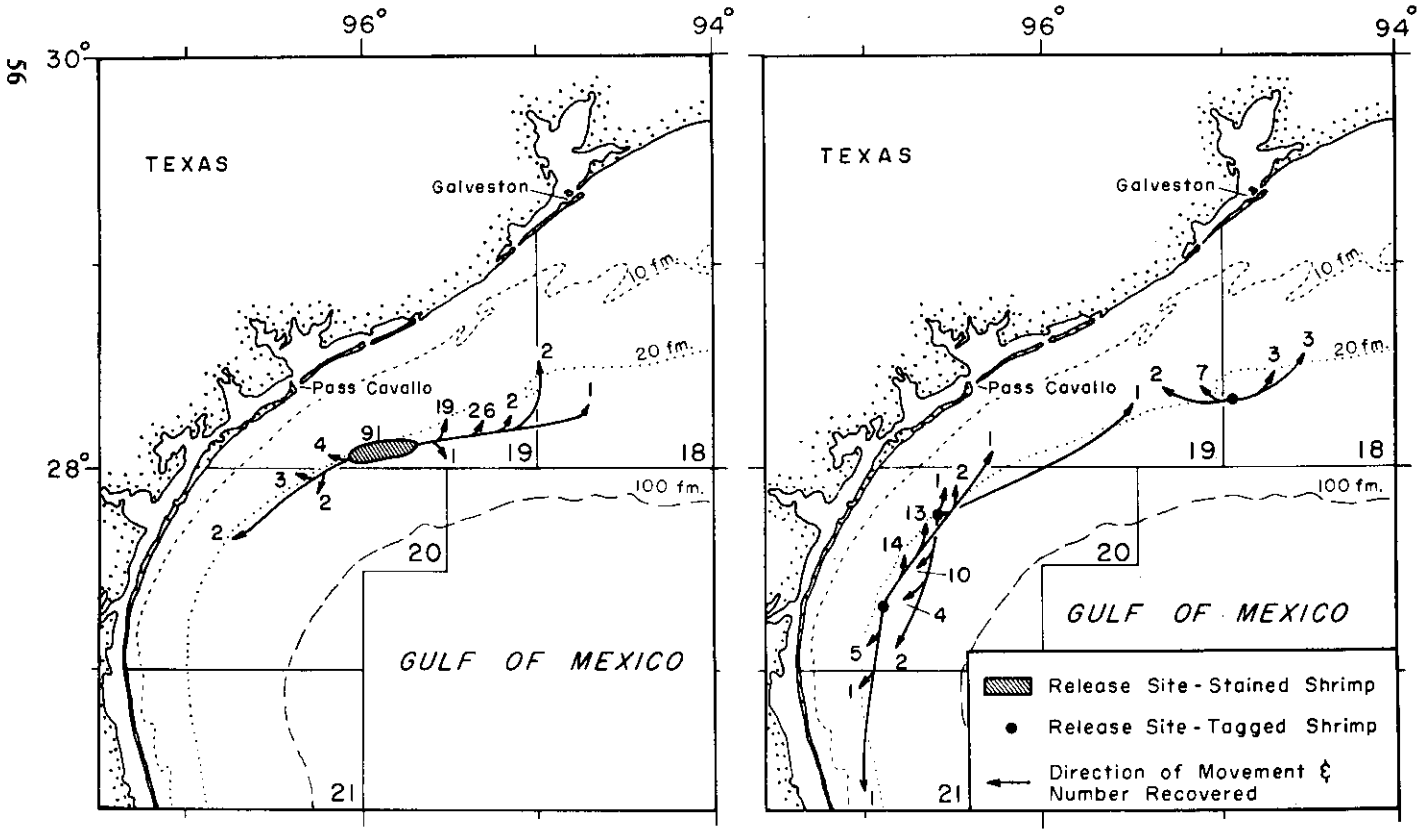


FIG. 1. Movements of marked brown shrimp recovered along the Texas Gulf coast from April, 1962, through February, 1963.

depth contours over approximately the same general area in which they were released. More than 99% of those recovered were caught within the 25-fathom contour, with none being taken beyond 30 fathoms (Table 2). Since less than 200 hours of fishing effort were expended at depths greater than 30 fathoms, it was not possible to determine whether significant offshore movement occurred during this period. The distribution of recoveries in the experiment's later stages (July-February) suggested little offshore movement, for few marked shrimp were recaptured at greater depths even though considerably more fishing effort was expended there. All told, these data indicate minimal offshore movement from April through June. In reference to movements inshore, more than 7,000 hours of commercial fishing effort expended at depths of less than 15 fathoms through June resulted in the recapture of only one shrimp, indicating that such movements were also minimal. The pattern of recoveries indicates that the depth distribution of tagged shrimp was similar to that of the stained group (Fig. 1).

TABLE 2

DEPTH DISTRIBUTION OF RECAPTURED (STAINED) BROWN SHRIMP AND CORRESPONDING TOTAL FISHING EFFORT (IN THOUSANDS OF HOURS) — TEXAS GULF COAST, APRIL, 1962

| Period | April - June | | July - February | |
|---|---|---|---|---|
| Depth in fathoms | Number recovered | Fishing effort | Number recovered | Fishing effort |
| 11-15 | 0 | 7.3 | 1 | 159.3 |
| 16-20 | 68 | 13.4 | 2 | 118.4 |
| 21-25 | 70 | 8.0 | 8 | 44.4 |
| 26-30 | 1 | 1.0 | 2 | 31.0 |
| 31 & over | 0 | 0.2 | 1 | 2.3 |

More than 90% of the marked recaptures were taken within 30 miles of their sites of release. The longest movement was about 70 miles. Examination of the average distance traveled revealed that the marked shrimp did not move greater distances with increased time at large. Several shrimp at liberty for more than 180 days had traveled an average of only 17 miles, whereas shrimp that were recaptured within 180 days had traveled a mean distance of 16 miles. What little movement occurred appeared to be parallel to the coast between the 16- and 30-fathom depth contours.

MORTALITY: The following formulae, as derived by Beverton and Holt (1957), were used to estimate mortality coefficients for the stained shrimp population during the period April through June:

$$F = \frac{\frac{n_1}{\gamma} \log_e\left(\frac{n_1}{n_2}\right)}{N_0 \left(1 - \frac{n_2}{n_1}\right)}$$

$$X = \frac{1}{\gamma}\left[\log_e\left(\frac{n_1}{n_2}\right)\right]\left[1 - \frac{n_1}{N_0\left(1 - \frac{n_2}{n_1}\right)}\right]$$

where F is the instantaneous mortality rate caused by fishing; X is the instantaneous rate of loss attributable to all other causes, including natural mortality, marking mortality, emigration, and failure of the fishermen to return recaptured marked shrimp; $n_1$ and $n_2$ are the calculated numbers of recoveries during the experiment's first and second time periods; $N_0$ is the number of marked shrimp released; and $\gamma$ is the length of a time period.

The value of X provides an estimate of natural mortality when losses due to other factors are negligible. In the present experiment, care exercised during staining and releasing operations insured that mortality due to marking and to predation during release was minimal. Evidence cited above indicates that losses of stained shrimp due to emigration from the study area were also probably unimportant. No estimate of losses caused by failure of fishermen to recover from or to report stained shrimp in their catches is available, but this type of error is believed to have had little influence on experimental results because of sustained efforts to maintain fisherman-interest in the recovery of marked shrimp. Accordingly, it seemed reasonable to assume that a constant proportion of stained shrimp caught during each interval of the experiment was reported. Even if the proportion of nonrecovered individuals constituted as much as 20% of the total number recaptured in each interval, the resulting estimate of F would have differed by only four units in the second decimal place from the value obtained and employed below.

The 80% confidence intervals presented in Table 3 indicate no significant change in fishing effort during the study period, thereby making it unnecessary to adjust the number of recoveries from each time interval to a uniform effort. Recovery information from three 30-day time intervals, covering the period from April 3 to July 2, 1962, proved sufficient to calculate estimates F and X. When converted to monthly rates of reduction, these estimates suggested that 21% of those shrimp present at the beginning of a month died before the end of that month as a result of commercial fishing activities, whereas 60% died during the same period from natural causes.

***Brown Shrimp, July, 1962***

Stain-marked brown shrimp were released near Grand Isle, Louisiana, and off Galveston, Texas, in July (Table 1). Although the experiments were undertaken to obtain information on movements, growth, and mortality, these objectives were only partially achieved. In both instances, more than 90% of the stained shrimp recovered were caught within 10 days of release. The unusually short recovery periods are attributed to the small size of the areas in which the marked shrimp were released and to movements of the commercial fleet from these areas as the experiments progressed.

TABLE 3

RECOVERIES OF STAINED BROWN SHRIMP AND RELATED FISHING EFFORT (IN THOUSANDS OF HOURS) DURING THE APRIL, 1962, EXPERIMENT OFF THE TEXAS GULF COAST

| Time period (30-day intervals) | Number recovered | Fishing effort |
|---|---|---|
| 1 | 99 | 7.9 ± 1.3 |
| 2 | 30 | 7.3 ± 0.6 |
| 3 | 10 | 7.2 ± 0.1 |

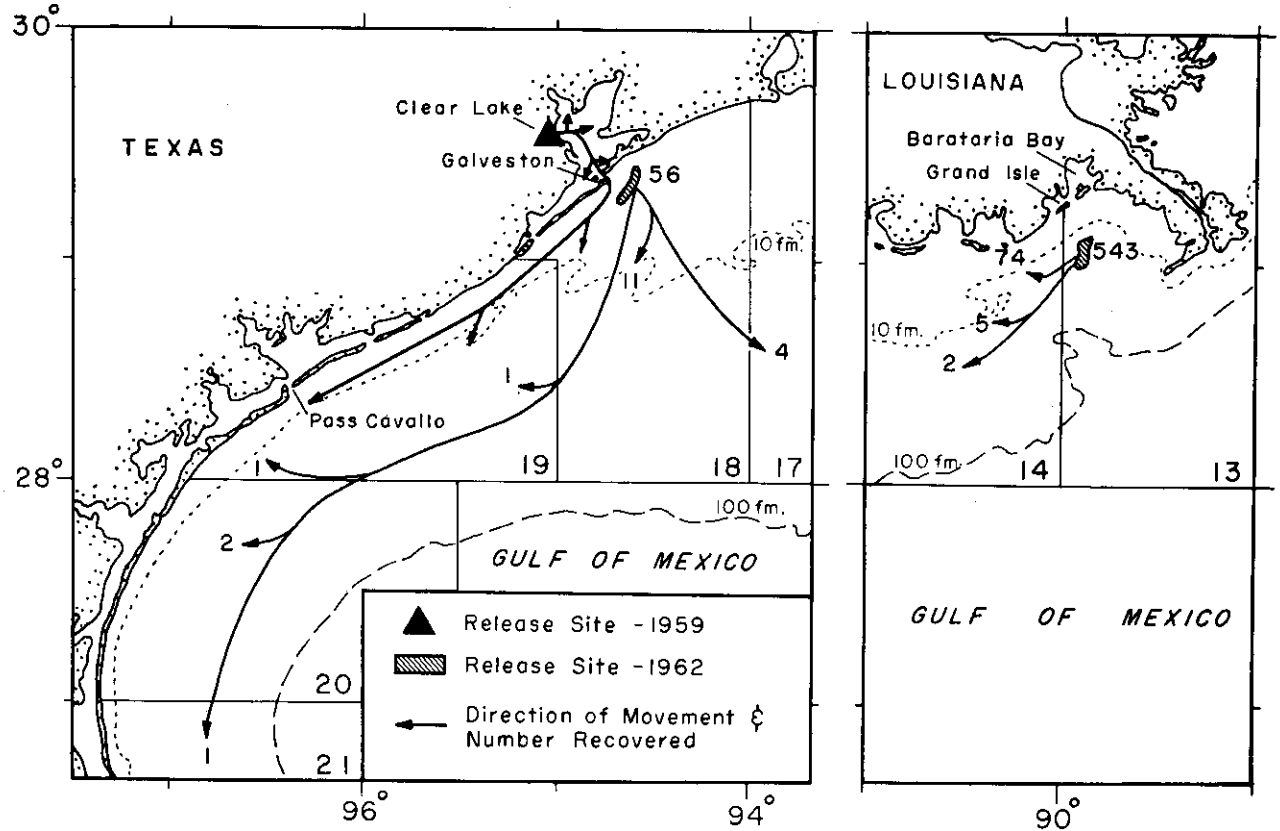


FIG. 2. Movements of marked brown shrimp recaptured off the Texas-Louisiana coast.

MOVEMENTS: More than 98% of the shrimp recovered from the Louisiana experiment were recaptured within 30 miles of the release area, the remaining 2% having moved less than 60 miles (Fig. 2). Movements were seaward and generally to the west.

Because of a combination of low fishing intensity and a state law which prohibited the landing of brown shrimp smaller than 30-count heads-on, less than 3% of the 2,973 marked shrimp released off Galveston were eventually recovered. Most individuals in this group were smaller than the legal size permitted in Texas, and almost 80% of those recovered were caught by boats which landed their shrimp at Louisiana ports where no size law was in effect. Over 88% of the marked shrimp recovered from the Texas experiment were caught within 30 miles of the area of release, while 6% had traveled more than 60 miles in a southwesterly direction (Fig. 2). The greatest distance recorded was 195 miles. An earlier experiment initiated in Galveston Bay resulted in four marked brown shrimp being recaptured in the Gulf between Galveston and Pass Cavallo (Inglis, 1959). Results of both the experiments conducted in Texas waters indicate that small brown shrimp which leave Galveston Bay are recruited to the fished population along most of the Texas coast.

The shrimp released at the beginning of the Louisiana and Texas experiments were marked with either a biological stain or with a combination of a biological stain and a fluorescent pigment. Since this was the first time the combination mark had ever been used, it was of interest to compare recovery rates of shrimp bearing the "single" mark with those bearing the "double" mark. The marked groups compared herein were subjected to similar conditions and otherwise treated in like manner except for the type of mark applied. A comparison of the number of returns of shrimp with the two types of marks yielded Chi-square values of 0.529 and 1.233 with 1 degree of freedom for the Texas and Louisiana experiments, respectively. These values are not significant at the 5% level, and the hypothesis that there was no difference in the recoverability of the two types of marks is accepted.

***White Shrimp, September, 1962***

A total of 4,205 marked white shrimp was released in statistical areas 16 and 17 off the western Louisiana coast in depths of 3 to 5 fathoms (Table 1, Fig. 3). To obtain information on growth, the marked shrimp were released in three lots, each consisting of individuals selected on the basis of uniform length and grouped accordingly (Table 1). Overall recoveries comprised 292 (9%) of the shrimp released in the Cameron area and 76 (4%) of those liberated off Vermilion Bay.

MOVEMENTS: Ninety-seven percent of all recoveries were made between September and December. Considering only recoveries during this period, there appeared to be limited movement of the marked shrimp between the two release areas. More than 88% of the recoveries were taken within 30 miles of each area, with the greatest distance traveled approaching 80 miles. Three shrimp were recovered in February and March (1963) east of the release areas off Eugene Island, Louisiana, one having traveled 70 miles and the others more than 120 miles.

MORTALITY: When originally conceived, this experiment was designed to provide estimates of mortality rates for each of the three groups of marked white shrimp released. Complexities of the fishery and other shortcomings in the data

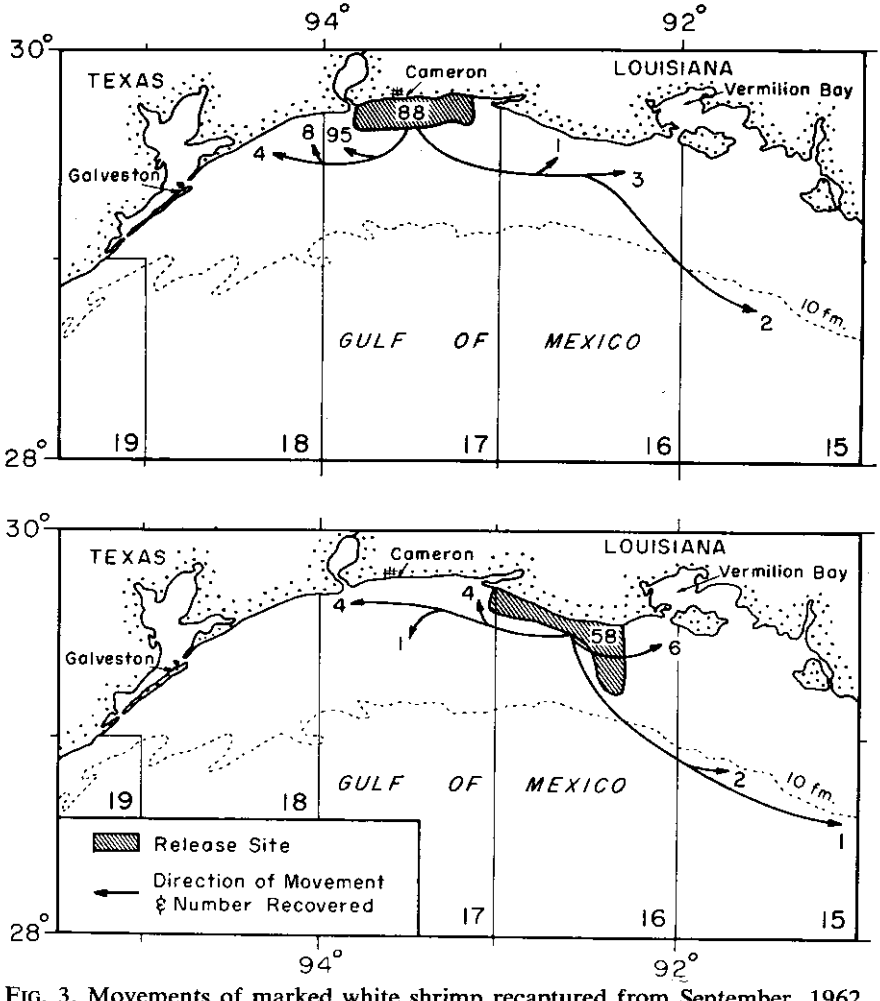


FIG. 3. Movements of marked white shrimp recaptured from September, 1962, through March, 1963, off the Louisiana Gulf coast.

made it possible, however, to derive for only one group an estimate of its total mortality rate which could not be separated into the components of major interest. Although this value has limited practical use, it does indicate the general level of mortality to be expected in an exploited group of white shrimp.

If losses of marked shrimp due either to the failure of fishermen to report recaptured individuals or to emigration from the study area are not constant throughout the recovery period, mortality estimates will be biased. But, because of the high degree of publicity associated with the study and the small amount of emigration suggested by the recovery patterns, it was concluded that the effects of such factors could be considered of minor importance in the present case. Adjustment of the number of recoveries to unit fishing effort from each

14-day interval was necessary, however, since expenditures of effort by the shrimp fleet in the study area were not uniform during the period of interest (Table 4). A regression line fitted to the natural logarithms of the corrected number of recoveries yielded an instantaneous total mortality rate of 0.92. Transformation of this value to a 14-day rate of decline gave an estimate of 60%.

TABLE 4

RECOVERIES OF STAINED WHITE SHRIMP ADJUSTED TO UNIT FISHING EFFORT (IN THOUSANDS OF HOURS)—LOUISIANA GULF COAST, SEPTEMBER - NOVEMBER, 1962

| Time periods (14-day intervals) | Number recovered | Fishing effort | Recoveries adjusted to unit fishing effort |
|---|---|---|---|
| 1 | 77 | 9.46 ± 1.5 | 75.7 |
| 2 | 34 | 10.72 ± 1.7 | 29.5 |
| 3 | 10 | 7.72 ± 1.8 | 12.0 |

GROWTH: Recovery data from the three size groups released in September, 1962, proved suitable for measuring the average growth rate of late subadult and adult white shrimp during the fall season (Table 5). Ideally, growth calculations should be made for each sex. In the present instance, however, the number of shrimp recovered during each time interval of the experiment was insufficient to permit this refinement. To obtain valid estimates from data which include both sexes, it is necessary that the sex ratios of recaptures remain constant throughout the experiment. A Chi-square test indicated that such was the case during the study being described ($X^2$ with 15 degrees of freedom = 21.4; $X^2_{.05}$ = 25.0).

TABLE 5

AVERAGE WEIGHTS (IN GRAMS) AT RECAPTURE OF WHITE SHRIMP (SEXES COMBINED) REPRESENTING THREE SIZE GROUPS—LOUISIANA GULF COAST, SEPTEMBER - NOVEMBER, 1962

| Group | A | | B | | C | |
|---|---|---|---|---|---|---|
| Time periods (7-day intervals) | Average weight | Number | Average weight | Number | Average weight | Number |
| 1 | 13.3 | 20 | 20.0 | 46 | 27.3 | 4 |
| 2 | 14.5 | 10 | 21.8 | 48 | 28.3 | 13 |
| 3 | 17.0 | 4 | 23.9 | 26 | 30.1 | 16 |
| 4 | 19.6 | 4 | 27.0 | 16 | 31.6 | 25 |
| 5 | 20.9 | 5 | 28.2 | 13 | 35.5 | 3 |
| 6 | | | | | 36.5 | 4 |
| 7 | | | | | | |
| 8 | | | | | 41.1 | 4 |

Recoveries from each of the three narrowly defined length classes were grouped into successive 7-day units, after which the von Bertalanffy growth-in-weight equation (Beverton and Holt, 1957) was used to describe their growth. Estimates of two of the parameters of the growth equation, $W_\infty$ and K, were obtained by fitting a line to a Walford plot of the resulting average

weights. The parameter $t_0$ was determined by conventional means, wherein the age at release of the smallest shrimp used in the experiment was estimated to have been 12 weeks. The equation describing the growth of adult white shrimp during the period from September to November was found to be:

$$w_t = 87 \text{ g } \left( 1 - e^{-0.12[t - (-0.57)]} \right)^3$$

Although this equation is based on data from a relatively brief period in the white shrimp's overall growth history, it imparts information of particular interest in studies of the species' dynamics because it describes growth during that portion of the life history (and season) when exploitation of the white shrimp is greatest.

Calculations based on the above equation indicate that white shrimp increase in size during the fall from 54-count, heads-off (120 mm) to 33-count (141 mm) in 4 weeks, and to 23-count (159 mm) in 8 weeks. A comparison of these results with growth measurements for female white shrimp reported by Lindner and Anderson (1956) reveals close agreement (Table 6). It should be pointed out, however, that these authors estimated a somewhat lower growth rate when they employed data wherein the sexes were combined.

## SUMMARY

Adult brown shrimp, *Penaeus aztecus,* marked with biological stains or Petersen disc tags, were released off the Texas coast in April, 1962. Recoveries from this experiment indicated that movement was parallel to the coast and confined to depths between 16 and 30 fathoms. Comparisons of the distance traveled over time revealed that most of the marked shrimp remained within 30 miles of the release site. The greatest distance traveled was about 70 miles. Analysis of the recovery data indicated that fishing mortality was 21% and mortality due to natural causes was 60% per month during the period from April through June.

TABLE 6

COMPARISON OF CALCULATED LENGTHS (MM) OF WHITE SHRIMP (SEXES COMBINED) FROM THE SEPTEMBER, 1962, MARK-RECAPTURE EXPERIMENT OFF LOUISIANA WITH THOSE OF FEMALES REPORTED FOR THE SAME AREA AND SEASON BY LINDNER AND ANDERSON (1956)

| Time in months | Total length from Lindner and Anderson | Total length from mark-recapture experiment, Sept., 1962 |
|---|---|---|
| 0 | 120 | 120 |
| 1 | 143 | 141 |
| 2 | 160 | 159 |
| 3 | 172 | 172 |

Small brown shrimp, marked with biological stains and fluorescent pigments, were released off Grand Isle, Louisiana, and Galveston, Texas, in July, 1962. Again, a large proportion of the recoveries were taken within 30 miles of the release areas. The longest distance traveled was 195 miles.

White shrimp, *P. setiferus,* representing several restricted size groups, were marked with biological stains and released in two adjacent areas off the

Louisiana coast in September, 1962. The distribution of recaptures indicated limited movement of the marked groups between the two areas and little or no offshore movement. Analysis of the recovery data revealed that during September-November total mortality was 60% per 14-day period. After fitting the von Bertalanffy growth function to the mean weights of the recaptured shrimp (sexes combined), it was estimated that, during the fall of the year, white shrimp in this area required 2 months to increase in size from 54-count, heads-off (120 mm) to about 23-count (159 mm).


## ACKNOWLEDGMENTS

For their assistance in the mark and release phases of the project, I wish to thank Mr. Charles Knight and the crews of the Bureau's exploratory vessels, the M/V SILVER BAY and the M/V GEORGE M. BOWERS. Special credit is also due Mr. Morrison Duet and other Fishery Reporting Specialists of the Branch of Statistics, as well as the shrimp processors and fishermen who aided in the project's recovery phases.


## LITERATURE CITED


BEVERTON, RAYMOND J. H. AND SYDNEY J. HOLT
1957. On the dynamics of exploited fish populations. Min. Agri. and Fish., Fish. Invest., *2* (19): 1-533.

COSTELLO, THOMAS J.
1959. Marking shrimp with biological stains. Proc. Gulf and Caribb. Fish. Inst., 11th Ann. Sess., 1958, p. 1-6.
In press. Field techniques for staining-recapture experiments with commercial shrimp. U. S. Fish and Wildl. Serv., Spec. Sci. Rept.—Fish.

INGLIS, ANTHONY
1959. Migration of brown shrimp. U. S. Fish and Wildl. Serv. Cir. 62, p. 35-37.

KLIMA, EDWARD F.
(MS) Evaluation of some biological stains, inks, and fluorescent pigments as marks for shrimp.

LINDNER, MILTON J. AND WILLIAM W. ANDERSON
1956. Growth, migrations, spawning and size distribution of shrimp, *Penaeus setiferus*. U. S. Fish and Wildl. Serv., Fish Bull., *106* (56): 553-645.


---

# The Shrimp Fishery of Alaska


GEORGE Y. HARRY, JR.
*U.S. Bureau of Commercial Fisheries*
*Biological Laboratory*
*Auke Bay, Alaska*



**Abstract**

Until 1958 the shrimp fishery of Alaska was confined to southeastern Alaska where from 1 to 2 million pounds of hand-picked shrimp were packed annually for more than 30 years. In 1958 the shrimp fishery expanded westward, with new plants in Seldovia, Kodiak, and Seward. Alaska has the potential for a much