PRELIMINARY INVESTIGATIONS OF MIGRATION AND MOVEMENT OF NORTH CAROLINA COMMERCIAL PENAEID SHRIMPS

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ABSTRACT

Pink or spotted *(Penaeus duorarum)*, brown *(P. aztecus)*, and white *(P. setiferus)* shrimp, marked with biological stains and fluorescent pigments, were released in nursery areas tributary to the Core Sound and Lower Cape Fear River estuaries in North Carolina to obtain information concerning population dynamics including movement and migration patterns. A combined total of 26,989 pink, brown, and white shrimp was marked and released from April to October, 1966. Of these, 1,671 or 6.2% were returned. The combined average interval between release and recapture was 17.5 days, and the average distance traveled was 0.5 miles per day. Data indicated that size distribution "levels of equilibrium" were reached in individual nursery areas, whereby the size frequency modes increased to characteristic levels and subsequently remained at these levels during the study of each species. With few exceptions, all "inside" movement was toward waters of higher salinity. A southward coastwise migration was evident throughout the periods of study and involved movement to St. Augustine, Florida.

INTRODUCTION

This paper deals with shrimp movement and migration information obtained during the first year (ending 31 January, 1967) of a three-year study by the Research and Development Section of the North Carolina Division of Commercial and Sports Fisheries. The study was accepted by the U. S. Bureau of Commercial Fisheries for federal financing as authorized by the Commercial Fisheries Research and Development Act of 1964 (P.L. 88-309) at the 75% level of cost sharing.

Objectives involved mark-recapture experiments with the State's three commercially important species of shrimp: pink or spotted *(Penaeus duorarum)*, brown *(P. aztecus)*, and white *(P. setiferus)*, to obtain an understanding of their population dynamics including movement and migration patterns. Shrimp were marked with injections of biological stains and fluorescent pigments and released in nursery areas tributary to Core Sound and the lower Cape Fear River.

No movement or migration patterns have previously been established for pink or brown shrimp on the Atlantic coast. White shrimp tagged and released along the Atlantic coast by Lindner and Anderson (1956) exhibited a southward coastwise migration pattern.

Commercial shrimping in North Carolina has contributed an average of $1,592,000 per year, or 20% of the total dockside value of fishery earnings since 1957. Management of this resource is the designated responsibility of the North Carolina Department of Conservation and Development through the Division of Commercial and Sports Fisheries and with the cooperation of the University of North Carolina Institute of Marine Sciences (formerly Institute of Fisheries Research). Past management practices, often resulting from the well-meaning conservation ideas of several and sometimes opposing factions, have consisted mainly of manipulation of dates and times of commercial fishing activities, and special license requirements and gear restrictions. Information gained during this study, and that anticipated as a result of its continuation, should supplement available information and improve our ability to manage this important fishery and the species upon which it depends.

METHODS AND PROCEDURES

Study Areas

Two major estuarine areas, as shown in Figure 1, were chosen for studies of the three shrimp species: Core Sound located near the center of the State, and the lower Cape Fear River located near the southern boundary of the State. Because geographic replication was desired within these major areas, smaller nursery units, tributary to each, were selected for marking and releasing shrimp. Jarrett Bay and North River provided the smaller nursery units within Core Sound, and pink and brown shrimp were marked and released in these areas. The Dutchman Creek-Elizabeth River and Cape Creek areas provided the smaller nursery units of the Cape Fear River estuary. White shrimp were marked and released in these tributary areas.

Jarrett Bay and North River are located some six and four miles,

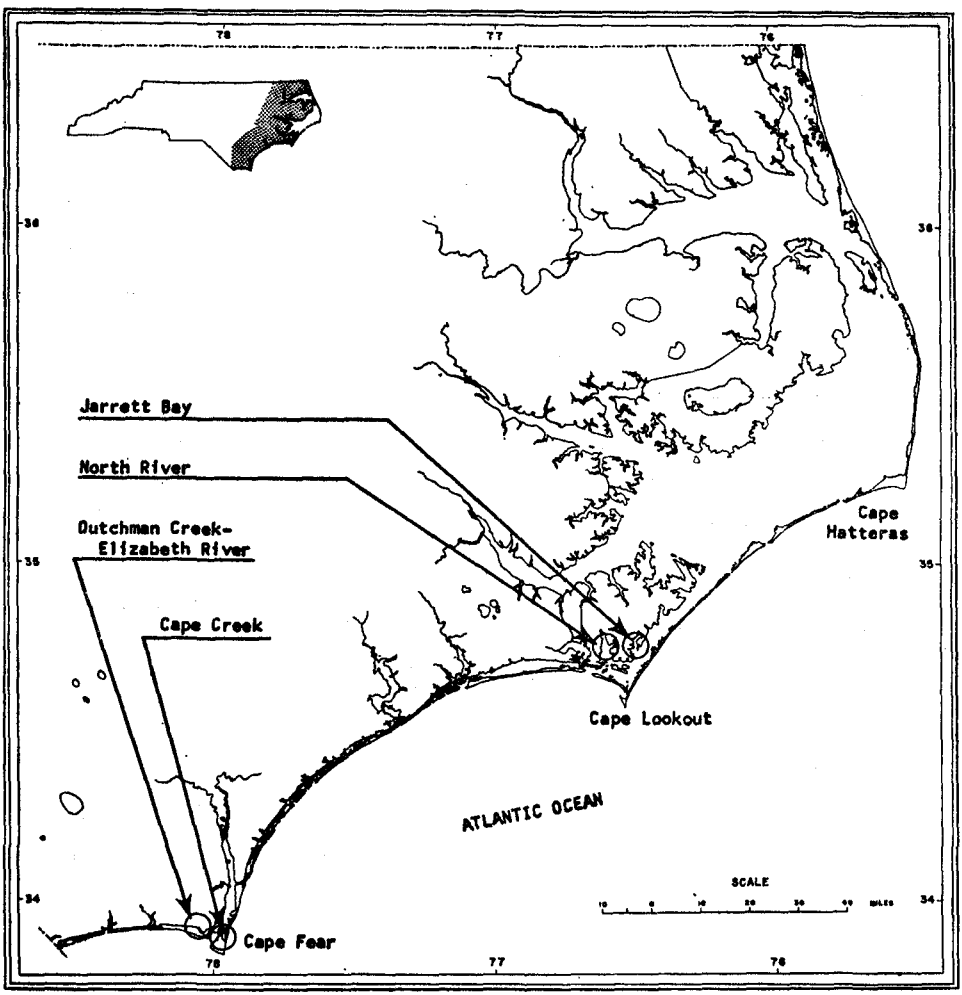


Figure 1.—The shrimp mark-release study areas in relation to coastal North Carolina.

respectively, from Beaufort Inlet, through which most of the water exchange between Core Sound and the Atlantic Ocean occurs. Both areas are relatively shallow with an average depth of approximately three feet at mean low water. Jarrett Bay is about two miles long and contains some 1,800 surface acres within which the mark-release area included approximately 400 acres in the lower half. North River is approximately three and one-half miles long and contains about 7,600 surface acres. The mark-release area was located approximately in the center of North River and contained some 900 acres. Tidal amplitude and currents are more pronounced nearer Beaufort Inlet which has a mean amplitude of two and one-half feet.

The Dutchman Creek-Elizabeth River and Cape Creek areas are located some two miles northwest and one mile east, respectively, from Cape Fear Inlet. Strong currents and a mean tidal amplitude of four and one-half feet characterize Cape Fear Inlet and both study areas. Although no records of current velocity were obtained for the purposes of this study, the 35-foot deep Wilmington harbor channel through the area probably carries the strongest tidal currents of any North Carolina area.

The Dutchman Creek-Elizabeth River area is comprised of an approximate 630-acre network of narrow tidal creeks and mud flats intersected by and including the Intracoastal Waterway (IWW). Two mark-release areas, approximately 30 acres in the lower half of Dutchman Creek north of the IWW and approximately 70 acres in the mid-Elizabeth River sector south of the IWW, were used in this more complex Dutchman Creek-Elizabeth River area.

The Cape Creek nursery area is about four miles long and contains some 280 surface acres. The mark-release area included about 90 acres in the lower one-third of the creek.

Collection and Handling of Shrimp

The nocturnal habits of pink and brown shrimp necessitated their collection at night. White shrimp were readily collected during the daylight hours. Collections were made with 25-foot, three-quarter-inch bar mesh shrimp trawls towed from 5 to 20 minutes. Towing time depended on availability of shrimp, amount of detritus, and water temperature. As water temperatures increased above 75°F, tows were limited to five minutes because an increased mortality was evident in the longer tows. Higher water temperatures, averaging above 80°F, were especially prevalent during the brown shrimp mark-release phase of the study (Tables 3 and 4).

The trawl tail bag (cod end) was emptied directly into a holding box supplied with circulating seawater. Shrimp were removed from the catch with small dip nets and transferred to other holding boxes. After trying several methods, this procedure proved most efficient because the shrimp normally displayed a tendency to separate from other species within the catch.

A shore-based box (4 x 8 x 4 feet deep), subdivided into four compartments and supplied with circulating seawater, was used for holding shrimp during and after marking. Seawater was directed onto the surface in each compartment to provide aeration. A 15-inch wide table, with shrimp measuring boards and inset plastic trays (12 x 10 x 5 inches deep) for holding small numbers of shrimp while marking, was attached to the holding box.

Water temperatures were recorded daily while collecting pink and brown shrimp. A continuous recording thermometer was installed and provided temperature data in the white shrimp study area. Salinity determinations were obtained daily in the collection aera for all three species.

Marking Agents

Two biological stains (fast green FCF and Trypan blue) and four fluorescent pigments (Neon Red A-12, Blaze Orange A-15, Arc Yellow A-16, and Saturn Yellow A-17), reported by Costello (1964) and Klima (1965) as suitable for use in mark-recapture experiments with shrimp,

were available for the study reported herein. A fifth fluorescent pigment (Resoform Yellow 10-2001), also reported as suitable, has since been discontinued by the manufacturer. Aqueous solutions of 0.5% fast green FCF or 0.25% Trypan blue provide primary marks, and a 4.0% mixture of the fluorescent pigments in petroleum jelly provides secondary marks. The stains are expected to remain visible and the pigments detectable for periods up to eight months.

The two biological stains are classified as primary marks because they concentrate in the gills a short time after injection into the body and are easily seen by commercial shrimpers and shrimp headers. The fluorescent pigments are classified as secondary marks when used in combination with one of the primary stains. These secondary marks, normally not visible to shrimpers and headers, remain at the site of injection and are readily distinguishable under ultraviolet light. With the two primary marks and four secondary marks, a total of ten separate combinations were possible by using each primary mark alone for two combinations, and each secondary mark paired with each primary mark for eight combinations. The two primary marks were used with each species to identify separate and smaller nursery divisions tributary to the larger units. The four secondary marks were used in each nursery division to identify selected 10-mm range size groups.

Studies by Zein-Eldin and Klima (1965) and Klima (1965) indicate that, when properly administered, biological stains and fluorescent pigments injected into shrimp do not affect their metabolic rate or survival.

Mark-Release Periods

A mark-release period was designated as one week and shrimp were marked and released five days each period (Monday through Friday). The middle day of each period was selected as the date of release for all shrimp marked that week.

On the first day of each period, the size distribution of a random sample of approximately 100 shrimp was determined and recorded in 10-mm size groups. The size group representing the mode of the curve, or the group containing the largest number of individuals, was then selected to receive both primary and secondary marks during that period. Weekly length-frequency distribution curves were obtained for the entire study by combining daily individual measurements of all marked shrimp.

Large numbers of marked shrimp are required for reliable movement and migration information. Because of the uncertainty of obtaining sufficient numbers within the selected size groups, all shrimp collected were marked with a primary mark. These shrimp, therefore, could not be subsequently identified as to size and date of release. Shrimp receiving both primary and secondary marks, which could be so identified, were expected to yield additional information concerning miles per day traveled.

Shrimp collected for marking each day were individually measured and a primary mark injected through the articular membrane of the fifth abdominal joint. Shrimp in the modal group, as indicated by that week's size distribution sample, were placed in holding compartments separate from individuals receiving only the primary mark. Following completion of all the primary markings, the individuals comprising the modal groups received a secondary mark which was injected underneath the mid-dorsal carapace at the joint of the sixth abdominal segment.

Marked shrimp were held in the shore-based holding box for 12 to 20 hours after marking to insure detection of individuals adversely affected. Those shrimp displaying no apparent sign of distress were transferred to holding boxes aboard the boat and counted as they were released in the area of collection.

Recapture and Return of Marked Shrimp

All shrimp houses from Pamlico Sound, North Carolina to Charleston, South Carolina, and the major houses between Charleston and Cape Kennedy, Florida, were contacted and supplied with posters ex-

plaining the program, and visited periodically for returned shrimp. Forms for the date and place of recapture, and containers of 10% formalin for preserving recaptured shrimp, were also provided. In addition, news articles explaining the program and providing instructions for the return of recaptured shrimp were prepared and released in North Carolina, South Carolina, Georgia, and Florida. State departments responsible for management of estuarine resources in each southern state were informed and supplied with posters, and their assistance in publicizing the program and contacting major shrimp houses was solicited.

No reward was offered for the return of recaptured shrimp. Under this system, contact was maintained primarily with shrimp houses rather than with individual fishermen or trawlers.

Returned shrimp were placed under an ultraviolet light to determine if they contained a secondary mark. Comparison with known fluorescent pigments was made to determine the exact color of the pigment in shrimp containing a secondary mark. The date of capture, place of capture, species, mark or marks, total length, sex, and distance traveled were recorded for each returned shrimp. The number of days since release was also recorded for shrimp with both primary and secondary marks.

RESULTS AND DISCUSSION

Movements and Migration

A combined total of 26,989 pink, brown, and white shrimp was marked and released from April to October, 1966. Of these, 1,671 or 6.2% were returned. The combined average interval between release and recapture was 17.5 days, and the average distance traveled was 0.5 miles per day.

Release and recovery information on mark-recapture experiments with pink and brown shrimp in Jarrett Bay and North River, and with white shrimp in Dutchman Creek, Elizabeth River, and Cape Creek is presented in Tables 1 through 6, respectively. The period released, size at release (midpoint of the 10-mm size group receiving primary and secondary marks), number released, number returned, percent returned, mean distance traveled per day, and mean days out are shown for each species. The mean water temperature and salinity obtained during each period is also presented.

The numbers released and recaptured, and movement between the areas of release and the Atlantic Ocean for pink, brown, and white shrimp are presented in Figures 2, 3, and 4, respectively. A combined average of 65% of all shrimp returned were recaptured before they reached the Atlantic Ocean. The resulting direction of "inside" movement was toward the nearest major inlet for each species.

Movement of pink and brown shrimp was toward Beaufort Inlet with a minor proportion of the pink shrimp migrating through Barden Inlet at Cape Lookout. The tidal influence is stronger toward Beaufort

TABLE 1 — 1966 RELEASE AND RECOVERY INFORMATION ON MARK-RECAPTURE EXPERIMENTS WITH PINK SHRIMP RELEASED IN JARRETT BAY, TRIBUTARY OF CORE SOUND, NORTH CAROLINA.

Period Released	Mean Water Temp. °F	Mean Water Salinity ppt	Released Size[a] (mm)	Released Number	Returned Number	Returned Percent	Mean Travel (mi/day)	Mean Days Out
4/25-29	72	30.9	95	775	42	5.4	0.1	26.9
5/ 9-13	65	33.4	105	1,069	81	7.6	0.4	23.8
5/23-27	74	29.0	105	1,037	58	5.6	0.2	13.8
6/ 6-10	80	26.0	105	408	42	10.3	1.4	6.1
4/25-6/10[b]	73	29.8	61-159	3,489	337	9.7	0.6	18.4[c]
Totals	73	29.8	..	6,778	560	8.3	0.5	18.4

TABLE 2 — 1966 RELEASE AND RECOVERY INFORMATION ON MARK-RECAPTURE EXPERIMENTS WITH PINK SHRIMP RELEASED IN NORTH RIVER, TRIBUTARY OF CORE SOUND, NORTH CAROLINA.

Period Released	Mean Water Temp. °F	Mean Water Salinity ppt	Released Size[a] (mm)	Released Number	Returned Number	Returned Percent	Mean Travel (mi/day)	Mean Days Out
5/ 2-6	68	32.0	115	325	28	8.6	0.3	35.3
5/16-20	73	33.3	105	381	20	5.2	0.7	25.9
5/30-6/3	73	21.5	105	417	14	3.4	0.6	13.8
6/13-17	76	18.9	105	38	2	5.3	0	21.5
5/ 2-6/17[b]	73	26.4	61-159	1,658	145	8.7	0.6	27.2[c]
Totals	73	26.4	..	2,819	209	7.4	0.5	27.2

[a] Mid-point of selected 10-mm size groups receiving both primary and secondary marks.

[b] These shrimp, not in the modal groups, received a primary mark only and could not be identified as to date and size at release.

[c] The combined mean days out for shrimp containing both primary and secondary marks. This value was used to calculate the miles/day travel for this group.

TABLE 3 — 1966 RELEASE AND RECOVERY INFORMATION ON MARK-RECAPTURE EXPERIMENTS WITH BROWN SHRIMP RELEASED IN JARRETT BAY, TRIBUTARY OF CORE SOUND, NORTH CAROLINA.

Period Released	Mean Water Temp. °F	Mean Water Salinity ppt	Released Size[a] (mm)	Released Number	Returned Number	Returned Percent	Mean Travel (mi/day)	Mean Days Out
6/20-24	75	21.7	95	659	19	2.9	0	3.2
7/ 4-8	86	28.8	105	107	2	1.9	0	7.0
7/18-22	79	28.3	125	184	0	0	0	0
8/ 1-5	83	24.4	115	336	3	0.9	0	1.0
6/20-8/5[b]	81	25.8	61-159	3,169	78	2.5	0.5	3.3[c]
Totals	81	25.8	..	4,455	102	2.3	0.4	3.3

TABLE 4 — 1966 RELEASE AND RECOVERY INFORMATION ON MARK-RECAPTURE EXPERIMENTS WITH BROWN SHRIMP RELEASED IN NORTH RIVER, TRIBUTARY OF CORE SOUND, NORTH CAROLINA.

Period Released	Mean Water Temp. °F	Mean Water Salinity ppt	Released Size[a] (mm)	Released Number	Returned Number	Returned Percent	Mean Travel (mi/day)	Mean Days Out
6/27-7/1	82	26.3	105	304	5	1.6	0.5	18.4
7/11-15	86	25.5	115	79	4	5.1	1.1	9.0
7/25-29	83	25.9	115	128	4	3.1	0	2.5
8/ 8-12	85	26.8	115	228	0	0	0	0
6/27-8/12[b]	84	26.1	61-159	1,542	44	2.9	2.2	10.6[c]
Totals	84	26.1	..	2,281	57	2.5	1.8	10.6

[a] Mid-point of selected 10-mm size groups receiving both primary and secondary marks.

[b] These shrimp, not in the modal groups, received a primary mark only and could not be identified as to date and size at release.

[c] The combined mean days out for shrimp containing both primary and secondary marks. This value was used to calculate the miles/day travel for this group.

TABLE 5 — 1966 RELEASE AND RECOVERY INFORMATION ON MARK-RECAPTURE EXPERIMENTS WITH WHITE SHRIMP RELEASED IN THE DUTCHMAN CREEK-ELIZABETH RIVER TRIBUTARIES OF THE LOWER CAPE FEAR RIVER, NORTH CAROLINA.

Period Released	Mean Water Temp. °F	Mean Water Salinity ppt	Released Size[a] (mm)	Released Number	Returned Number	Returned Percent	Mean Travel (mi/day)	Mean Days Out
8/29-9/2	80	22.2	95	342	9	2.6	0.2	31.1
9/ 5-9	80	24.5	95	461	30	6.5	0.2	10.0
9/12-16	76	28.2	95	386	29	7.5	0.3	12.2
9/19-23	75	12.7	105	463	43	9.3	0.2	16.5
9/26-30	75	19.4	105	349	15	4.3	0.3	17.5
8/29-9/30[b]	77	21.4	61-149	4,256	293	6.9	0.4	15.1[c]
Totals	77	21.4	..	6,257	419	6.7	0.4	15.1

TABLE 6 — 1966 RELEASE AND RECOVERY INFORMATION ON MARK-RECAPTURE EXPERIMENTS WITH WHITE SHRIMP RELEASED IN THE CAPE CREEK TRIBUTARY OF THE LOWER CAPE FEAR RIVER, NORTH CAROLINA.

Period Released	Mean Water Temp. °F	Mean Water Salinity ppt	Released Size[a] (mm)	Released Number	Returned Number	Returned Percent	Mean Travel (mi/day)	Mean Days Out
10/ 3-7	73	20.5	115	296	24	8.1	0.3	23.2
10/10-14	71	25.1	115	518	44	8.5	0.3	12.9
10/17-21	73	25.7	115	351	16	4.6	0.5	15.4
9/ 5-9 and 10/ 3-21[b]	72	23.8	61-149	3,234	240	7.4	0.6	16.3[c]
Totals	72	23.8	..	4,399	324	7.4	0.5	16.3

[a] Mid-point of selected 10-mm size groups receiving both primary and secondary marks.

[b] These shrimp, not in the modal groups, received a primary mark only and could not be identified as to date and size at release.

[c] The combined mean days out for shrimp containing both primary and secondary marks. This value was used to calculate the miles/day travel for this group.

Inlet and probably accounts for the greater movement of shrimp in that direction. Movement into the mouth of Bogue Sound was minor and probably caused by tidal influence.

The resulting direction of movement for white shrimp from the mark-release areas was toward Cape Fear Inlet, although significant movement up the Cape Fear River did occur as evidenced by the number of recaptures in that area. As indicated by mode frequencies, initial movement from the Cape Creek area occurred at a total length 20 mm greater than in the Dutchman Creek-Elizabeth River area (Figure 10). The water temperature and salinity determinations were essentially the same in both areas (Tables 5 and 6). Yet, a constant percentage of the total number released in each area was recovered from upstream areas of the Cape Fear River. It would appear then that the strong tidal influence was the greatest factor affecting movement up the Cape Fear River. It would also appear that other motivating factors, such as competition for food and/or space, differences in water quality, etc., were present and possibly accounted for the difference in size at which initial movement from the mark-release areas occurred.

With few exceptions, all inside movement was toward waters of higher salinity. Movement up the Cape Fear River, apparently caused

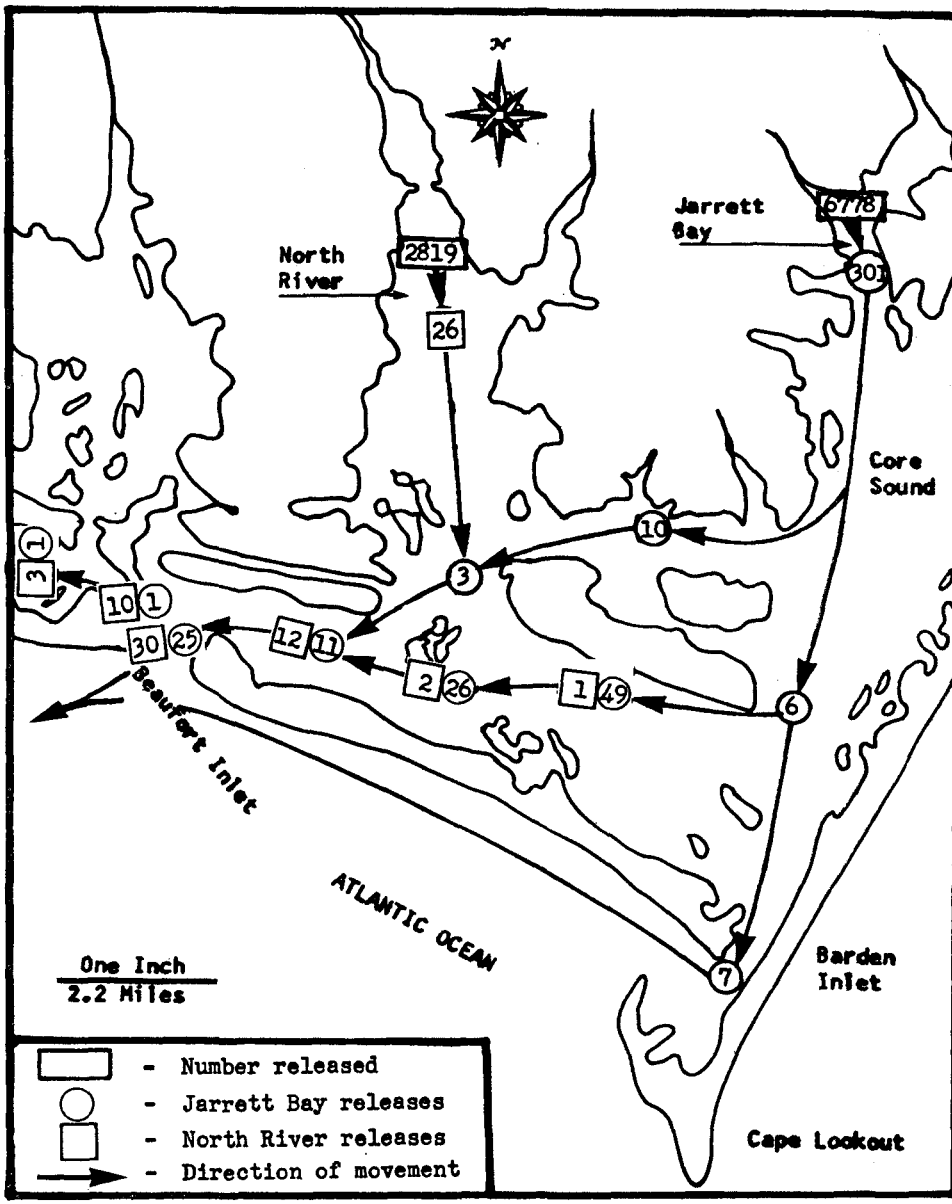


Figure 2 — Pink shrimp release areas, movements, and number recaptured by area between the areas of release and the Atlantic Ocean.

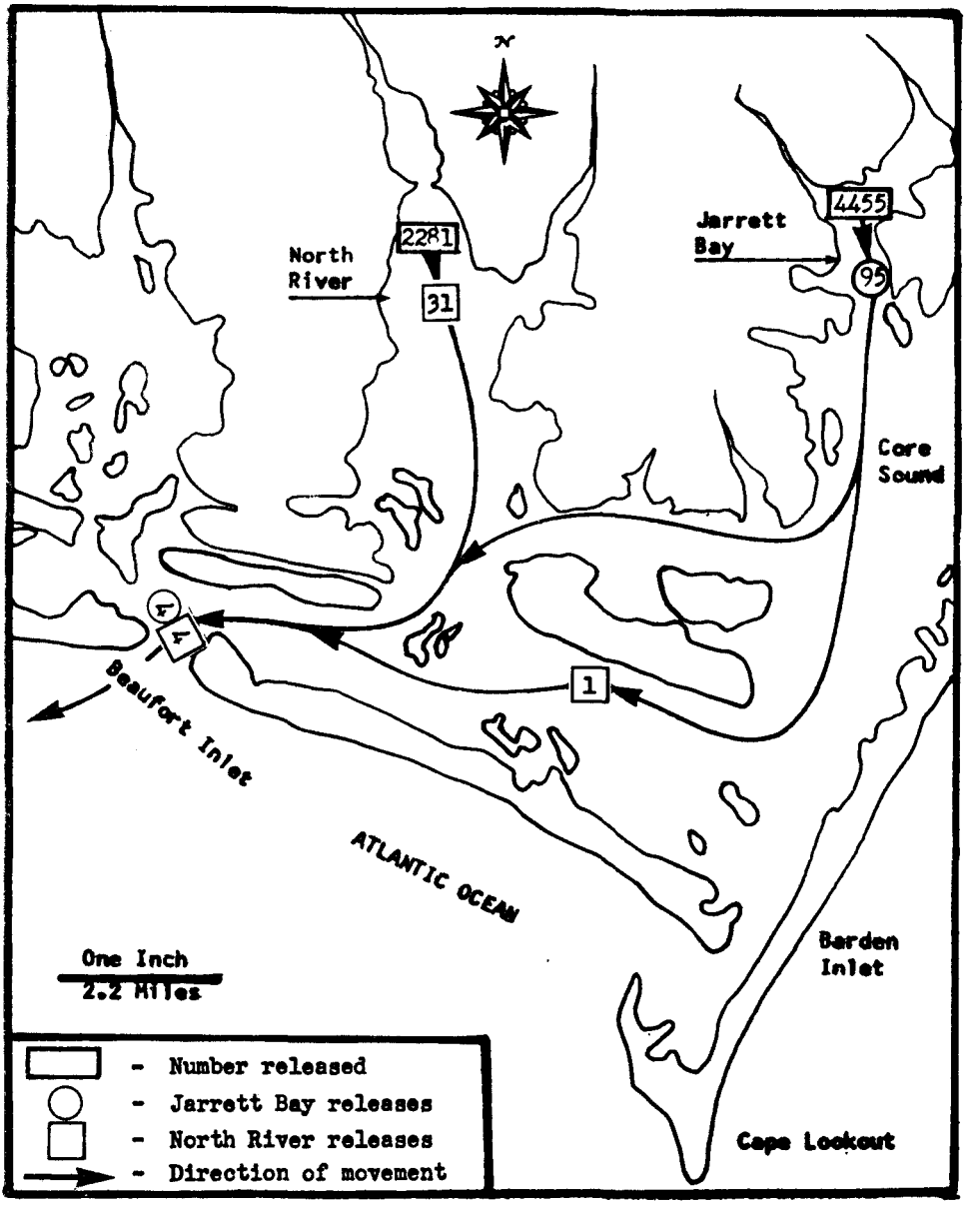


Figure 3 — Brown shrimp release areas, movements, and number recaptured by area between the areas of release and the Atlantic Ocean.

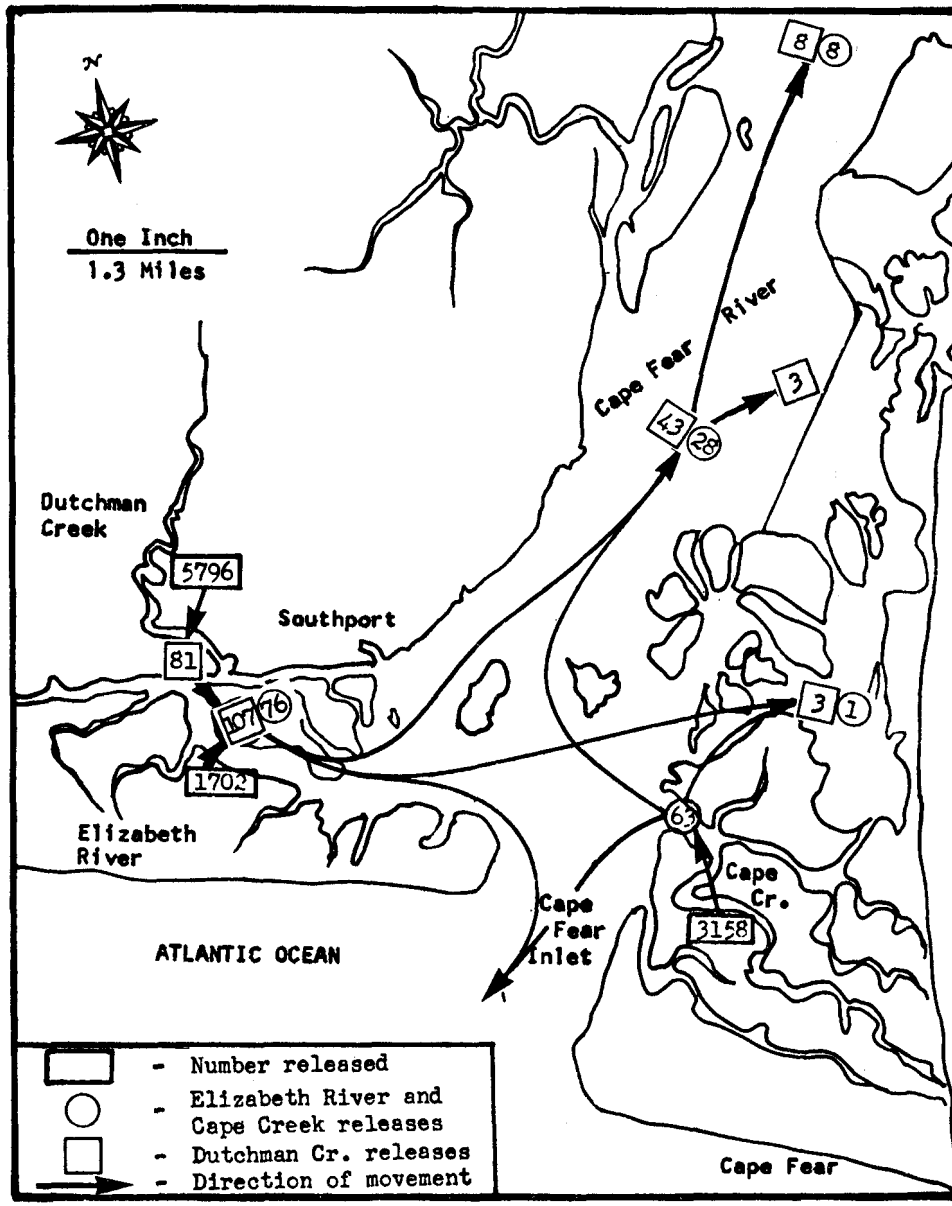


Figure 4 — White shrimp release areas, movements, and number recaptured by area between the areas of release and the Atlantic Ocean.

by the strong tidal influence, was the only significant exception. In the Dutchman Creek-Elizabeth River area, for example, fishing pressure and success were considered about equal in the IWW on both sides of the actual mark-release area, and many of the same fishermen worked in both areas. However, of the 6,257 shrimp released here, none were returned from the waterway area west of the immediate release area.

Movements and number of recaptures in the ocean between Beaufort Inlet and Ocean Drive, South Carolina for pink and brown shrimp, and between Cape Fear Inlet and Cape Kennedy, Florida for white shrimp, are presented in Figures 5, 6, and 7, respectively. These data indicate a definite southward coastwise migration pattern. Lindner and Anderson (1956) also reported a southward coastwise movement for tagged white shrimp along the Atlantic coast.

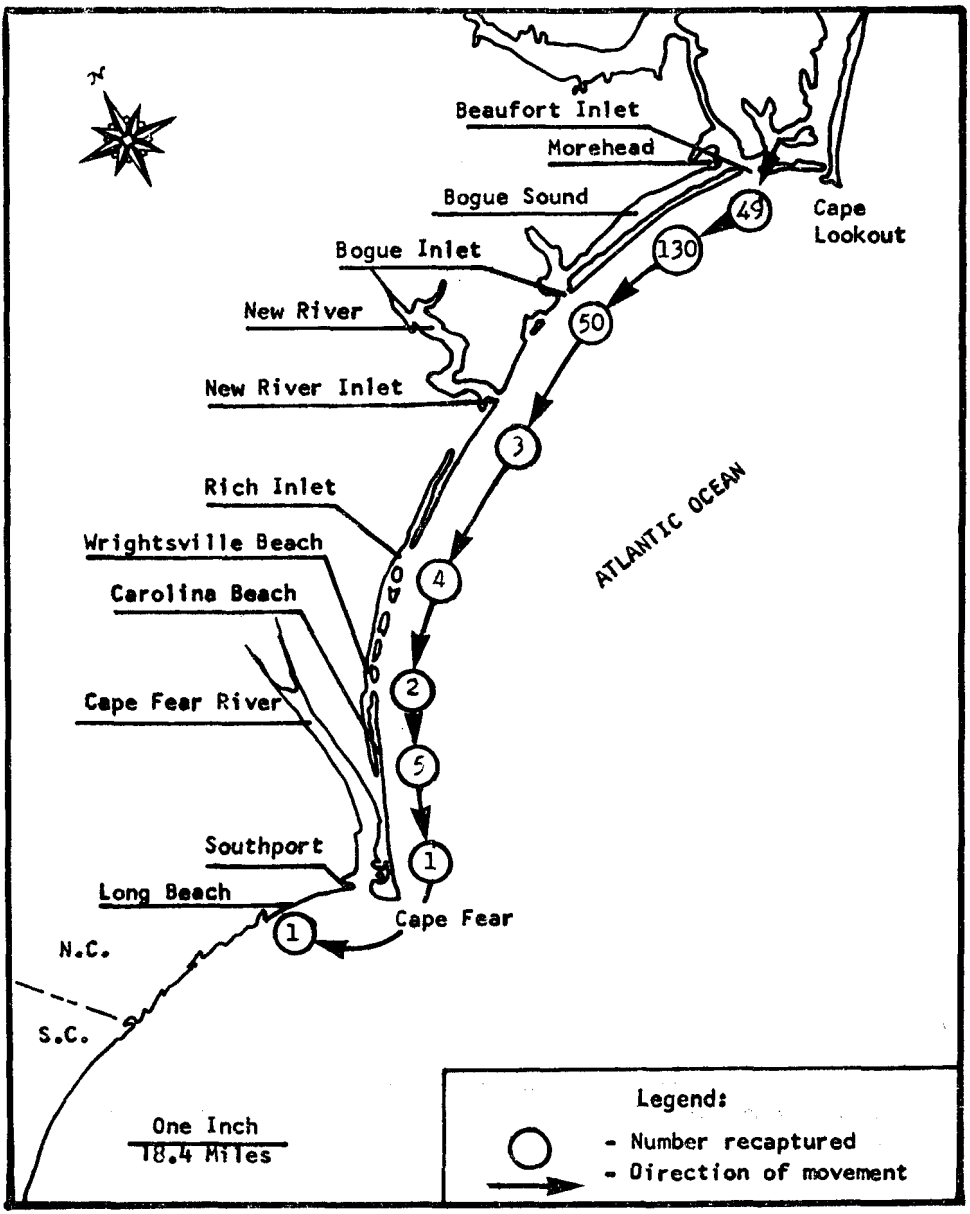


Figure 5 — Pink shrimp movements and number recaptured by area between Beaufort Inlet and Long Beach, North Carolina.

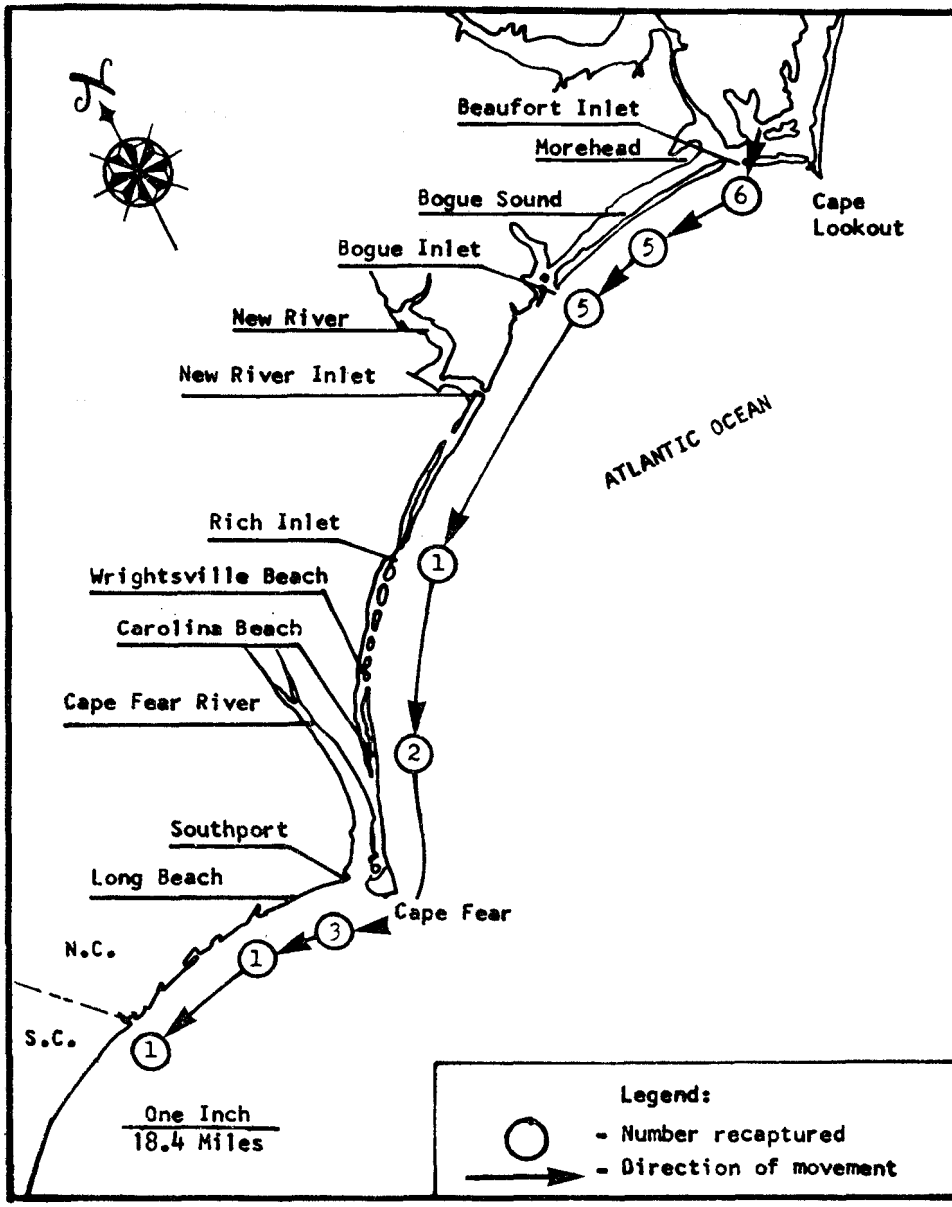


Figure 6 — Brown shrimp movements and number recaptured by area between Beaufort Inlet, North Carolina, and Ocean Drive, South Carolina.

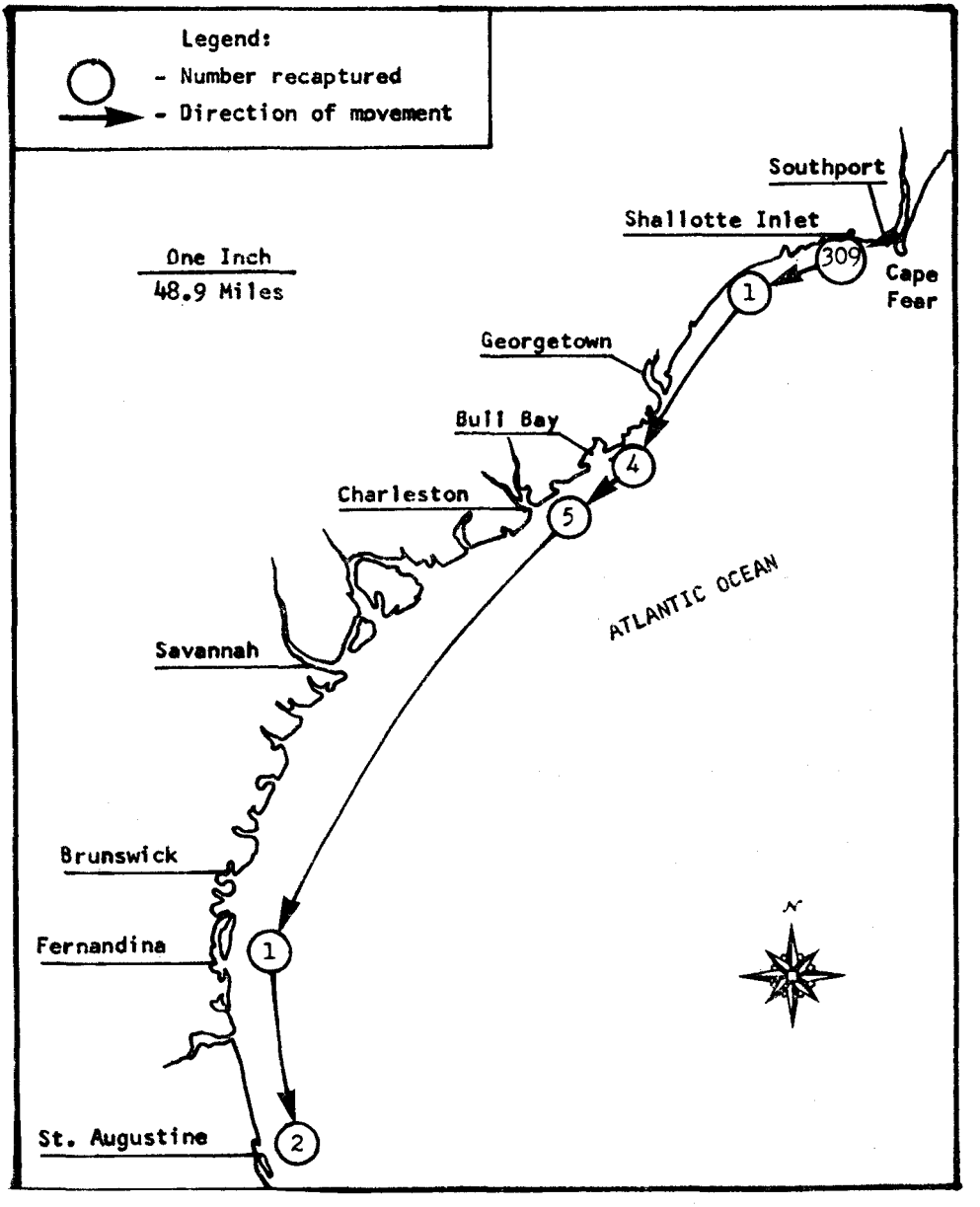


Figure 7 — White shrimp movements and number recaptured by area between the Cape Fear Inlet, North Carolina, and St. Augustine, Florida.

The record migration for pink shrimp was approximately 120 miles in five weeks and involved movement to Long Beach, North Carolina. The brown shrimp record was approximately 150 miles in five weeks involving movement to Ocean Drive, South Carolina. Two white shrimp were recaptured off St. Augustine, Florida establishing migration records of approximately 345 miles.

The pink and brown shrimp populations included in this study appear

to be more endemic to North Carolina, whereas the major white shrimp population from the Cape Fear River area apparently contributes to the shrimp fishery off South Carolina, Georgia, and Florida.

The possibility of offshore movements or concentrations of North Carolina shrimp outside the normal fishing areas has been discussed by both local fishermen and researchers. However, little or no shrimp trawling is done off this coast at depths greater than 50 feet. Present study data, although by no means conclusive, suggest that such an offshore segment of at least the brown shrimp population may occur.

Brown shrimp were marked and released in the Core Sound areas from 20 June to 12 August. Only 2.4% of the 6,736 released were returned and of those returned, 85% were caught in inland waters. Although a high natural mortality is suspected, escapement, especially after reaching ocean waters, also appears high. Only two recaptures were recorded from the ocean after 11 August, and both of these were taken near the Cape Fear Bar (approximately 120 miles south of Beaufort Inlet) during the period 20 September to 4 October when trawlers encountered a concentration of large brown shrimp (25 to 30 count, heads off). This "run" apparently moved out of that area about 6 October. These brown shrimp may have moved offshore and outside the fishing area after leaving Beaufort Inlet until, for some reason, they moved inshore near the Cape Fear Bar in late September.

Kutkuhn (1962) reported that the majority of brown shrimp taken off the Louisiana and Texas coasts are from depths of 11 to 20 fathoms and off the east Mexican coast, most browns are taken in depths of 21 to 45 fathoms. He also reported that most pink shrimp from the Sanibel-Tortugas area and the majority of pink and brown shrimp from the Gulf are caught offshore in depths of 11 to 20 fathoms, whereas most white shrimp from the entire Gulf are taken in shallower waters from 0 to 10 fathoms.

Rough bottom terrain along most of the North Carolina coast restricts shrimping activities to relatively shallow waters. Perhaps additional catches of brown and pink shrimp can be made if suitable offshore towing areas are located and new types of gear developed.

Length-Frequency Distribution

The weekly length-frequency distribution curves obtained for pink, brown, and white shrimp are presented in Figures 8, 9, and 10, respectively. With all three species, and in each mark-release area, the modes of the length-frequency distribution curves were at, or increased to, levels that indicated static populations. These levels were reached at total lengths of 105 and 115 mm for pink and brown shrimp, respectively, in both the Jarrett Bay and North River areas. Comparable levels for white shrimp were 95 and 115 mm in the Dutchman Creek-Elizabeth River and Cape Creek areas, respectively.

Recaptures of marked shrimp proved migration was occurring and dispelled the possibility of static populations. Maintenance of this apparent state of equilibrium, therefore, resulted from migration of larger individuals outside the mark-release areas and immigration of smaller ones from upstream reaches into the mark-release areas. Although shrimp less than 65 mm total length were seldom taken, growth of juveniles within the mark-release areas is also a contributing factor because shrimp considerably less than 65 mm were known to be present in greater abundance than the trawl data indicated.

Further research pertaining to the level or levels of "equilibrium" in all suspected nursery areas should yield important management information concerning regulation of commercial shrimping within such areas. However, regulations imposed upon these areas should consider the combined merits of wise conservation and local economic factors such as associated growth and mortality rates and prices. For example, during most of September and October fishermen working in and adjacent to the Elizabeth River study area received averages of 60c per pound for 60-70 count shrimp (heads off), and 53c per pound for 70+ counts, due to a local demand for small shrimp.[1]

[1] Dealer records, personal observation, and personal communication with fishermen.

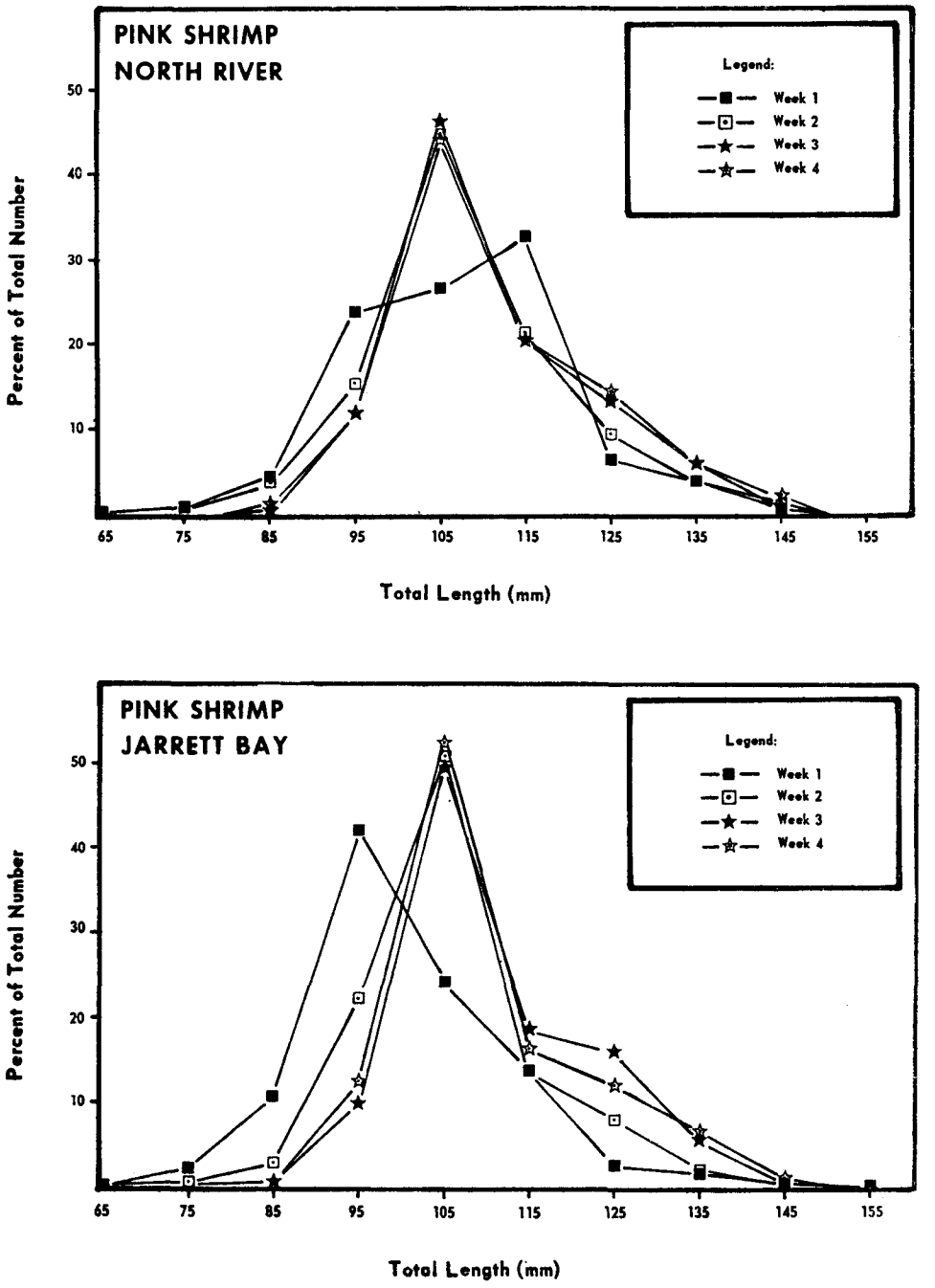


Figure 8 — Length-frequency distribution. Individual weekly curves as obtained from length records of all pink shrimp marked during each time period.

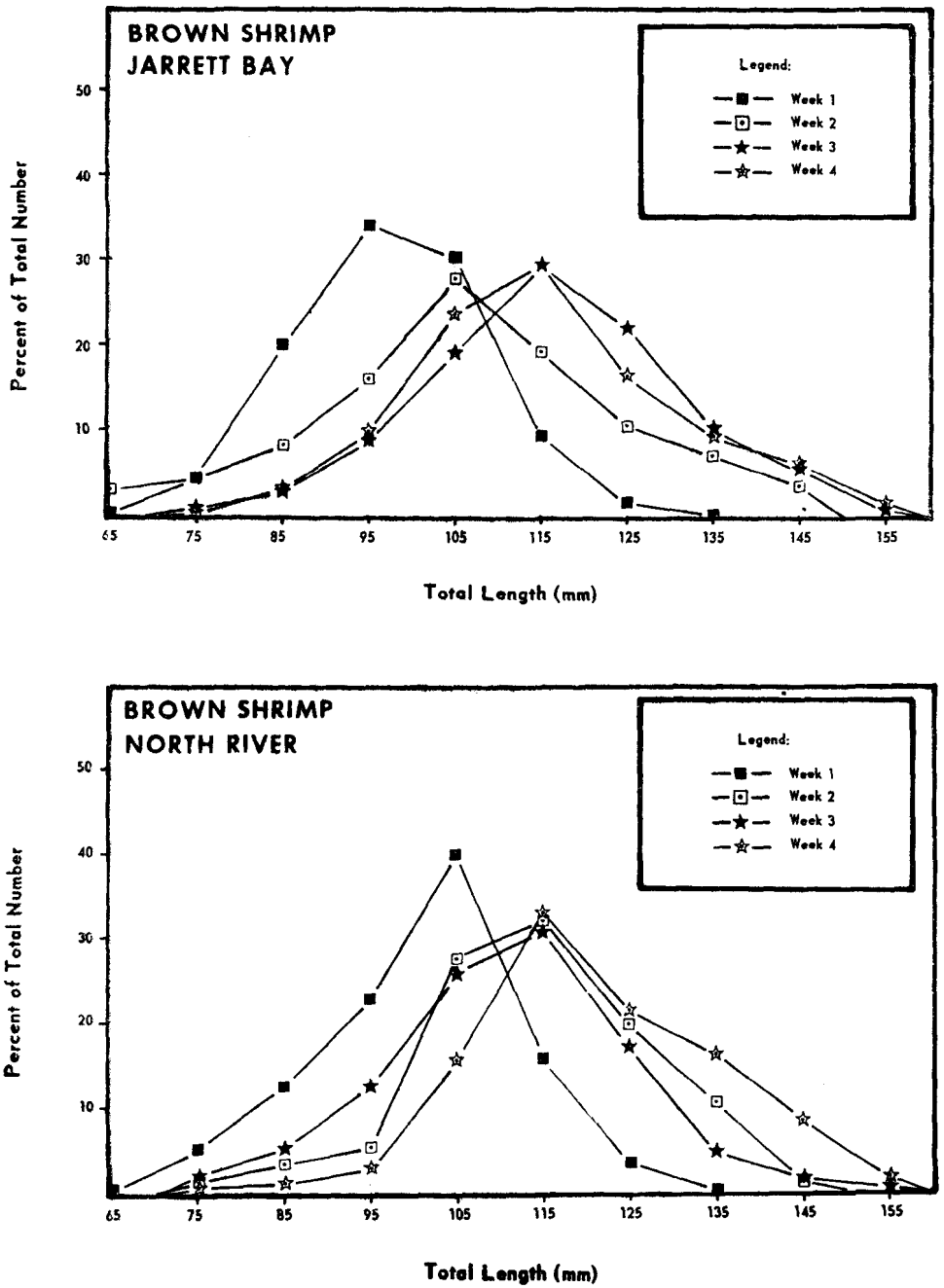
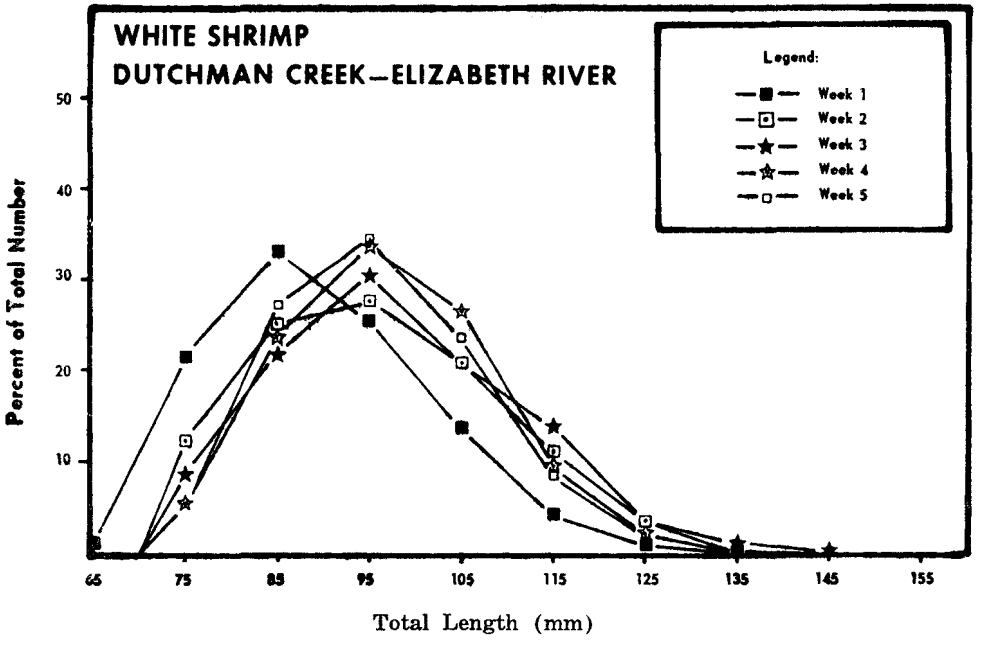


Figure 9 — Length-frequency distribution. Individual weekly curves as obtained from length records of all brown shrimp marked during each time period.



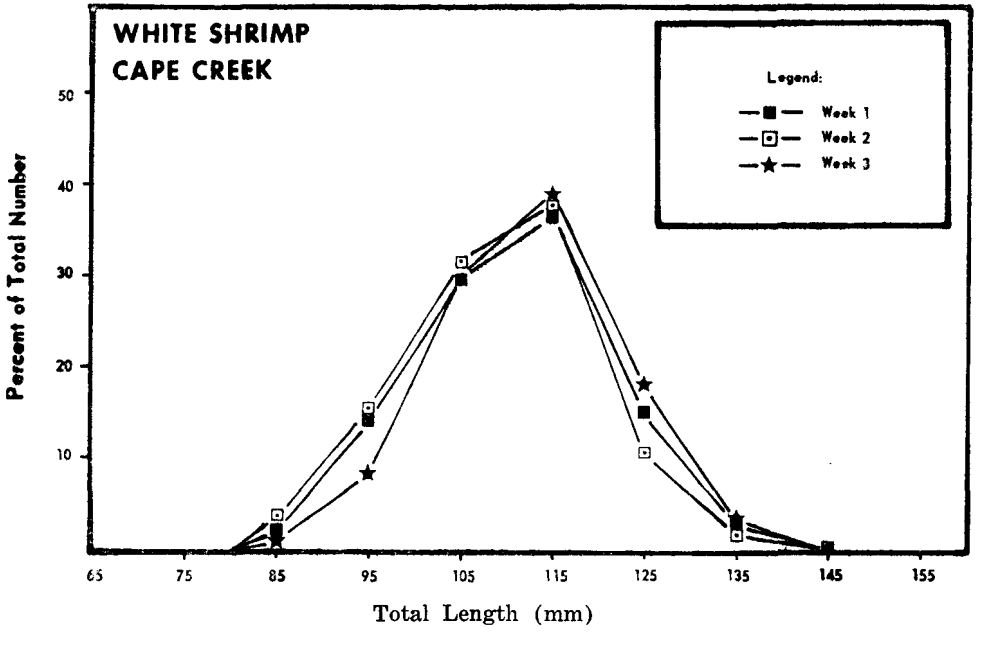


Figure 10 — Length-frequency distribution. Individual weekly curves as obtained from length records of all white shrimp marked during each period.

Shrimpers in the Core Sound area during the same period were receiving the equivalent of 53c per pound (heads off) for 40-50 count shrimp. Throughout this period, study data size-class-modes in the Elizabeth River area remained constant at values indicating an "equilibrium level" of approximately 100 count shrimp (heads off). Enforcement of a closed season, therefore, probably would not have resulted in a significant decrease in average shrimp counts per pound within the study area since migration of the larger individuals is occurring continually. Also, a total mortality estimate of 81% per month, of which only 21% was attributed to fishing, was obtained in a mark-recapture experiment conducted with brown shrimp off the Texas Coast (Klima, 1963). Should a similar mortality rate have been operative on shrimp in this area, continued enforcement of a closed season may have resulted in a significant loss of shrimp due to natural mortality and migration and consequently of earnings to local shrimp fishermen, neither of which would be wise conservation.

Reliable growth data would also have predictive value. In nursery areas where "levels of equilibrium" occur at larger shrimp sizes, and associated higher dockside values are anticipated, growth information would indicate the approximate number of days until certain count decreases should prevail.

SUMMARY AND CONCLUSIONS

Pink, brown, and white shrimp, marked with biological stains and fluorescent pigments were released in nursery areas tributary to the Core Sound and lower Cape Fear River estuaries in North Carolina to obtain information concerning population dynamics including movement and migration patterns.

To provide replication within each of the major estuaries, two smaller nursery units tributary to each were selected as mark-release areas. Pink and brown shrimp were marked and released in Jarrett Bay and North River of the Core Sound estuary while white shrimp were marked and released in Dutchman Creek-Elizabeth River and Cape Creek of the lower Cape Fear River estuary. Two biological stains or primary marks were used with each species to identify all shrimp marked in the smaller nursery units and four fluorescent pigments or secondary marks were used to identify selected 10-mm size groups in each area. A mark-release period was one week, and shrimp were marked and released five days each week.

A combined total of 26,989 pink, brown, and white shrimp was marked and released from April to October, 1966. Of these, 1,671 or 6.2% were returned. The combined average interval between release and recapture was 17.5 days, and the average distance traveled was 0.5 miles per day.

A combined average of 65% of all shrimp returned were recaptured before they reached the Atlantic Ocean. The resulting direction of "inside" movement was toward the nearest major inlet for each species. Movement of pink and brown shrimp from the mark-release area was primarily toward Beaufort Inlet. Although significant movement up the Cape Fear River occurred, the resulting direction of movement of white shrimp was toward Cape Fear Inlet.

With few exceptions, all indicated movement was toward waters of higher salinity. Movement up the Cape Fear River, apparently caused by the strong tidal influence, was the only significant exception. In the Dutchman Creek-Elizabeth River study area, for example, fishing pressure and success were considered about equal in the IWW on both sides of the actual mark-release area, and many of the same fishermen worked in both areas. However, of the 6,257 shrimp released there, none were returned from the waterway area west of the immediate release area.

All three species exhibited a definite southward coastwise migration pattern. The record migration for pink shrimp was approximately 120 miles in five weeks and involved movement to Long Beach, North Carolina. The brown shrimp record migration was approximately 150

miles in five weeks involving movement to Ocean Drive, South Carolina. Two white shrimp were recaptured off St. Augustine, Florida establishing migration records of 345 miles.

The pink and brown shrimp populations included in this study appear to be more endemic to North Carolina, whereas the major white shrimp population from the Cape Fear River area apparently contributes to the shrimp fishery off South Carolina, Georgia, and Florida.

Rough bottom terrain along most of the North Carolina coast restricts shrimping activities to relatively shallow waters. Perhaps additional catches of brown and pink shrimp can be made if suitable offshore towing areas are located and new types of gear developed.

Weekly length-frequency distribution curves were obtained by combining daily measurements of all marked shrimp. The modes of the length-frequency distribution curves for all three species were at, or increased to, "levels of equilibrium" in the mark-release areas that were apparently caused by migration of larger individuals from the area, immigration of smaller ones from upstream reaches, and growth within the mark-release area.

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THE DEVELOPMENT OF A TAXONOMIC CODE AND DESIGN OF A SYSTEM FOR THE ANALYSIS OF BIOLOGICAL DATA[1]

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ABSTRACT

The voluminous amounts of biological information collected for the Mississippi Estuarine Inventory required the development of a system for the automatic processing of this data.

The prime requirement of such a system was preparing a taxonomic code that could be easily updated and efficiently handled by EDP equipment. A modified version of the phylogenetic taxonomic structure was used to reduce the extent of the code and make optimum use of computer time. By the use of several search algorithms, computer memory requirements were substantially reduced.

[1] Conducted in cooperation with the United States Department of Interior, Bureau of Commercial Fisheries, under Public Law 88-309. (Project 2-25-R).