BIOLOGY OF THE BLUE CRAB, *CALLINECTES SAPIDUS* RATHBUN, IN THE ST. JOHNS RIVER, FLORIDA

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ABSTRACT

Blue crabs commonly mated from March to July and from October to December in the St. Johns River; the proportion of males and females that matured at a small size was larger in salt water than in fresh water.

Blue crabs spawned in the first 30 km. of river above the mouth, and the eggs hatched in the ocean within 6 km. of shore. Spawning began as early as February and continued through October.

Some blue crabs of both sexes migrated from the St. Johns River to the Intracoastal Waterway, to four other rivers, and to the ocean. Among crabs tagged 40 to 195 km. above the mouth of the St. Johns River and recovered at a distance from the tagging site, 89 percent of the males and 96 percent of the females were recaptured downstream from the point of release. Many females tagged in the ocean were recaptured in inland waters throughout the year. During the spawning season some reentered the St. Johns River for a second spawning within 15 days after their eggs hatched.

First- and second-stage zoeae and megalops of crabs of the genus *Callinectes* were collected as far as 40 km. upstream. Of 22 kinds of crab zoeae collected near the mouth, *Callinectes* ranked third in abundance in 1961 and second in 1962.

Small blue crabs (2–9 mm. wide) entered the river in waves and moved as far as 135 km. upstream. Nearly all of the upstream migrants were beyond the first postlarval stages except during early winter.

Blue crabs 5 to 200 mm. wide fed principally on mollusks (primarily clams and mussels), fish, and crustaceans (primarily amphipods and crabs). Generally, they ate the same type of food regardless of crab size, area, and season.

This report presents the results of studies in 1961–63, on the biology of the blue crab, *Callinectes sapidus* Rathbun, in the St. Johns River. Detailed information on their biology is necessary to learn which factors affect the harvestable population.

The blue crab supports important fisheries along the Atlantic and Gulf coasts of the United States. Landings in 1950–65 averaged about 58 million kg. per year. The 1965 catch was 71 million kg., worth slightly more than $12 million to the fishermen. In the St. Johns River, 109 fishermen, using pots and 52 fishing trawls, caught 1,465,840 kg. of blue crabs during 1962 (Tagatz, 1965).

The biology of the blue crab has been investigated extensively in Chesapeake Bay (Hay, 1905; Churchill, 1919; Truitt, 1939; Pearson, 1948; and Van Engel, 1958), and to a lesser degree in Delaware (Porter, 1956), Louisiana (Darnell, 1959), and Texas (Daugherty, 1952; Pounds, 1961). No investigation has been reported, however, of the biology of the blue crab in the St. Johns River or in other Florida waters.

Blue crabs occur far upstream in the St. Johns River, at least as far as Lake Harney, 305 km. above the mouth (Moody, 1963). Their widespread distribution in the fresh-water portion of the river is thought to be largely due to the abundance of calcium chloride in the water and to the presence of the salt springs that drain into the river (Odum, 1953). In other estuaries, blue crabs seldom penetrate far into fresh water (Williams, 1965). Our studies on the St. Johns River extended 215 km. upstream to Astor, the terminus of the commercial fishery for crabs (fig. 1).

MATERIALS AND METHODS

Sampling and tagging were conducted to determine the size, sex composition, sexual maturity, distribution, and movements of adult blue crabs.

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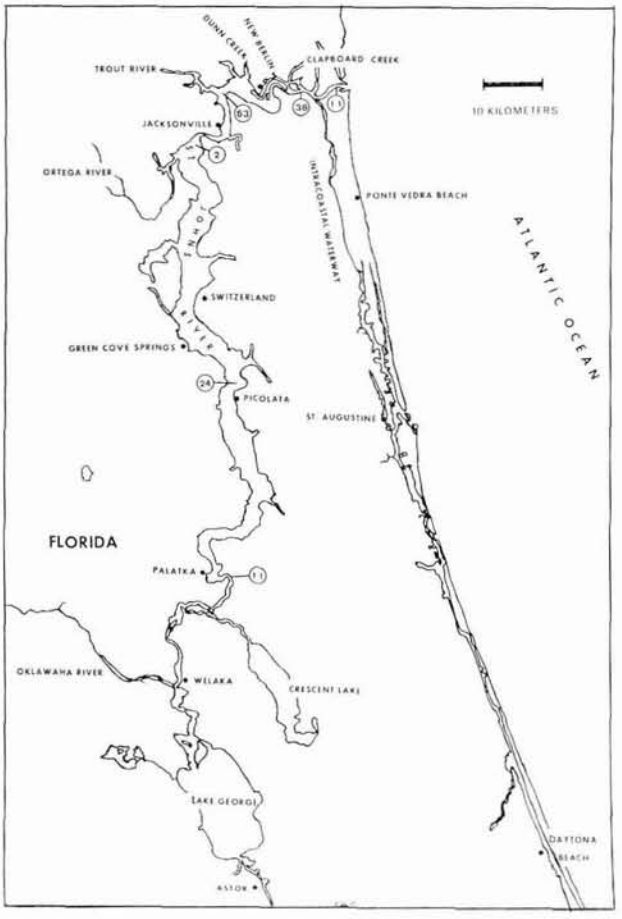

FIGURE 1.—St. Johns River, Fla., from mouth to Astor. (Circled numerals indicate buoys referred to in text.)

In 1961 and 1962, 92 samples of about 150 crabs each were obtained from the unculled commercial catches of crabs in the river, and on 1 or 2 days each month, crabs were observed in catches of shrimp trawlers fishing 1 to 8 km. offshore between Fernandina Beach and Ponte Vedra Beach. Samples were taken monthly with a 3-m.-wide trawl at selected stations in the river to supplement data from the fishery. Size, recorded as width, is the distance between the tips of the large lateral spines of the carapace.

I examined females and every fifth male crab in samples from commercial catches for sexual maturity, which is more obvious in the female blue crab than in the male—the apron (abdomen) is semicircular in mature females and triangular in immature females. I also examined every fifth mature female to determine stage of ova development. The shape of the apron of the male does not change at maturity; I based maturity in males on the development of the anterior and middle vasa deferentia. In the mature male the vasa deferentia are large prominent ducts and the middle vas deferens is bright pink. In the immature male the vasa deferentia are small and the middle vas deferens is white.

From April 1961 to April 1963, 8,927 blue crabs (6,383 males, 2,544 females) were tagged in the St. Johns River and 2,595 (58 males, 2,537 females) in the ocean off the mouth of the river, 1.5 to 5 km. offshore and 1.5 km. north to 11 km. south of the jetties. I obtained these crabs from commercial fishermen. Only mature females and males wider than 135 mm. were tagged; maturity of males could not be determined by external observation. Each tag was plastic, bore a number, and was fastened by stainless steel wire between the large lateral spines of the carapace (fig. 2). Cronin (1949) reported that this method of tagging was more effective than others he tested.

I collected larval crabs in the St. Johns River in 1961 and 1962, using Clarke-Bumpus samplers for simultaneous collections at the surface (0.3-m. depth) and bottom (10 m.). Collections, water temperatures, and salinities (surface and bottom) were obtained hourly over any selected 4- to 11-hour period. Captured plankton was placed in jars which were then filled to capacity (135 ml.) by addition of water. Crab larvae were identified and counted in three 4-ml. subsamples removed from each jar.

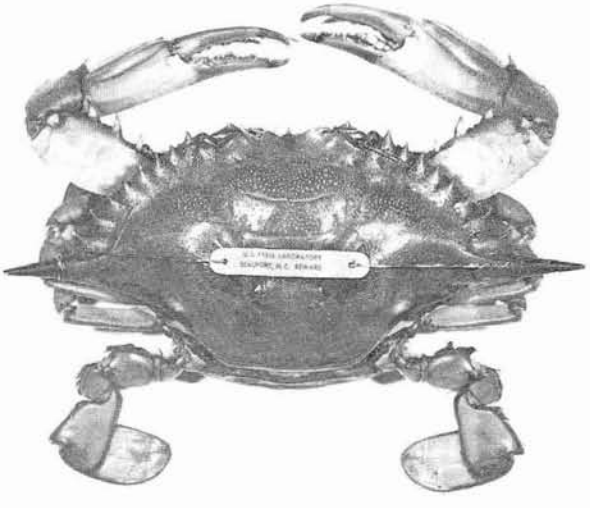

FIGURE 2.—Blue crab with carapace tag attached.

Reliable separation of the larvae of *Callinectes sapidus* from those of other species of *Callinectes* is not yet possible. Because *C. similis* and *C. ornatus* are common in the lower 40 km. of the river and in the ocean off the river's mouth (Williams, 1966), and their spawning seasons coincide with that of *C. sapidus*, larvae of *Callinectes* were designated by genus only.

A 21-m.-long seine with a funnel-shaped bag (4-mm. stretched mesh) and a 2.5-m.-wide trawl (tail bag was 6-mm. stretched mesh) were used to determine the distribution of juvenile blue crabs in the St. Johns River. In addition to extensive random sampling (1961–63), certain areas were sampled at 2-week intervals (1962–63).

The stomachs of 695 blue crabs 5 to 200 mm. wide were obtained from December 1962 to August 1963 for the food study. Crabs were selected from samples taken during scheduled collecting with a seine and trawl. The percentage frequency of each class of organism was determined. For each stomach, the percentage of each food type in the total volume of food was estimated.

Aquatic plants, fish, and invertebrates obtained in the nets and with a Petersen dredge were counted to indicate natural abundance of foods selected by crabs, and representative specimens were preserved for comparison with stomach contents.

THE ST. JOHNS RIVER

The St. Johns River lies entirely within Florida. It rises from headwater marshes 80 km. north of Lake Okeechobee and 24 km. inland from Florida's east coast, flows north for 420 km. to Jacksonville, and continues east 40 km. to the Atlantic Ocean. North and south jetties extend from the mouth of the river about 1.5 km. into the ocean. Along its course the river receives the flow of many tributaries and often expands into lakes. Its largest tributary is the 200-km.-long Oklawaha River (172 km. upstream); its largest lake is 9.5-km. wide and 19-km. long Lake George (185 km. upstream). The Intracoastal Waterway intersects the river 8 km. from the mouth. The St. Johns River is less than 1.5 km. wide from the jetties to 11 km. upstream, 1.5 to 5 km. wide from this point 125 km. upstream to Palatka (except for a narrow section at Jacksonville), and 1.5 km. wide from Palatka upstream 145 km. to Sanford. Upstream from Sanford, the greatest width is less than 1 km. The depth of the river channel is 10 m. from the mouth to Jacksonville, 4 m. to Palatka, and 3.5 m. to Sanford.

Characteristics of the St. Johns River are low gradient, extensive tidal influence, and varying salinity and temperature. The river drops only about 6 m. in the 460 km. from its source to the ocean and has a slow current. The usual head of tidal influence is Lake George, 185 km. upstream. Salinity readings 15 km. from the mouth of the river ranged from 2.5 to 33.4 p.p.t. (parts per thousand) during 1961–62. They varied with depth, direction of the tide, and season (salinity was lowest in late summer and highest in late spring). South of Jacksonville, 40 km. from the mouth, salinity is normally less than 1 p.p.t. Water temperature between the mouth and Jacksonville ranged from a winter low of 8.2° C. to a summer high of 34.1° C.

ADULT CRABS

SEX COMPOSITION

Most of the blue crabs of commercial size (larger than 120 mm.) caught during most of the year in the lower river were females, but males were always dominant in the upper river. Among crabs caught in the first 24 km. of the lower river, 60 to 90 percent were females in January to September and 10 to 25 percent in October to December. In the next 24 km. of river, extending to 8 km. south of Jacksonville, females made up 75 percent of the catch in December to February and 15 to 55 percent in March to November. From a point about 8 km. above Jacksonville to Palatka the percentage of females ranged during the year from 10 to 35 percent; and above Palatka, from 5 to 35 percent.

Except in the fall when large numbers of males occasionally were captured very close to the jetties, nearly all of the adult blue crabs caught in the ocean were females.

MATING AND SIZE AT SEXUAL MATURITY

Female blue crabs mate once, after the last in a series of molts, but males may mate during each of their last three growth stages (Truitt, 1939). Before mating, the male carries the female beneath him, often for more than 2 days, until she sheds her immature shell. Sperm from the male is then

transferred to the spermathecae of the female where it remains viable a year or more and is used for repeated spawnings.

Mating blue crabs were commonly observed from 11 to 215 km. above the mouth of the river. Primary mating areas were the shallower near shore waters of the main river and tributary streams. Mating occurred sparingly in January and February, was common in March to July, decreased sharply in late summer, and was common again in October to December. Among 25 randomly collected mating pairs that I measured, the smallest male was 121 mm. and the smallest female was 71 mm.

Maturity of blue crabs is attained at varying widths. The proportion of male and female crabs that matured at a small size was larger in salt water (from the mouth of the river to Jacksonville) than in fresh water (south of Jacksonville, table 1). The smallest mature female measured in the St. Johns River was 99 mm. and the largest immature female was 177 mm. Mature females believed to be *Callinectes sapidus* have been captured in North Carolina as small as 52 mm. (Fischler, 1959), but to my knowledge no immature female as large as 177 mm. has been reported for any other area. Overlap in the size ranges of immature and mature females in the St. Johns River was considerably greater than reported by Tyler and Cargo (1963) for Chesapeake Bay; their smallest mature female was 118 mm. wide and the largest immature female was 135 mm.

TABLE 1.—*Percentage of mature male and female blue crabs in samples of commercial catches from the lower St. Johns River (salt water) and from the upper river (fresh water), 1961–62*

Carapace width	Males				Females			
	Lower river		Upper river		Lower river		Upper river	
	Number examined	Mature	Number examined	Mature	Number examined	Mature	Number examined	Mature
Mm.	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
120–24	16	44	28	0	64	31	182	2
125–29	22	50	51	8	56	52	150	6
130–34	23	52	55	14	93	83	155	15
135–39	23	70	54	18	121	90	121	27
140–44	32	66	76	33	199	96	121	46
145–49	43	84	103	42	258	98	90	66
150–54	42	88	105	50	371	99	110	80
155–59	44	95	132	66	425	100	131	90
160–64	65	88	127	72	473	100	148	96
165–69	49	98	95	76	422	100	139	99

SPAWNING

Intervals between mating and spawning of blue crabs, or migrations preparatory to spawning, vary with season. Spawning usually takes place within 1 to 2 months after mating in spring and summer. If crabs mate during fall or winter, spawning is delayed until warmer temperatures the following spring. Most mature females of the upper river migrate downstream to near Jacksonville (about 30 to 55 km. above the mouth) for maturation of the ovaries. In spring and fall, almost all females make the migration soon after mating and during early development of the ovaries. In summer and winter, however, more mature females delay migration downstream, and 20 to 50 percent of those in the upper river have large ovaries with well-developed eggs.

Most blue crabs spawn in the lower 32 km. of the river. Relatively few females spawn near Jacksonville, and I observed no spawning south of there. The eggs, numbering between 1 and 2 million and known as a sponge, are deposited on the abdominal appendages and carried by the female until they hatch. They are initially yellow-orange, but as the larvae develop and absorb the yolk during the 2 weeks required for hatching, the eggs become brown and finally black.

Spawning occurs in the St. Johns River 8 or 9 months of the year; only the very coldest winter months are excluded. In 1962, sponge crabs first appeared in the lower 32 km. of the river in February, were most abundant from March to September (when 40 to 82 percent of the mature females collected were with sponge), and were present through October. In 1963, sponges did not appear until March, probably because of the colder water in February. Water temperature in 1962 increased from an average of 13.2° C. in January to 18.4° C. in February. In 1963, water temperature decreased from 12.9° C. in January to 11.4° C. in February; in March it rose to 20.4° C.

As the eggs develop, the females move from the river into the ocean where the eggs hatch. Almost all of the sponges of river females are yellow-orange, whereas most sponges on blue crabs in the ocean are dark brown or black. Sponge crabs were first common in the ocean in March or April but only within 1 km. of shore at the river mouth. As the spawning season progressed, egg-bearing females were found over a wider and wider ocean

area. In June they were common out to 2.5 km., and from July through September, when they were most abundant, large numbers were 5 to 6 km. offshore between Fernandina Beach and Ponte Vedra Beach. The number of females offshore dropped sharply in October, but 62 percent were in sponge compared with 4 percent in the lower 32 km. of river. From November to February, female crabs were least common in the sampling area off the mouth of the St. Johns. During this period only one sponge crab was taken (in January) but the well-developed ova of most of the females indicated that they would spawn in the spring.

Many if not all female blue crabs spawn twice—in the same season or over two seasons—and they often return to inland waters to develop their second sponge. Throughout the spawning season, some females reentered the lower 40 km. of the river from the ocean and developed another sponge. These repeat spawners could be distinguished by the appearance of their shells. Crabs which have not left the river have shiny, clean, bright-colored shells. Crabs which have spent time in the ocean have dull-colored shells with an encrustation of fouling organisms—especially the turtle barnacle, *Chelonibia patula*. Blue crabs which had previously had sponges also could be distinguished by the ragged appearance of their abdominal appendages and the presence of eggshell remnants.

TAGGING AND RECOVERY

The few tagging studies that have been made to determine movements of adult blue crabs have been confined largely to bays and to lower parts of estuaries. Fiedler (1930) found that tagged females released in the northern part of Chesapeake Bay migrated to the southern portion and tended to remain there. The direction of movement for males was random. Cronin (1954) detected no clear pattern for movements of crabs in Delaware Bay. Some males and females moved up Delaware Bay after wintering near the mouth; none of the tagged crabs was returned from other coastal regions. Cargo (1958), who tagged only females in Chincoteague Bay, Va., found they moved southward to the lower bay even if released in areas where high-salinity water was to the north. Only two crabs were captured outside Chincoteague Bay—one at Oyster, Va., the other in Delaware Bay. Fischler and Walburg (1962) released 4,353 tagged blue crabs in three estuaries and two offshore locations in South Carolina. Both male and female crabs moved considerably between the lower estuaries and adjoining coastal waters. Only seven males and six females were recaptured in estuaries other than those in which the crabs were released. Crabs that entered estuaries were almost always from the adjacent ocean tagging site. All but two crabs were recaptured within 80 km. of the release area. The authors concluded that, in South Carolina at least, adult blue crabs do not migrate between estuaries but limit their movements to the estuary or adjacent marine area.

Of the 11,522 blue crabs tagged in the St. Johns River and in the ocean off its mouth, 4,059 (35 percent) were recovered. Ninety-seven percent of the recoveries were by commercial gear, which was fished every month of the year; 3 percent of the recoveries were by sport fishermen.

Return of tags from 2,839 males and 830 females recaptured after release in the river indicated some movement of both sexes throughout the year. Migrations within the river were principally downstream (table 2). Among crabs tagged from Jacksonville to Lake George and recovered at a distance from the tagging site, 89 percent of the males and 96 percent of the females were recaptured north or downstream from the point of release. Some males moved randomly between New Berlin and Picolata, but nearly all of those tagged south of Picolata were recaptured downstream. Females tagged at all sites during spring and summer usually migrated into the ocean within 1 month, but those tagged in late fall and early winter entered the ocean after 3 or more months. Only three females were recaptured more than 25 km. upriver from any tagging site. Many females from the upper river congregated near Jacksonville in late fall. They moved downstream to New Berlin as early as January but in greater numbers during March. Early in the spawning season (February–May) females were slower to spawn and lingered longer at New Berlin before entering the ocean than those of later months (May–September).

Two hundred thirty-five blue crabs (52 males and 183 females) tagged in the St. Johns River were recovered from other waters (fig. 3). Males entered the Intracoastal Waterway north of the

TABLE 2.—*Number of tagged adult male blue crabs recovered after release at different localities in the St. Johns River*

Locality of release [1]	Crabs tagged	Area of recovery (kilometers upstream from mouth of river) [2]									Total recoveries
		215	195	170	135	95	70	40	15	0	
Km.	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Percent*
195	1,287	5	481	74	19	36	7	1	2	2	49
170	790	1	18	274	53	58	6	2	3	0	53
135	717	0	0	2	151	109	12	5	6	1	40
95	1,474	0	0	1	2	575	41	43	16	6	46
70	738	0	0	0	0	35	219	32	11	3	41
40	599	0	0	0	0	1	5	203	22	10	40
15	778	0	0	0	0	2	2	32	220	30	37

[1] Kilometers upstream from mouth of St. Johns River.
[2] Approximate areas of recovery corresponding to kilometers upstream are: 215 km.—Astor; 195—Lake George; 170—Welaka; 135—Palatka; 95—Picolata; 70—Switzerland; 40—Jacksonville; 15—New Berlin; and 0—outside river.

St. Johns River and the Nassau River during all seasons of the year and migrated to the waterway south of the St. Johns River, to the Ft. George River, and to the ocean (from Fernandina Beach to Cocoa Beach) primarily during fall and early winter. Females migrated into the ocean from April through October. Most returns were from the vicinity of the mouth of the river, but others ranged from Jekyll Island, Ga., to New Smyrna Beach, Fla. Sixty-six females recaptured in inland waters north of the St. Johns River were taken in the Intracoastal Waterway, the Ft. George, Nassau, St. Marys, and Crooked Rivers, and Kings Bay. Eight returns were from the waterway south of the St. Johns. Two of these crabs, which were tagged during late fall 1962, were recaptured dur-

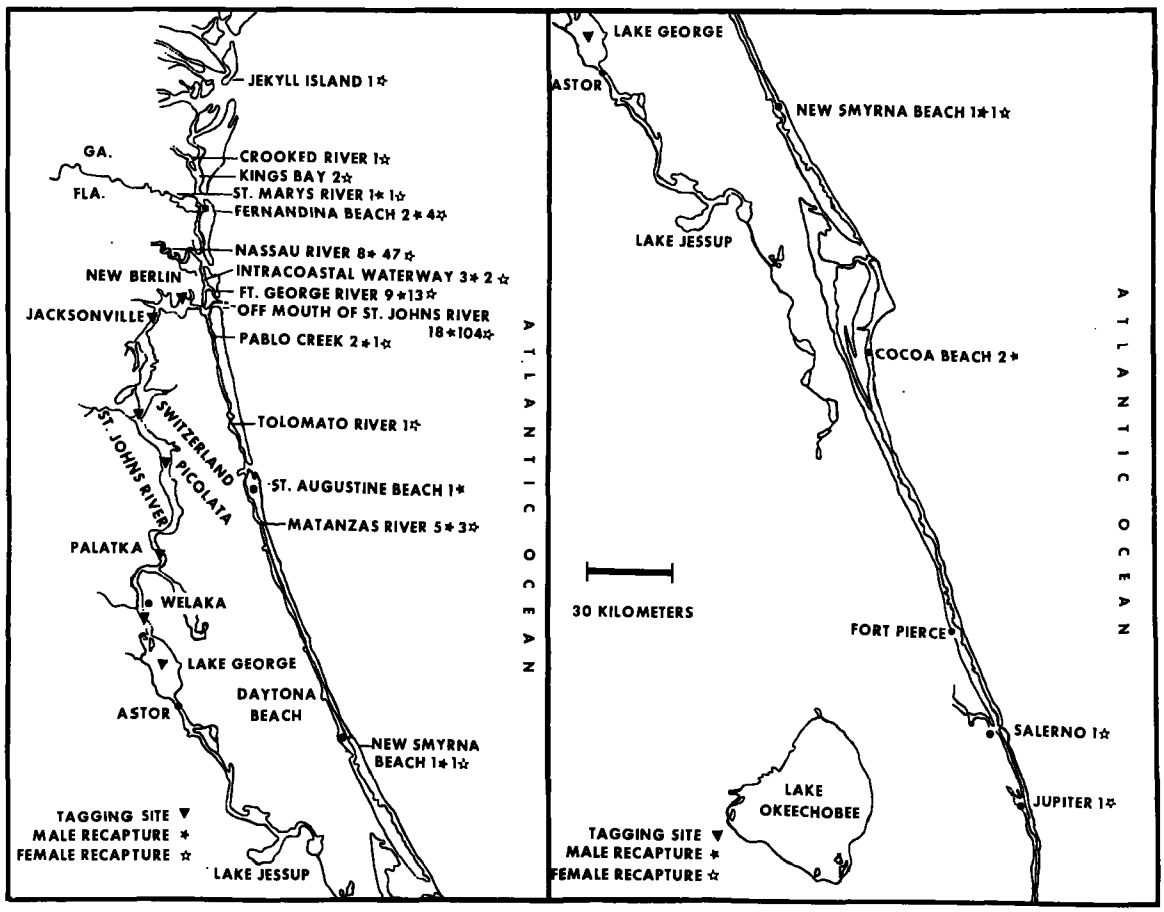

FIGURE 3.—Localities of recapture of blue crabs tagged in the St. Johns River that were recovered outside the river.

ing the succeeding winter near Salerno and Jupiter, about 460 and 540 km. from the point of release. The female recovered at Salerno traveled an average of at least 7.9 km. per day.

Some sponge female blue crabs migrated from New Berlin directly into the Intracoastal Waterway (north) and apparently entered the ocean by way of other rivers. Ten sponge females tagged at New Berlin (from April to September) were recaptured in the waterway and the Ft. George and Nassau Rivers within 3 to 14 days and before hatching in the ocean and return to inland waters were possible.

The migration of female blue crabs toward spawning grounds in high-salinity waters resembles that in other areas. The similar migration of at least some males, often parallel to females in time and distance, is unlike that reported elsewhere. In Chesapeake Bay, Van Engel (1958) reported that when females migrated downstream to the lower bay, adult males remained in brackish waters and many moved farther upstream.

Of the 381 tags recovered from female blue crabs tagged in the ocean off the mouth of the St. Johns River, 107 were from inland waters (fig. 4). Of these, 59 were recovered in the St. Johns River, 38 in the Nassau River, and the remainder in Cumberland Sound, Intracoastal Waterway, Crooked River, St. Marys River, and Ft. George River. Sixteen of the crabs that had been tagged off the mouth between May and January were recaptured in the St. Johns River during January, February, and March. These returns indicated, as did the composition of the commercial catches, that some crabs which spawned the previous season and others which matured and left the river in winter reentered the river before and during the earliest part of the spawning season. After their eggs hatched, females continued to enter the St. Johns and Nassau Rivers during summer and fall. Nearly all of the returns in the St. Johns River were between New Berlin and Jacksonville; a tag from Picolata was the only return upstream from Jacksonville. Returns from the Nassau River were mostly more than 11 km. from the mouth and extended upstream as far as 32 km.

Some female blue crabs reenter rivers very soon after their eggs hatch. From May through September, the majority of the returns in the St. Johns and Nassau Rivers of females tagged in the ocean

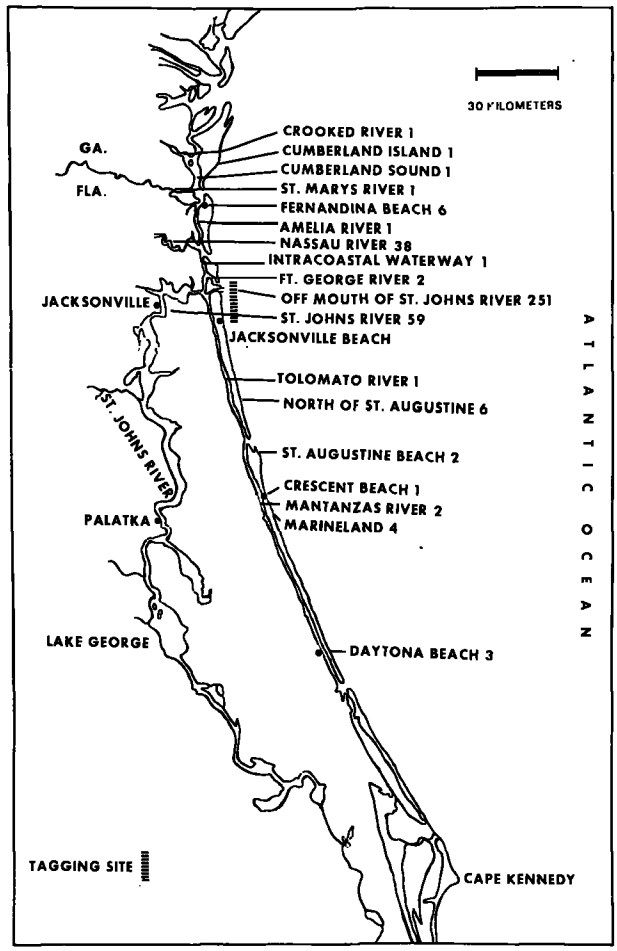

FIGURE 4.—Recovery locations of female blue crabs tagged in the ocean off the mouth of the St. Johns River.

(almost all in sponge or recently in sponge) came within 30 days, and most came within 15 days. Fifty-four of the sponge females tagged at New Berlin were recovered in the St. Johns and Nassau Rivers after more than 15 days, and, therefore, after hatching of the eggs. Of these, 40 were recovered in the rivers as soon as 16 to 45 days after release.

Eight of nine returns of male blue crabs tagged in the ocean off the mouth of the river were recaptured in that vicinity within 2 months. One male tagged in August was recovered in the Ft. George River in November.

LONGEVITY

In the St. Johns River, relatively few blue crabs survive more than 1 year after reaching maturity. We recovered only 13 tagged crabs more than 12

months after release. Three females were recaptured during the third spawning season, 20 to 24 months after they were tagged; and two males were recaptured after 33 and 36 months. If these periods are added to the approximately 12 months required to attain adult size, the maximum age of St. Johns crabs is estimated at little more than 4 years.

LARVAL STAGES

Newly hatched blue crabs pass through two larval forms, zoea and megalops. Rearing of larvae in the laboratory has shown that crabs have seven zoeal stages over a period of 31 to 49 days and a subsequent megalops stage of 6 to 20 days (Costlow and Bookhout, 1959).

Callinectes zoeae were found from April through October in samples taken between buoys 11 and 38, 3 to 11 km. above the mouth of the river. Peak abundance occurred earlier in 1962 than in 1961 (table 3). The number of zoeae per cubic meter of water ranged from 0 to 460.9. More *Callinectes* zoeae were collected near the surface than at the bottom regardless of tidal direction. No evidence appeared of retention of *Callinectes* zoeae within the estuary, as more were obtained during outgoing tides than during incoming tides.

Most of the larval *Callinectes* captured were first-stage zoeae, but some second-stage zoeae and some megalops also were caught. The proportion of second-stage to first-stage zoeae was 1 to 323. The second-stage form occurred in one surface sample in May (1.5 per 1 m.^{3}) and in four surface and four bottom samples in August (0.6–2.6 per 1 m.^{3}). The proportion of megalops to zoeae was 1 to 164. Megalops were found in three July samples (0.5–1.1 per 1 m.^{3}), two August samples (1.1–18.6 per 1 m.^{3}), and two September samples (0.4 and 0.5 per 1 m.^{3}). Ninety-six percent of the megalops were taken in bottom collections.

Zoeae of 22 kinds of crabs and megalops of 5 genera were collected between buoys 11 and 38. In 1961, *Callinectes* zoeae ranked third in abundance after *Uca* and *Sesarma* (table 4), and in 1962 *Callinectes* ranked second to *Uca* (table 5). Megalops of four other genera were collected from May through October. Sixteen samples contained *Uca*

TABLE 3.—*Number of* Callinectes *zoeae collected per cubic meter of water in the St. Johns River between buoys 11 and 38 (3–11 km. above mouth of river)*

Month and depth (meters)	1961			1962		
	Samples	Zoeae per 1 m.^{3}		Samples	Zoeae per 1 m.^{3}	
		Average	Range		Average	Range
	Number	*Number*	*Number*	*Number*	*Number*	*Number*
January:						
0.3				8	0	0
10.0				8	0	0
February:						
0.3				7	0	0
10.0				7	0	0
March:						
0.3				8	0	0
10.0				8	0	0
April:						
0.3				4	5.4	2.3– 8.2
10.0				4	1.5	0 – 4.2
May:						
0.3	12	0.3	0 – 3.7	8	51.4	0 –157.3
10.0	12	.7	0 – 7.6	8	18.2	1.1– 52.4
June:						
0.3	11	6.2	0 – 24.0	16	53.8	0 –460.9
10.0	11	2.0	0 – 8.3	16	24.2	0 –129.0
July:						
0.3				8	6.2	0 – 23.7
10.0				8	6.9	0.5– 22.3
August:						
0.3	8	119.5	16.9–358.0	23	4.0	0 – 25.2
10.0	8	82.8	12.1–231.8	23	1.7	0 – 9.0
September:						
0.3	8	.2	0 – 1.3	15	.9	0 – 4.1
10.0	8	.4	0 – .9	15	.3	0 – 2.0
October:						
0.3	16	.1	0 – 1.4	14	.1	0 – .8
10.0	16	.1	0 – 1.2	14	0	0
November:						
0.3	8	0	0	14	0	0
10.0	8	0	0	14	0	0
December:						
0.3	8	0	0			
10.0	8	0	0			

TABLE 4.—*Estimated average number of crab zoeae per cubic meter of water, between buoys 11 and 38 (3–11 km. above mouth of St. Johns River) in May, June, and August–December, 1961*

[Number of samples each month in parentheses]

Species	May (24)	June (22)	Aug. (16)	Sept. (16)	Oct. (32)	Nov. (16)	Dec. (16)	Total (142)	Rank in abundance
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	
Callinectes sp.	0.5	4.1	101.2	0.3	0.1	0.0	0.0	106.2	3
Emerita sp.	[1].0	.1	.0	.2	.0	.0	.0	.3	16
Eurypanopeus sp.	3.2	1.7	28.2	3.5	.9	.0	.0	37.5	5
Hepatus sp.	.0	.0	.8	2.4	.0	.0	.0	3.2	9
Leucosiidae	.0	.0	.2	1.0	.0	.0	.0	1.2	14
Menippe sp.	[1].0	.6	1.5	3.1	.0	.0	.0	5.2	7
Neopanope sp.	.6	.0	2.5	.9	.1	.0	.0	4.1	8
Pachygrapsus sp.	.0	.0	.0	.0	[1].0	.1	.0	.1	18
Panopeus sp.	.7	1.4	51.8	19.9	.1	.0	[1].0	73.9	4
Pilumnus sp.	.0	.0	.0	.1	.0	.0	.0	.1	18
Pinnixa sp.	.4	.3	.7	10.2	.5	.2	.3	12.6	6
Pinnotheres maculatus	.0	.4	.8	.7	[1].0	.1	.0	2.0	12
Pinnotheres ostreum	[1].0	[1].0	2.1	.2	.1	.0	.0	2.4	11
Polyonyx sp.	.2	.0	.2	2.5	[1].0	.0	.0	2.9	10
Portunus gibbesii	.0	.1	1.0	.8	.0	.0	.0	1.9	13
Portunus sayi	.2	.0	.0	.0	.0	.0	.0	.2	17
Rithropanopeus sp.	.8	.0	.1	.1	[1].0	.0	.0	1.0	15
Sesarma sp.	2.5	6.3	104.4	6.6	.2	.0	.0	120.0	2
Uca sp.	4.4	29.3	742.5	18.5	.4	.0	.0	795.1	1
Unknown A	.0	.0	[1].0	.1	[1].0	.0	.0	.1	18
Unknown D	.0	.0	.0	.0	.0	.1	.0	.1	18

[1] Less than 0.06.

(0.6–59.6 per 1 m.^{3}), 12 contained *Sesarma* (0.6–19.8 per 1 m.^{3}), 10 contained *Neopanope* (0.5–9.7 per 1 m.^{3}), and 9 contained *Panopeus* (0.5–2.3 per 1 m.^{3}). Megalops of *Uca* and *Sesarma* were more abundant than *Callinectes*. As for *Callinectes*, 96 percent of the megalops of the other genera were from bottom collections.

Plankton collections were made also at buoy 63, 40 km. from the mouth of the river, during May and October 1961 and August 1961 and 1962 (table 6). *Callinectes* zoeae occurred in three May samples (1.2–4.7 per 1 m.^{3}) and 10 August samples (0.9–6.1 per 1 m.^{3}); 10 of these 13 samples were taken near the bottom. One bottom sample in May contained second-stage zoeae (2.4 per 1 m.^{3}), and two bottom collections in August had megalops (both 1.2 per 1 m.^{3}). *Rithropanopeus*, *Sesarma*, and *Uca* were the most abundant genera in the collections. Megalops collected in May were, in decreasing order of abundance, *Sesarma*, *Uca*, *Rithropanopeus*, and *Panopeus*. August samples contained megalops of only *Uca* and *Callinectes*.

Most of the larval *Callinectes* collected in the St. Johns River occurred at salinities and temperatures favorable to larvae reared in the laboratory. Laboratory-reared larvae of *C. sapidus* had a uniform rate of growth in salinities between 20.1 and 31.1 p.p.t. at 25° C. (Costlow and Bookhout, 1959). Even though almost all *Callinectes* larvae captured near the mouth of the St. Johns River (buoys 11–38) both at the surface and near the bottom were in favorable salinities, some of those captured upriver (buoy 63) were in salinities which probably would be too low to sustain them over extended periods. Salinity near the mouth (surface and bottom) was between 25 and 35 p.p.t. from April to July and between 12 and 36 p.p.t. from August to October. Bottom salinity was nearly always greater than that at the surface, particularly during ebb tide. At buoy 63, larval *Callinectes* were captured in salinities from 9 to 27 p.p.t. Water temperature (April to October) in the lower 40 km. of river ranged from lows of 20° C. in April and October to a high of 31° C. in August. Temperature at the surface and bottom usually differed less than 1° C.

Plankton was collected between buoys 2 and 3 in south Jacksonville (48 km. above mouth of river) during August and October 1961. No *Callinectes* larvae were obtained. Zoeae and megalops of *Rithropanopeus* were predominant and present in almost all of the collections (zoeae: 0.7–61.7 per 1 m.^{3}). Zoeae of *Uca* and *Sesarma*, many of them dead, were the only other larvae collected. Surface salinities in these months ranged from 0 to 10 p.p.t. and bottom salinities from 5 to 11 p.p.t.

Plankton collections made in the South Atlantic by the *Theodore N. Gill* in 1953–54 have been analyzed for the occurrence of *Callinectes* larvae (Nichols and Keney, 1963). Six stations were sampled off the mouth of the St. Johns River—one at the mouth, and five others, 32 km. apart, extending due east. Stages of zoeae found at the inshore station were the same as in the river—primarily

TABLE 5.—*Estimated average number of crab zoeae per cubic meter of water, between buoys 11 and 38 (3–11 km. above mouth of St. Johns River) in January–November, 1962*

[Number of samples each month in parentheses]

Species	Jan. (16)	Feb. (14)	Mar. (16)	Apr. (8)	May (16)	June (32)	July (16)	Aug. (46)	Sept. (30)	Oct. (28)	Nov. (28)	Total (250)	Rank in abundance
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	
Callinectes sp.	0.0	0.0	0.0	3.4	34.8	39.0	6.5	2.8	0.6	[1] 0.0	0.0	87.1	2
Dissodactylus sp.	.0	.0	.0	.0	.2	.0	.0	.0	.0	.0	.0	.2	17
Eurypanopeus sp.	.0	.0	.2	1.0	11.1	5.4	.7	.9	1.6	.6	.0	21.5	5
Hepatus sp.	.0	.0	.0	.0	4.9	.3	[1] .0	.1	.4	.1	.0	5.8	9
Leucosiidae	.0	.0	.0	.0	1.4	.1	[1] .0	.2	.1	.0	.0	1.8	12
Menippe sp.	.0	.0	.0	.0	.1	.1	.4	.5	1.3	.2	.0	2.6	11
Neopanope sp.	.0	.0	[1] .0	2.4	4.8	1.2	.2	.3	.3	.1	[1] .0	9.3	6
Pachygrapsus sp.	.0	.0	.0	.0	.0	.0	.0	.0	[1] .0	.0	[1] .0	[1] .0	19
Panopeus sp.	.0	.0	.0	3.9	26.3	5.2	.9	1.2	.2	.1	.0	37.8	4
Pilumnus sp.	.0	.0	.0	.0	[1] .0	.0	.0	[1] .0	[1] .0	[1] .0	.0	[1] .0	19
Pinnixa sp.	.3	.2	[1] .0	.4	3.6	1.0	.3	.3	.7	.4	.3	7.5	7
Pinnotheres maculatus	.0	.0	.0	.0	.1	.8	.0	.2	.2	.1	.1	1.5	14
Pinnotheres ostreum	.0	.0	.0	2.3	2.4	1.3	.2	[1] .0	[1] .0	.1	[1] .0	6.3	8
Polyonyx sp.	.4	.0	.2	.4	.3	.1	[1] .0	[1] .0	.2	.1	[1] .0	1.7	13
Portunus gibbesii	.0	.0	.0	.3	.5	.0	.0	[1] .0	.0	.0	.0	.8	15
Portunus sayi	.0	.0	.1	.0	2.1	.6	[1] .0	.0	.0	.0	.0	2.8	10
Rithropanopeus sp.	.0	.0	.0	.1	[1] .0	.2	.0	[1] .0	.2	[1] .0	[1] .0	.5	16
Sesarma sp.	.0	.0	.0	8.6	33.6	3.4	3.7	6.6	4.3	1.1	.0	61.3	3
Uca sp.	.0	.0	.0	63.5	137.6	17.2	7.0	5.5	4.2	2.5	.0	237.5	1
Unknown A	.0	.0	.0	.0	.0	.0	.0	.0	.0	.1	.0	.1	18
Unknown D	.0	.0	.0	.0	.0	.0	.0	.0	.0	[1] .0	.0	[1] .0	19

[1] Less than 0.06.

TABLE 6.—*Estimated average number of crab zoeae per cubic meter of water at buoy 63 (40 km. above mouth of St. Johns River) for certain months, 1961–62*

[Number of samples each month in parentheses]

Species	May (16)	Aug. (38)	Oct. (16)	Range
	Number	*Number*	*Number*	*Number*
Callinectes sp.	0.6	0.5	0.0	0– 6.1
Eurypanopeus sp.	5.9	.2	.2	0– 21.5
Menippe sp.	.0	[1].0	.0	0– .7
Neopanope sp.	1.9	.1	.0	0– 7.2
Panopeus sp.	.4	.2	.0	0– 2.2
Pinnixa sp.	.2	[1].0	.1	0– 1.6
Pinnotheres maculatus	.2	.0	.0	0– 1.9
Pinnotheres ostreum	.1	[1].0	.0	0– 2.1
Portunus gibbesii	.1	.0	.0	0– 1.1
Portunus sayi	.0	[1].0	.0	0– .9
Rithropanopeus sp.	25.2	22.4	.2	0–184.7
Sesarma sp.	28.8	2.6	.0	0–132.6
Uca sp.	112.3	6.5	.0	0–294.0

[1] Less than 0.06.

first but some second stage. All stages occurred at 32, 64, and 96 km. offshore. A few zoeae were obtained about 160 km. from shore. The relatively few megalops collected were at 64 and 128 km. offshore. *Callinectes* megalops were collected directly off the jetties in July, however, during limited sampling offshore in our study.

In brief, sampling for larval crabs in the St. Johns indicated that *Callinectes* was one of the most abundant forms in the region near the mouth. First- and second-stage zoeae entered and left the lower 40 km. of river from April to October. They were transported by surface and bottom currents; megalops usually were confined to the bottom. Early development occurs in the ocean within a few kilometers of shore, and growth after the second zoeal stage takes place farther offshore. Some larvae return to inshore waters as megalops.

JUVENILE CRABS

Although juvenile blue crabs were found in many localities from the mouth of the river to Astor, they usually occurred in small numbers or in larger numbers for short periods of time. Preferred habitats of those less than 40 mm. wide were in shallow water where the bottom consisted of either muck covered with dead plant material or firmer mud covered with dense growths of coontail (*Ceratophyllum*) and eelgrass (*Vallisneria*). Certain areas, where relatively large numbers of crabs congregated the year round, were selected for sampling at regular intervals in 1962 and 1963. These areas, and distances from the mouth of the St. Johns, were: Clapboard Creek (15 km.); Dunn Creek (30 km.); Trout River (40 km.); buoy 24, Picolata (95 km.); and buoy 11, Palatka (135 km.).

Postlarval stages of crabs continue to molt periodically until full size is attained. The megalops molts directly into the first crab stage (2–3 mm. wide), which has the general appearance of the adult. Growth ceases after about 20 postlarval molts. Full size is attained in about 1 year; crabs shed every few days at the earliest stages and at intervals of 1 month or more at later preadult stages.

Early stages of blue crabs (2–9 mm. wide) entered the sampling areas in the lower 40 km. of river primarily as waves, beginning 5 or more months after spawning began and continuing to the end of the year. A few early crab stages appeared before this time, but only the occurrence of large numbers was considered a wave. The waves, except in early winter, were made up of crabs predominantly 6 to 9 mm. wide and beyond the initial crab stages. I collected few crabs 2 to 3 mm. wide during summer and fall. Escape of an appreciable number of first crab stages through the nets was unlikely as the catch in the stations of the lower river was always mixed with a great amount of mud and debris.

The area of metamorphosis of the megalops to the first crab stage has not been determined, but transformation probably takes place most frequently in the ocean. In the south Atlantic, most *Callinectes* megalops were found 64 or more kilometers offshore (Nichols and Keney, 1963). It is not surprising that we collected relatively few first and second crab stages in the river if transformation to the first crab stage also happens beyond 64 km. Some megalops may enter the first crab stage within the estuary, because megalops do appear in the river and directly off its mouth. Two megalops were collected along with early crab stages in Trout River.

The first waves of early crab stages in Dunn Creek and Trout River were in July 1962 and September 1963. With the early waves each year, abundance of individuals less than 20 mm. wide increase markedly (fig. 5). Like the initial spawning run, the first appreciable occurrence of young crabs was later in 1963 than in 1962.

First and second crab stages (2–4 mm. wide) predominated among early stages (2–9 mm. wide)

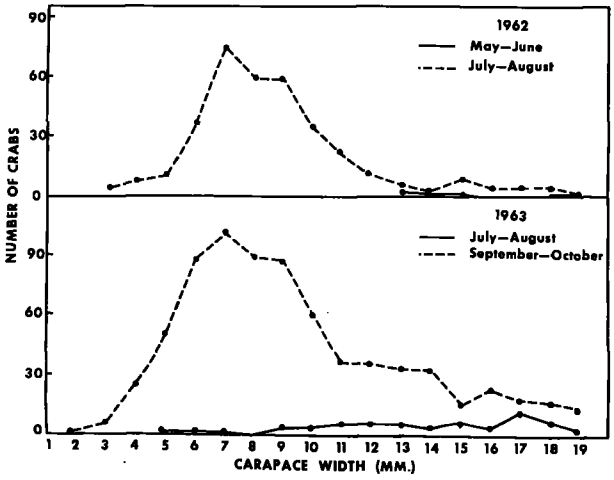

FIGURE 5.—Width distribution of blue crabs less than 20 mm. wide collected before and after the initial wave in Dunn Creek and Trout River.

in Dunn Creek and Trout River during December and January (fig. 6). These crabs were hatched in October and November, and subsequent winter temperatures probably inhibited postlarval growth. They shed throughout the winter but less frequently than in other seasons.

Waves of early blue crab stages also entered Clapboard Creek in 1962, but no appreciable influx was observed during 1963. Small numbers, including a few first crab stages, occurred among much larger numbers of *Callinectes similis* or *C. ornatus* from July to October 1963. No congregations of blue crabs developed, possibly because of competition for food and space from small juveniles of these other species, which were established in Clapboard Creek as early as May (Tagatz, 1967).

The influx of early crab stages was not confined to the lower river but extended 95 km. and more upstream. Early crab stages over 5 mm. wide first appeared at Picolata (buoy 24) during the same month as the initial waves in the lower river—July 1962 and September 1963. In 1962, most early crab stages were widely scattered in shallow areas adjacent to buoy 24; in 1963, waves and subsequent growth were clearly evident at this station (fig. 7). Crabs that made up the waves were larger than those entering lower river areas, and no crabs less than 6 mm. wide were caught. A few early crab stages 8 to 9 mm. wide were collected at Palatka (buoy 11).

In the St. Johns River, some juvenile blue crabs grew to maturity (or a harvestable size of at least 120 mm.) between the mouth and Jacksonville, but most females attained maturity between Jacksonville and Palatka; most males matured upstream of Palatka. Juvenile males were less abundant than juvenile females in the lower river, and the percentage of males increased with distance upstream (table 7). I found the largest concentrations of juvenile crabs 20 to 119 mm. wide at Picolata (buoy 24). Because of variation in growth rate and a long spawning season, significant numbers of crabs were one or more molts away from harvestable size during all seasons (table 8). Juveniles 20 to 39 mm. wide were most common in spring and fall. They were more widely distributed in the shallows along shore than larger crabs which remained in the channel. Juveniles 20 to 119 mm. wide also concentrated at Palatka (buoy 11). Upstream of Palatka, juveniles were nearly

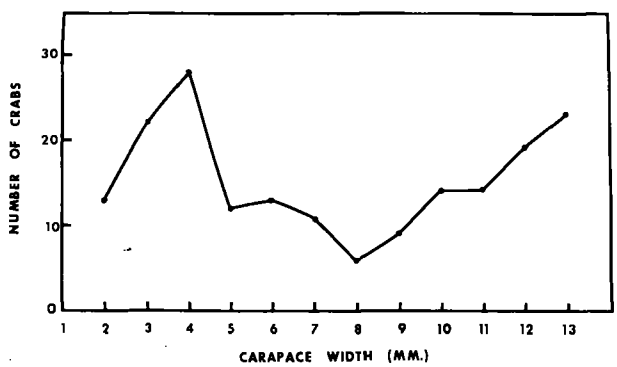

FIGURE 6.—Width distribution of blue crabs less than 14 mm. wide collected in Dunn Creek and Trout River during December 1962 and January 1963.

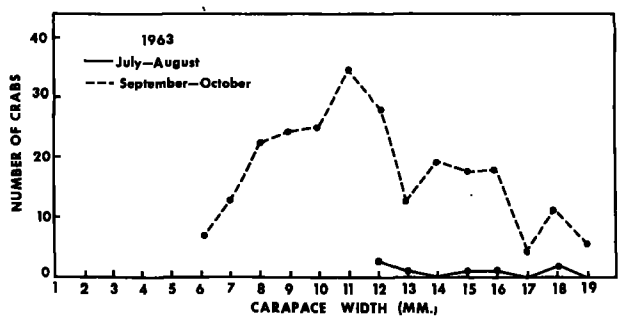

FIGURE 7.—Width distribution of blue crabs less than 20 mm. wide collected before and after the initial wave at Picolata (buoy 24).

TABLE 7.—*Percentage of males among juvenile blue crabs collected at selected stations in the St. Johns River. Distance upstream in kilometers is shown in parentheses*

Width	Trout River (40)		Buoy 24 Picolata (95)		Buoy 11 Palatka (135)	
	Crabs collected	Males	Crabs collected	Males	Crabs collected	Males
Mm.	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
20- 39	231	47	211	52	56	79
40- 59	167	43	376	50	121	68
60- 79	118	47	481	50	162	76
80- 99	118	32	502	47	161	61
100-119	103	27	639	41	114	66
Total	737	41	2,209	47	614	69

all males and generally were larger than 100 mm. wide (relatively few mates are available to the mature males that remain above Palatka). Juvenile blue crabs under 100 mm. and usually over 30 mm. occurred irregularly between Palatka and Welaka. Nearly all juveniles above Welaka were over 100 mm. wide; the smallest blue crab I caught was 25 mm.

In summary, juveniles, primarily beyond the initial crab stages, enter the St. Johns in waves during the latter part of the spawning season. The time of the first wave appeared to depend on the time of initial spawning. Many first and second crab stages entered in early winter. Individuals as small as 8 mm. wide moved at least 135 km. upstream. Juvenile blue crabs were widely distributed but concentrated the year around in certain localities. Those less than 40 mm. wide were most common in shallower waters; those more than 40 mm., in deeper areas. Females predominated in the lower river and males in the upper river.

FOOD OF BLUE CRABS

Blue crabs eat a great variety of foods. Fish, alive and dead, are eaten regularly (dead fish are used as bait in the commercial fishery). The diet of blue crabs includes many types of aquatic vegetation (Truitt, 1939), and they have been reported to eat oysters (Lunz, 1947) and other bivalves (Carriker, 1951). Darnell (1958) found that blue crabs of Lake Pontchartrain, La., fed principally on mollusks (clams, mussels, and snails), crustaceans (mostly crabs but also barnacles and undetermined forms), and to a lesser degree on insects, hydroids, annelid worms, fish, algae, and vascular plants.

Little is known of the foods that sustain larval crabs. Most successful foods for growth of zoeae in the laboratory are yellow dinoflagellates (Sandoz and Rogers, 1944) and *Artemia* nauplii and *Arbacia* eggs (Costlow and Bookhout, 1959). The megalops is omnivorous and will eat pieces of fish, shellfish, and aquatic plants (Van Engel, 1958).

Of the 695 blue crab stomachs collected at four localities—Clapboard Creek (15 km. upstream from mouth of St. Johns River), Dunn Creek (30 km. upstream), Trout River (40 km. upstream), and buoy 24, Picolata (95 km. upstream)—668 contained food. Classes of food as percentage frequency of occurrence were:

Food item	*Percent*
Mollusks	32.4
Crustaceans	19.4
Organic debris	17.0
Fish	15.6
Plants	8.5
Annelids	5.0
Insects	1.4
Bryozoans	.6

Classes of food as percentage of the total volume of food per stomach were:

Food item	*Percent*
Mollusks	39.0
Organic debris	19.8
Fish	19.4
Crustaceans	15.0
Plants	3.9
Annelids	1.8
Insects	.9
Bryozoans	.1

TABLE 8.—*Monthly size distribution of juvenile blue crabs collected at buoy 24, Picolata, St. Johns River, Fla., 1962*

Width	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Mm.	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
20- 39	5	9	13	2	7	1	2	14	21	21	14	22
40- 59	21	16	25	12	12	12	3	10	35	23	15	15
60- 79	29	19	21	22	30	30	11	9	20	22	19	19
80- 99	28	19	23	27	30	27	20	17	12	14	23	22
100-119	17	37	18	36	21	30	64	50	12	19	29	22
Total number of crabs	187	104	381	313	186	246	142	174	113	188	143	32

A large percentage of stomach contents consisted of organic material in advanced stages of digestion which could not be identified. Sand, mud, wood, charcoal, and similar debris (not recorded) were often taken by crabs incidentally in feeding. Sand, ranging from a single grain to several hundred grains, occurred in all gastric mills. A greater proportion of sand, relative to food content, was present in smaller crabs (less than 50 mm. wide) than in larger ones.

Generally all sizes of blue crabs ate the same types of foods (table 9) at all four stations sampled (table 10). Most of the mollusks eaten were mussels and clams. No mussels were found in crabs less than 21 mm. wide. Mussels eaten in the lower river stations (Clapboard Creek, Dunn Creek, and Trout River) were almost all *Modiolus demissus* but included a few *Musculus niger*. The only species present and eaten at Picolata was *Mytilopsis leucopheata*. Mussels were strongly predominant in crabs from Picolata where clams played a relatively minor role in the diet. Small numbers of *M. leucopheata* were present in Trout River, but none appeared in stomach samples. Mussels selected were less than an estimated 15 mm. long, and usually the shell in the stomach was fragmented. Very small mussels, 1.5 to 5.0 mm., were preferred; the gastric mill of adults often contained 25 to 50. Of the clams, Sphaerridae, *Rangia cuneata*, and *Mulinia lateralis* were consumed, and probably other clams common to the lower river—*Tellina alternata*, *T. syharitica*, *Tagelus gibbus*, and *Mactra fragilis*. Crabs less than 21 mm. wide selected clams less than 2 mm., and even adults usually took clams under 10 mm. The stomachs of small crabs most often contained 5 to 10 clams, whereas those of larger crabs usually had 20 to 35 individuals. A few of the mollusks eaten were oyster spat, *Crassostrea virginica*, and snails, *Nassarius obsoletus* and possibly *Nassarius vibex* and *Neritina reclivata*.

Amphipods and crabs were the dominant Crustacea eaten. *Gammarus fasciatus* was taken at all stations, and *Corophium* sp. was a particularly important food of all sizes of blue crabs at Picolata. *Carinogammarus mucronatus* and *Talorchestia longicornis*, present in the lower river, probably were among other amphipods eaten. Crabs less than 31 mm. wide commonly had 10 to 15 amphipods in their stomachs. Of the crabs eaten, about one-half of those that could be identified were blue crabs and the remainder mud crabs—*Rithropanopeus harrisi* and probably *Panopeus herbstii* and *Eurypanopeus depressus*. No more than four individuals were in any food tract, and none appeared to have exceeded 20 mm. The mysid, *Neomysis americana* (listed as a shrimplike form), was taken fairly frequently, particularly in Clapboard Creek. Shrimplike forms as large as an estimated 30 mm. provided food but were too fragmented for positive identification. The most common shrimp at all stations were *Palaemonetes pugio* and *P. vulgaris*, and at Picolata, also *Macrobrachium ohione*. Ostracods

TABLE 9.—*Food of the blue crab, by crab size, in the St. Johns River as percentage frequency of occurrence and (in parentheses) as percentage of total volume per stomach*

[Number of stomachs with food in parentheses below designation of size group of crabs]

Food item	Width in mm.							
	5–10 (32)	11–20 (94)	21–30 (82)	31–40 (56)	41–50 (42)	51–100 (139)	101–200 (223)	Total (668)
Bryozoans		[1]1(0)			[1]2(0)	[1]1(0)	[1]2(0)	[1]1(0)
Mussels			5(1)	9(4)	10(3)	34(25)	46(36)	24(18)
Clams	9(4)	31(19)	49(26)	38(18)	33(17)	34(21)	32(17)	34(19)
Oysters						1(1)	4(2)	2(1)
Snails			13(3)	9(4)	5(3)	4(1)	[1]1(0)	4(1)
Nereis pelagica	[1]6(0)	7(1)	21(4)	18(5)	24(7)	10(1)	[1]2(0)	10(2)
Other annelids						[1]1(0)		[1]0(0)
Amphipods	6(6)	3(2)	18(6)	12(8)	17(9)	27(12)	10(2)	14(6)
Barnacles		[1]1(0)	[1]1(0)			[1]1(0)	[1]2(0)	[1]1(0)
Ostracods	9(5)	[1]2(0)					[1]1(0)	[1]1(0)
Shrimplike forms			4(2)	4(2)	5(5)	4(1)	[1]1(0)	2(1)
Crabs		[1]1(0)	10(4)	12(7)	12(2)	19(7)	13(3)	12(4)
Other crustaceans	28(22)	23(14)	8(5)	11(4)	7(1)	5(1)	[1]1(0)	8(4)
Insects		6(4)	5(2)	7(1)	[1]2(0)	[1]1(0)	[1]1(0)	3(1)
Fish		16(9)	39(19)	27(16)	38(26)	32(19)	38(26)	31(19)
Algae	12(4)	16(6)	11(3)	14(5)	14(2)	4(1)	[1]3(0)	8(2)
Vascular plants		[1]3(0)	7(1)	7(1)	21(6)	12(1)	8(2)	8(2)
Organic debris	72(59)	66(43)	43(24)	50(24)	36(17)	16(8)	18(10)	34(20)

[1] Less than 0.6 percent.

TABLE 10.—*Food of the blue crab, by crab size and by station, in the St. Johns River as percentage frequency of occurrence and (in parentheses) as percentage of total volume per stomach*

[Stations and distance from mouth: 1–Clapboard Creek 15 km., 2–Dunn Creek 30 km., 3–Trout River 40 km., 4–Picolata 95 km. Number of stomachs with food in parentheses below designation of station]

Food item	Width in mm., station number, and number of stomachs with food											
	5–50				51–100				101–200			
	1 (55)	2 (120)	3 (100)	4 (31)	1 (31)	2 (15)	3 (37)	4 (56)	1 (67)	2 (34)	3 (46)	4 (76)
Bryozoans		[1]1(0)	[1]1(0)				[1]3(0)			[1]3(0)	[1]2(0)	[1]4(0)
Mussels			9(3)	13(5)	[1]6(0)	7(3)	30(23)	61(44)	12(5)	15(11)	65(45)	79(68)
Clams	73(47)	27(13)	35(15)		58(31)	67(50)	43(28)	7(3)	43(31)	59(24)	35(20)	8(1)
Oysters					6(4)				12(7)	3(1)	[1]2(0)	
Snails		[1]1(0)	17(6)		3(1)		11(4)	[1]2(0)	[1]1(0)			[1]1(0)
Nereis pelagica	5(2)	[1]10(0)	31(9)		16(1)	[1]7(0)	22(4)		[1]3(0)	[1]9(0)		
Other annelids							[1]3(0)	[1]2(0)				
Amphipods	[1]2(0)	2(1)	16(5)	48(30)	3(1)	[1]13(7)		62(28)		[1]3(0)		29(6)
Barnacles			[1]2(0)			7(0)					2(1)	4(1)
Ostracods	5(3)		[1]1(0)	3(2)								[1]3(0)
Shrimplike forms	11(8)		[1]1(0)		6(2)	7(1)	8(1)			[1]3(0)	2(1)	
Crabs	[1]2(0)	4(2)	12(5)	10(4)	10(5)	20(8)	32(14)	14(3)	12(2)	15(3)	11(3)	16(3)
Other crustaceans	16(8)	12(7)	15(8)	29(22)	[1]3(0)		8(1)	5(2)				[1]3(0)
Insects		9(4)	2(1)	6(1)			[1]3(0)	[1]2(0)		[1]3(0)		[1]1(0)
Fish	27(15)	28(16)	27(12)	10(10)	48(37)	40(25)	32(15)	20(11)	52(42)	62(39)	35(26)	17(8)
Algae	9(1)	9(5)	19(5)	22(4)	10(1)		3(2)	[1]4(0)	[1]3(0)	[1]3(0)		5(1)
Vascular plants	5(2)	[1]2(0)	13(2)	10(2)	[1]10(0)	20(1)	16(2)	9(2)	4(2)	15(2)	[1]2(0)	12(4)
Organic debris	38(13)	64(49)	51(28)	45(21)	19(16)	7(5)	16(6)	16(6)	18(11)	24(19)	9(3)	21(9)

[1] Less than 0.6 percent.

were an important food of 5- to 10-mm. crabs. Barnacles were infrequent foods but as many as 50 small *Balanus eburneus* were eaten by a 124-mm. crab at Picolata. Many crustaceans were too decomposed or fragmented to classify—particularly microcrustacea in crabs less than 21 mm. Some of the larger fragments closely resembled isopods.

Fish was a major food, especially of larger crabs. Ingested fish could not be identified, but distinguishable parts indicated that small and large fish of many species were eaten. No fish was observed in crabs less than 11 mm. wide.

Algae and vascular plants were frequent in the stomachs of blue crabs. Algae with the exception of *Ulva* were not identified but most often occurred as many filaments. Crabs ate the leaves, stems, roots, and seeds of various species of higher plants (only *Ceratophyllum* and *Vallisneria* were identified). Occasionally 20 to 30 small uniform-sized pieces of *Vallisneria* leaves in a stomach appeared to have been eaten from the plant.

Among lesser food items, *Nereis pelagica* was regularly consumed by all sizes of crabs at the lower river stations. Other annelids were taken infrequently at Trout River and Picolata. Insects were eaten at all stations except Clapboard Creek. Each stomach always contained several individuals. Gastric mill contents included adults of Coleoptera, Diptera, Hemiptera, and Hymenoptera, and young of Diptera and Odonata. Bryozoa occurred only as occasional fragments.

Blue crabs often ate the same food items during each of the three seasons of sampling (table 11), and they usually consumed the most available foods. The largest numbers of mussels were eaten in spring and summer when young mussels (less than 5 mm.) were first abundant. We found clams of all sizes common in the lower river during all seasons. Because small clams were uncommon at Picolata the abundant mussel population probably was utilized to a greater degree. Oysters and snails (particularly *Nassarius obsoletus*) were common in the lower river but provided only limited amounts of food. Amphipods were most abundant at Picolata, where they were consumed most extensively. Young blue crabs and mud crabs were common in all months of sampling, but relatively few occurred in the food tracts in winter. Shrimplike forms were not eaten in proportion to the large number generally present at all stations. We collected many fish of all sizes the year around. The percentage eaten was smaller at Picolata than at the lower river stations, which served as nursery areas for a greater variety of abundant species. Consumption of fish was high during winter before recruitment of young mussels. Although aquatic plants grew most profusely at Picolata, they were not a preferred food.

TABLE 11.—*Food of the blue crab, by crab size and by season, in the St. Johns River as percentage frequency of occurrence and (in parentheses) as percentage of total volume per stomach*

[Number of stomachs with food in parentheses below designation of season]

Food item	Width in mm., season, and number of stomachs with food								
	5–50			51–100			101–200		
	Dec.–Feb. (61)	Mar.–May (160)	June–Aug. (85)	Dec.–Feb. (21)	Mar.–May (74)	June–Aug. (44)	Dec.–Feb. (25)	Mar.–May (143)	June–Aug. (55)
Bryozoans		[1] 1(0)			[1] 1(0)			[1] 2(0)	[1] 4(0)
Mussels		4(2)	7(2)	14(9)	44(35)	27(15)	20(14)	52(42)	42(29)
Clams	26(13)	34(20)	44(20)	24(15)	28(20)	50(26)	40(31)	28(13)	38(22)
Oysters						4(3)		6(2)	4(2)
Snails		2(2)	16(4)		[1] 3(0)	9(3)		[1] 1(0)	[1] 2(0)
Nereis pelagica	[1] 6(0)	17(4)	18(4)		9(1)	16(2)		[1] 3(0)	
Other annelids				[1] 5(0)	[1] 1(0)				
Amphipods	5(3)	11(5)	16(7)	28(14)	24(11)	32(13)	12(1)	[1] 6(0)	22(6)
Barnacles		[1] 1(0)	[1] 1(0)			[1] 2(0)			7(2)
Ostracods	2(1)	1(1)	[1] 2(0)					[1] 1(0)	[1] 2(0)
Shrimplike forms	6(5)	1(1)	[1] 2(0)	10(2)	[1] 3(0)	[1] 4(0)		[1] 1(0)	[1] 2(0)
Crabs	3(2)	7(4)	9(2)		22(8)	23(8)		11(2)	25(7)
Other crustaceans	18(14)	13(6)	18(12)	5(1)	[1] 3(0)	9(3)		[1] 1(0)	
Insects	[1] 2(0)	6(3)	6(2)		[1] 1(0)	[1] 2(0)		[1] 1(0)	[1] 2(0)
Fish	30(23)	20(11)	33(13)	57(44)	24(14)	32(16)	48(42)	41(27)	25(17)
Algae	23(10)	17(5)	[1] 1(0)	24(3)	1(1)		24(3)	[1] 1(0)	
Vascular plants	5(1)	8(1)	7(2)	[1] 5(0)	14(2)	14(1)	[1] 8(0)	9(3)	5(1)
Organic debris	38(28)	56(36)	60(31)	14(10)	15(6)	18(10)	12(9)	17(9)	24(12)

[1] Less than 0.6 percent.

The year-round abundance of preferred food items undoubtedly is a major cause for the large concentrations of juvenile blue crabs near Picolata. Random sampling with trawl and dredge below Picolata (between buoys 18 and 22) in summer indicated relatively less plant cover and less food, particularly amphipods and mussels. Juvenile crabs that fed on mollusks in the lower river conceivably are attracted to an accustomed food, such as mussels, at Picolata. Crabs also benefit from an interesting food chain transition at buoy 24. Young mussels occur most commonly within large clam valves. When the mussels are chewed off, chironomid larvae build algal tunnels on which amphipods feed and provide a second feeding for crabs.

In brief, blue crabs 5 to 200 mm. wide fed principally on mollusks, fish, and crustaceans and to a lesser degree on plants, annelids, insects, and bryozoans. Crabs generally ate the same type of food regardless of crab size, area, and season. They usually consumed the most available foods.

SUMMARY

Studies on the biology of the blue crab in the St. Johns River were made to obtain information necessary to determine factors which affect the harvestable population.

Females made up the majority of adult crabs during most of the year in the lower St. Johns River, but males were dominant in the upper river.

Blue crabs commonly mated from March to July and from October to December. The proportion of males and females that matured at a small size was larger in salt water than in fresh water. Size at maturity varied widely as evidenced by a 177-mm. wide immature female and a 99-mm. mature female; some of this variation can be attributed to individual differences in growth rate.

Spawning occurred in the first 30 km. of river above the mouth, and the eggs hatched in the ocean within 6 km. of shore. Spawning began in February 1962 and in March 1963 and continued to October in both years. An appreciable number of ovigerous females from the St. Johns River apparently entered the ocean by way of the Intracoastal Waterway and other rivers. Some females entered the river from the ocean before the spawning season. Many others returned to the St. Johns River or entered other rivers, often within 15 days after their eggs hatched, to spawn a second time in the same season.

Of crabs tagged 40 to 195 km. above the mouth and recovered at a distance from the tagging site, 89 percent of the males and 96 percent of the females were recaptured downstream from the point of release. In fall and early winter, females from the upper river congregated 30 to 55 km. above the mouth. During the same period aggregations of males appeared nearer the mouth and in the ocean directly off the mouth. Crabs of both sexes mi-

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grated from the St. Johns River to the Intracoastal Waterway, to four other rivers, and to the ocean.

Females tagged in the ocean off the mouth of the river were recaptured in the St. Johns River and other inland waters; in addition widespread recoveries were made in the ocean.

Time between tagging and recoveries indicated that relatively few blue crabs live longer than 1 year after becoming adults. Maximum age is about 4 years.

Zoeae—primarily first stage but some second—and megalops of crabs of the genus *Callinectes* were collected in the river as far as 40 km. from the mouth. Zoeae were present in April to October. Of 22 kinds of crab zoeae collected near the mouth, *Callinectes* ranked third in abundance in 1961 and second in 1962.

Early crab stages (2–9 mm. wide) entered lower river areas primarily in waves which started 5 or more months after spawning began and continued to the end of the year. Most individuals in these waves were beyond the initial crab stages except during early winter. The time of the first waves was later in 1963 than in 1962, probably because of the later spawning season in 1963. Influx of early crab stages was not confined to the lower river but extended 95 km. and more upstream.

Juvenile crabs of many sizes were widely distributed but were concentrated the year around in certain localities. Those less than 40 mm. wide were most common in shallower waters. Juvenile females outnumbered juvenile males in the lower river, but the percentage of males increased with distance upstream.

Crabs 5 to 200 mm. wide fed principally on mollusks (primarily clams and mussels), fish, and crustaceans (mostly amphipods and crabs). Lesser amounts of plants, annelids (almost all *Nereis pelagica*), insects, and bryozoans were eaten. Usually the same types of foods were taken by all sizes of crabs and at all areas sampled. Crabs often ate the same foods during different seasons and generally consumed the most available foods.

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