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THE POPULATION DYNAMICS AND DISTRIBUTION OF <u>CORBICULA MANILENSIS</u> (PHILIPPI) IN A SPRING-FED CENTRAL FLORIDA STREAM

BY

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B.A., University of Delaware, 1976

THESIS

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ABSTRACT

Asiatic clams (Corbicula manilensis Philippi) were sampled at twelve stations randomly located along a 16-km stretch of the Wekiva River, Florida, every three months from August 1976 to June 1977. Clams were found at most stations. Their abundance ranged from 4 to 1210 per m^2. Mean numbers of Corbicula were highest at stations where the bottom sediments were primarily sand and lowest at stations where the bottom sediments were silt and decomposing organic matter. A linear relationship between water temperature, water depth, current velocity, total alkalinity, and pH, and the abundance and distribution of Corbicula was not evident. Seasonally, the abundance of Corbicula was highest in August 1976 and lowest in December 1976.

The small size of the specimens suggest a recent invasion of Corbicula into the Wekiva River. The mean shell length of Corbicula in the river was 13.5 mm. The shell lengths of the largest clams ranged from 25.3 mm to 27.2 mm. Large clams were collected in December 1976 (mean shell length = 13.7 mm), whereas small clams were collected in March 1977 (mean shell length = 13.1 mm). Shell width and shell length were linearly correlated ($r = 0.98$ to 0.99), as were shell breadth and shell length ($r = 0.96$ to 0.99). The correlation between shell length and the number of rings on

the shell was lower (r = 0.68 to 0.88). Clams with smaller rings (more rings per unit length) were found at downstream stations, where abundance was hing, whereas clams with larger rings (fewer rings per unit length) were found at upstream stations, where abundance was low. The data suggest that relationships between age and size depend on the habitat in which the organisms live.

ACKNOWLEDGMENTS

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INTRODUCTION

The Asian clam (Corbicula manilensis Philippi) was introduced into the United States in 1938 on the Columbia River near Knappton, Washington (Clench, 1970; Sinclair, 1964). Recently, this exotic bivalve has been found in nearly every major river system in the country. Corbicula have been observed in the Sacremento and San Jaoquin Rivers of central California (Dundee and Dundee, 1958), the Ohio River bordering Kentucky (Sinclair and Isom, 1961), the Delaware River near Philadelphia (Fuller and Powell, 1973), the James River in Virginia (Diaz, 1974), the Savannah and Altamaha Rivers in Georgia (Gardner et al., 1976), the Mississippi River bordering northern Iowa (Eckblad, 1975), the Mobil River in Alabama (Hubricht, 1963), the Tennessee River in Tennessee (Sinclair and Ingram, 1961), and the Caloosahatchee River in Florida (Clench, 1970). The clam has restricted flow in irrigation canals, clogged industrial intake screens, blocked water pipes, and displaced native bivalve species. Despite being called the "most costly liability of all exotic mulluscs in North America" (Sinclair, 1971), very little is presently known about the ecology of Corbicula. Studies on the Altamaha River in Georgia and the Ohio River at Louisville, Kentucky provide information on the distribution, density, and substrate preferences of the clam in natural river systems (Gardner et al., 1976; Bickel, 1966). The relationship of Corbicula to the physical and chemical environment, however, is not fully understood even though its distribution has been documented.

The purpose of this study was to describe the distribution and abundance of Corbicula in a relatively undisturbed Central Florida stream and to relate its abundance to the physical and chemical features of the river. The Wekiva River was probably invaded within the last decade by Corbicula. It is a spring-fed tributary of the St. John's River and has a diversity of natural habitats into which Corbicula can become established.

History

The spread of Corbicula throughout the United States has been dramatic. After its introduction in 1938 into the Columbia River estuary, Washington, it has shown a phenomenal capacity for dispersal (Dundee and Harmon, 1963). The species was found throughout the west coast states during the 1940's and 1950's. Corbicula were recorded in the Sacremento and San Jaoquin River systems during the 1940's and in irrigation canals in southern California during the early 1950's (Dundee and Dundee, 1958). Corbicula were first noted east of the Mississippi River in 1957 in the Ohio River at Paducah, Kentucky. In 1962, the clam was observed in the Ohio River near Cincinnati (Keup, Horning, and Ingram, 1963). Corbicula were taken from the Tennessee River in 1959 (Sinclair and Ingram, 1961). By 1963, the clam had become established in the upper reaches of the Green and Cumberland Rivers (Sinclair, 1964). It was reported in 1960 in several Louisiana Gulf coast streams (Dundee and Harmon, 1963) and in the Mobil River, Alabama (Hubricht, 1963).

Corbicula was first reported in the Southern Atlantic Slope drainage in 1970 when specimens were found in the Ocumulgee River (Altamaha River system, Georgia) (Sickel, 1973). In 1972, collections were made in the Savannah River, Georgia, the Pee Dee River, South Carolina, and the Delaware River between Philadelphia, Pennsylvania and Trenton, New Jersey (Fuller and Powell, 1973). The clam was found in the James River, Virginia in 1973 (Diaz, 1974). Most recently Corbicula have been found in northeast Iowa. Specimens were collected from an effluent of a power plant on the Mississippi River about 600 miles above Cairo, Illinois (Eckblad, 1975). This was the first record of Corbicula in the northern section of the Mississippi River.

Corbicula have spread rapidly throughout the state of Florida. They were first observed in 1960 in the Escambia River in the northwest part of the state (Schneider, 1967). Due to the small size of specimens collected, a recent introduction was suspected. By 1967 the clam had become established in the Withlacoochee River in Levey County (Schneider, 1967). Two years later the species was discovered in the Caloosahatchee-Lake Okeechobee System, thus completing its spread down the Florida peninsula (Clench, 1970).

The clam was initially identified as *Corbicula fluminea* (Muller) (Bickel, 1966). Based on major differences in reproduction and development between *Corbicula fluminea* and *Corbicula manilensis* as described by Sinclair and Isom (1963), Bickel (1966) suggested the misuse of *C. fluminea*. *C. fluminea* are dioicious and nonincubatory, while *C. manilensis* are monecious and incubate there eggs in marsupia, a modification of the inner gill lamellae. *C. manilensis* are found in freshwater and have nonswimming pelagic larvae. Recent taxonomic and histologic data, however, indicates that *C. fluminea* may be the only representative of the genus *Corbicula* in the United States (Morton, 1977; Kraemer, 1977; Smith, 1977). Further histological and taxomonic comparisons between populations native to southeast Asia and the Philippines and those found in the United States will be necessary in order to clearly identify the species.

The unique reproduction of *Corbicula* has lead to its rapid spread across the United States. The veliger (approximately 200 microns in length) is discharged through the exhalent siphon into the surrounding water (Sinclair and Isom, 1963). Daily average reproduction has been observed as high as 387 veligers per adult clam (Aldridge and McMahon, 1976). Sinclair and Isom (1963) described these free-living veligers as benthic in function with a velum highly specialized for feeding and useless as a swimming organ. The planktonic veligers are the mode of entry into irrigation systems, condensers, and pipes. They settle and become attached by means of several byssal threads. The clams become sexually mature during their first year when they are about 6.5 mm in length (Sinclair and Isom, 1963).

Corbicula have been known to replace native species of bivalves. A decline in the populations of other bivalves was noted by Gardner et al. (1976) in the Altamaha River after Corbicula numbers reached 200 per m^2. In the Flint River, Georgia, other bivalves were not found where Corbicula were dense (Sickel, 1973). Sickel suggested that competition other than for space occurred since the size of individuals and their density did not appear to exclude larger bivalves.

Sediment composition is probably the most important factor affecting the distribution of Corbicula A direct relationship between mean particle size and clam densisty is possible (Fast, 1972). Corbicula may inhabit course and fine gravel, black clay, shifting sand bars, rock and rubble, and firm sand, but is commonly found on sandy substrates, which they prefer (Filice, 1958; Villadolid and Del Rosario, 1930; Cahn, 1951; Sickel, 1973; Fuller and Powell, 1973; and

Gardner et al., 1976).

Corbicula tolerate low dissolved oxygen concentrations although prolonged exposure to 0 ppm dissolved oxygen can be fatal (Sinclair and Isom, 1963). Low dissolved oxygen concentrations may restrict the presence of the clam in streams and reservoirs. Fast (1971) studied the effect of hypolimnetic stagnation of the El Capitan Reservoir, California on the clam and noted that thermal and chemical stratification limited the clams' presence to shallow habitats. He noted that *Corbicula* were not affected by prolonged artificial destratification. Aldridge and McMahon (1976) found that *Corbicula* was unable to maintain adequate oxygen uptake at low oxygen tensions. McMahon (personal communication) suggested that *Corbicula* prefer a sandy bottom because of the associated high oxygen content. Usually,few clams are found in silty or muddy bottoms because of the reduced oxygen concentrations.

Description of the Study Area

The Wekiva River is a spring-fed stream with its primary source (Wekiva Springs) located about 5 km east and 4 km north of Apopka, Florida in northwest Orange County, 28° 42' N and 81° 27' W. The river flows north-northeast along a 26 km course and enters the St. Johns River 10 km northwest of Sanford, Florida. The Little Wekiva River, Rock Springs Run, and Black Water Creek are its major tributaries (Fig. 1).

The climate in the area is mild with mean daily temperatures ranging between 16 and 26 °C. The annual rainfall in the area is 116 cm with most occurring during the summer.

The Wekiva Swamp and Seminole Swamp comprise most of the river's 490 km^2 watershed. The elevation of the river channel drops approximately 1 m per 5 km in length. The average discharge of the river is 8.16 m^3/sec at its mouth. The mean daily discharge has ranged from 2.97 m^3/sec to 58.3 m^3/sec since 1939 (U. S. Geological Survey, 1976). During the study period, the mean monthly discharge of the river ranged from 9.9 m^3/sec in August, 1976 to 5.1 m^3/sec in May, 1977 (U. S. Geological Survey, 1976 and 1977).

The average width of the Wekiva River is 77 m and varies between 32 and 200 m. Numerous small islands divert the flow as the river passes through the Wekiva Swamp, creating extensive eddies and quiet areas along the banks. The deposition of silts and organic debris is enhanced by low current velocities and submergent aquatic macrophytes. _Vallisneria_ _sp_. (eel grass) and _Egeria_ _densa_ (Brazilean Elodea) grow prolifically along the river bottom. _Eichhornia_ _crassipes_ (water hyacinth), a floating aquatic macrophyte, is an important source of bottom organic matter.

The Wekiva River widens and becomes shallow about 10 km downstream from the Wekiva Springs. The flood plain becomes considerably narrowed as the elevation of the surrounding topography becomes 5 to 10 m higher. The river bottom changes from organic silt to sand and *Egeria densa* becomes the dominant aquatic macrophyte, replacing *Vallisneria*. *Eichhornia crassipes* is more abundant in this area.

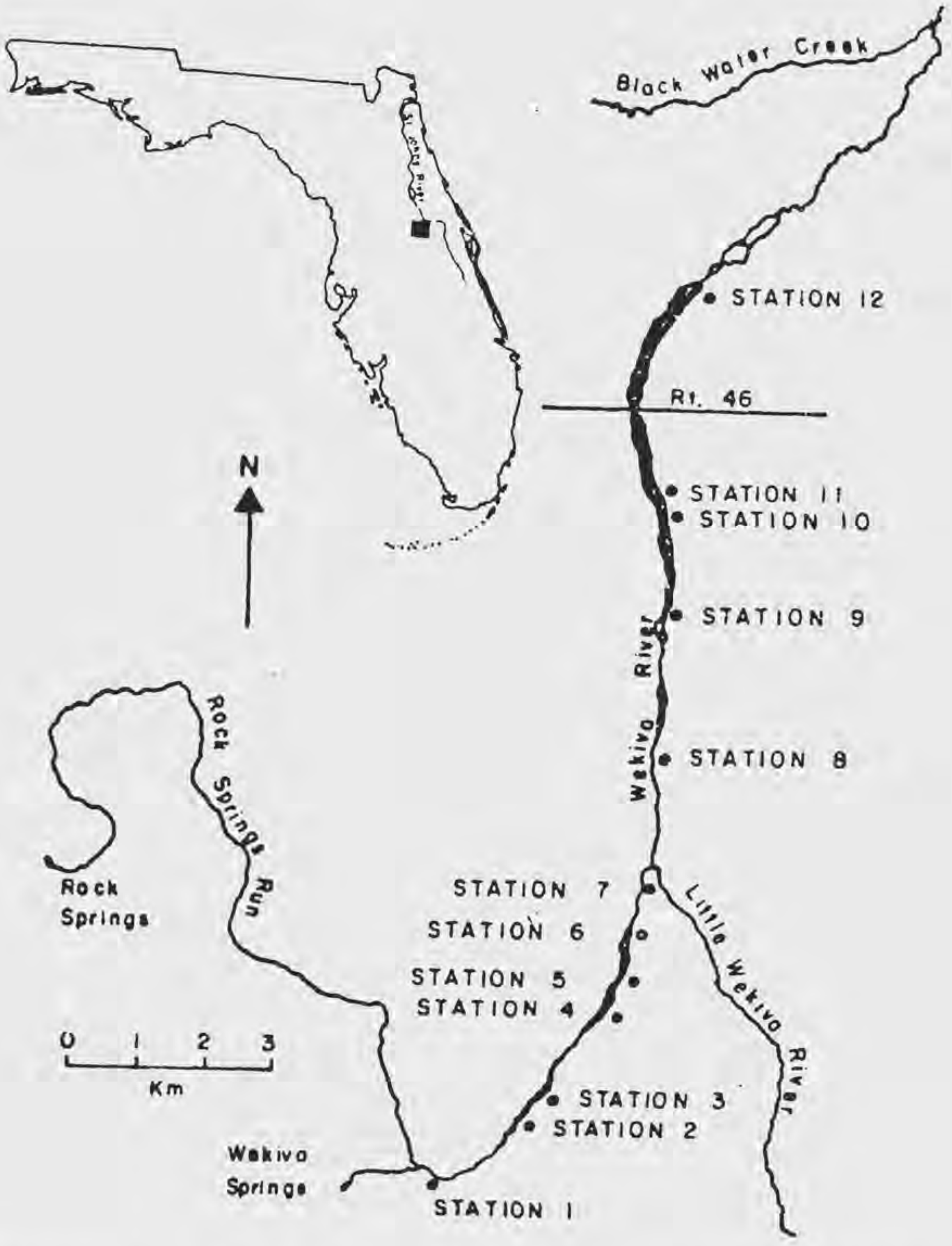

Figure 1. Map of the Wekiva River with station locations.

MATERIALS AND METHODS

Twelve permanent stations were selected at random along a 16 km stretch of the Wekiva River (Fig. 1). Sampling was conducted trimonthly from August, 1976 to June, 1977. Samples were collected at three sites per station. The sites were located near each bank and in the center of the channel.

Physicochemical measurements were taken concurrently at each site, trimonthly. Surface and bottom temperatures were measured with a YSI telethermometer. Current velocities were measured with a subsurface float (Welch, 1948). Turbidity was determined spectrophotometrically ith the methods outlined in Standard Methods (APHA, 1971). Bicarbonate, carbonate, and total alkalinity and hydrogen ion concentrations (pH) were determined using Standard Methods (APHA, 1971).

Sediment was collected at each site with a plexiglass tube (dia. = 5 cm). An 8 cm core sample was oven dried at 105 °C for 48 hours and weighed to the nearest 0.001 g. The dried sediment was ignited in an ash furnace at 600 °C for a period of 5 hours to determine the percent organic content by weight.

In June, 1977 sediment samples were collected at each sampling site to determine particle size. Samples were wet seived through six U. S. standard screens (0.11-2.5 mm openings). The sediment that remained in each screen was dried at 105 °C for 48 hours. Particle size was determined and expressed as a percent of the dry weight of the sediment. The sediment not collected in the smallest screen (0.11 mm) was considered insignificant.

Corbicula were collected with a Surber Sampler (0.093 m^2) (Surber, 1937) by removing 8 cm of sediment. Three collections were taken from each site for a total of nine samples per station. The clams were washed in a # 30 mesh seive and preserved in 20% formalin. The clams were enumerated and measured for length, width, and breadth to the nearest 0.1 mm with vernier calipers. The number of rings per clam was determined with the aid of a stereomicroscope.

Statistical procedures were conducted with an IBM 360 computer. A frequency distribution program (S.A.S., 1976) was used to place the individual clams into six size classes based on the length of the shell. Univariate and multivariate linear regression analyses using the principle of least squares (S.A.S., 1976) were used to determine linear relationships between physicochemical parameters and the abundance of Corbicula. These analyses were used to determine linear relationships between the length of the shell of the clams and their width, breadth, and the number of shell rings.

RESULTS AND DISCUSSION

Physicochemical Characteristics of the Wekiva River

The physicochemical measurements for the Wekiva River are presented in Tables 1, 2, 3, and 4. The mean water temperature at the stations ranged from 20 °C in December, 1976 to 26 °C in June, 1977. The lowest water temperature was 17 °C in December, 1976. Water temperature reached 30 °C at station 12 in June, 1977. The water was homothermal at each station on all sampling dates. Seasonal variation in the water temperatures near the Wekiva Springs was less than downstream. Water temperatures at station 1, 2, and 3 only varied between 22 and 25 °C. At station 12, sixteen km downstream from Wekiva Springs, the water temperature ranged seasonally from 20 to 30 °C. In general, downstream temperatures were cooler than mean water temperatures in winter and warmer than mean water temperatures in summer.

The mean depth of water at the stations ranged from 1.03 m in August, 1976 to 0.85 m in June, 1977. Upstream stations, where the river was narrower, were deeper than downstream stations. Station 7 was the deepest station, ranging in depth from 1.40 m in August, 1976 to 1.26 m in

Table 1. Physicochemical measurements at each station in the Wekiva River for August, 1976.

Station	Temp. °C	Depth m	Flow rate cm/sec	CO_3^{-2} ppm	HCO_3^{-1} ppm	Total alk. ppm	pH	% Org.
1	24.0	1.36	17.0	0	99	99	7.2	26.2
2	25.0	1.04	8.0	0	97	97	7.2	5.7
3	25.0	1.15	12.0	0	96	96	7.3	7.6
4	26.0	1.02	17.0	0	96	96	7.3	10.5
5	25.0	1.00	17.0	0	97	97	7.2	11.7
6	25.0	1.17	7.0	0	98	98	7.1	15.9
7	25.0	1.40	20.0	0	99	99	7.2	16.7
8	26.0	1.26	15.0	0	93	93	7.2	18.1
9	24.0	0.81	22.0	0	94	94	7.2	5.0
10	25.0	0.66	22.0	0	98	98	7.4	7.0
11	25.0	0.64	11.0	0	96	96	7.2	4.4
12	26.0	0.80	12.0	0	96	96	7.3	5.1

Table 2. Physicochemical measurements at each station in the Wekiva River for December, 1976.

Station	Temp. °C	Depth m	Flow rate cm/sec	CO_3^{-2} ppm	HCO_3^{-1} ppm	Total alk. ppm	pH	% Org.
1	22.0	0.89	22.0	0	99	99	7.3	29.1
2	22.0	0.94	14.0	0	97	97	7.2	22.3
3	23.0	0.77	14.0	0	95	95	7.2	6.4
4	23.0	1.02	16.0	0	96	96	7.3	13.2
5	22.0	0.88	14.0	0	94	94	7.2	14.2
6	21.0	1.02	10.0	0	95	95	7.1	15.5
7	17.0	1.33	18.0	0	95	95	7.1	19.1
8	17.0	1.33	12.0	0	96	96	7.1	9.7
9	17.0	0.75	22.0	0	97	97	7.2	6.1
10	18.0	0.62	0.21	0	99	99	7.5	5.6
11	18.0	0.55	21.0	0	98	98	7.7	7.7
12	20.0	0.62	0.23	0	101	101	7.7	3.8

Table 3. Physicochemical measurements at each station in the Wekiva River for March, 1977.

Station	Temp. °C	Depth m	Flow rate cm/sec	CO_3^{-2} ppm	HCO_3^{-1} ppm	Total alk. ppm	pH	% Org.
1	...	1.22	19.0	0	100	100	7.5	19.3
2	...	1.00	14.0	0	98	98	7.5	18.1
3	...	0.97	13.0	0	98	98	7.9	6.6
4	24.0	1.12	19.0	0	92	92	7.3	10.9
5	24.0	0.99	16.0	0	95	95	7.3	6.6
6	24.0	1.10	10.0	0	96	96	7.4	26.3
7	19.0	1.26	19.0	0	97	97	7.3	24.6
8	20.0	1.10	11.0	0	102	102	7.8	36.1
9	20.0	0.79	19.0	0	101	101	7.6	6.3
10	20.0	0.67	35.0	0	103	103	8.0	4.3
11	22.0	0.59	25.0	6	95	101	8.4	3.1
12	23	0.56	20.0	21	82	104	8.9	3.1

Table 4. Physicochemical measurements at each station in the Wekiva River for June, 1977.

Station	Temp. °C	Depth m	Flow rate cm/sec	CO_3^{-2} ppm	HCO_3^{-1} ppm	Total alk. ppm	pH	% Org.
1	24.0	1.12	24.0	...	...	...	7.7	31.3
2	24.0	0.87	13.0	0	100	100	7.6	24.4
3	25.0	0.75	19.0	0	101	101	8.0	7.0
4	26.0	0.95	12.0	0	106	106	8.4	24.0
5	25.0	0.91	17.0	0	103	103	7.5	14.9
6	25.0	1.02	7.0	0	106	106	7.7	40.5
7	25.0	1.35	22.0	0	107	107	7.8	22.9
8	26.0	1.03	11.0	0	100	100	7.3	33.3
9	27.0	0.70	16.0	0	100	100	7.5	34.5
10	28.0	0.56	24.0	0	100	100	7.9	4.3
11	27.0	0.53	19.0	0	101	101	7.6	4.9
12	30.0	0.45	18.0	0	100	100	8.0	3.3

March, 1977. Water was shallowest at station 11, where the water depth ranged from 0.64 m in August, 1976 to 0.53 m in June, 1977.

The mean current velocity of the river varied from 19 cm/sec in August, 1976 to 17 cm/sec in December, 1976 and June, 1977. Current velocities were highly variable at each station, although velocities at station 9 through 12 were generally above the mean river velocity throughout the study. Velocity was highest at station 10 and varied from 21 cm/sec in December, 1976 to 35 cm/sec in March, 1977. Slowest velocities were recorded at station 6; they varied from 7 cm/sec in August, 1976 to 10 cm/sec in December, 1976 and March, 1977. Current was slow at station 8, but varied from 11 cm/sec in March and June, 1977 to 15 cm/sec in August, 1976.

The total alkalinity for the stations ranged from 97 ppm in August and December, 1976 to 102 ppm in June, 1977. Total alkalinity was lowest at station 8 (August,1976 - 93 ppm) and highest at station 7 (June, 1977 - 107 ppm). Total alkalinity was highest at stations near the Wekiva Springs and at stations 10, 11, and 12, near the sources of smaller springs. Carbonate alkalinity was not detected except at stations 11 and 12 in March, 1977.

The mean pH (calculated from the antilog of the hydrogen ion concentration) ranged from 7.2 in August, 1976 to 7.7 in June, 1977. Lowest values were recorded at station

6 in August, 1976 and at stations 6, 7, and 8 in December, 1976 (pH = 7.1) The pH was highest at station 12 in March, 1977 (pH = 8.9). The higher pH values at downstream stations can be attributed to the discharge from the small calcarious springs and to increased photosynthesis of *Egeria densa*.

No turbidity was detected at the stations except when the bottom was disturbed by an occasional motor boat.

Sediment organic matter varied from 3.1 to 40.5 percent. Organic matter was highest at stations 1, 6, 7, and 8. At these stations the sediments were soft and often exceeded a meter in depth. In contrast, organic matter at stations 10, 11, and 12 was low and seldom exceeded 7 percent. Generally, organic matter occurred where current velocities were low. Variations in the organic matter are shown in Figures 2 and 3. Organic content was highest in March and June, 1977 (Fig. 2). This may have been caused by the winter decline in *Eichhornia crassipes* and other macrophytes.

Sediment particle size per station is presented in Table 5. Sediment was mainly composed of particles between 0.21 and 0.41 mm. These particles were largely fine quartz-type sand. Thirty-eight point eight to 75.1 percent of the sediment was composed of particles of this size. Particles between 0.42 and 0.77 mm were mainly sand. These sand particles were infrequent in the sediment and ranged from 4.3 percent at station 7 to 25.6 percent at station 1. Most of

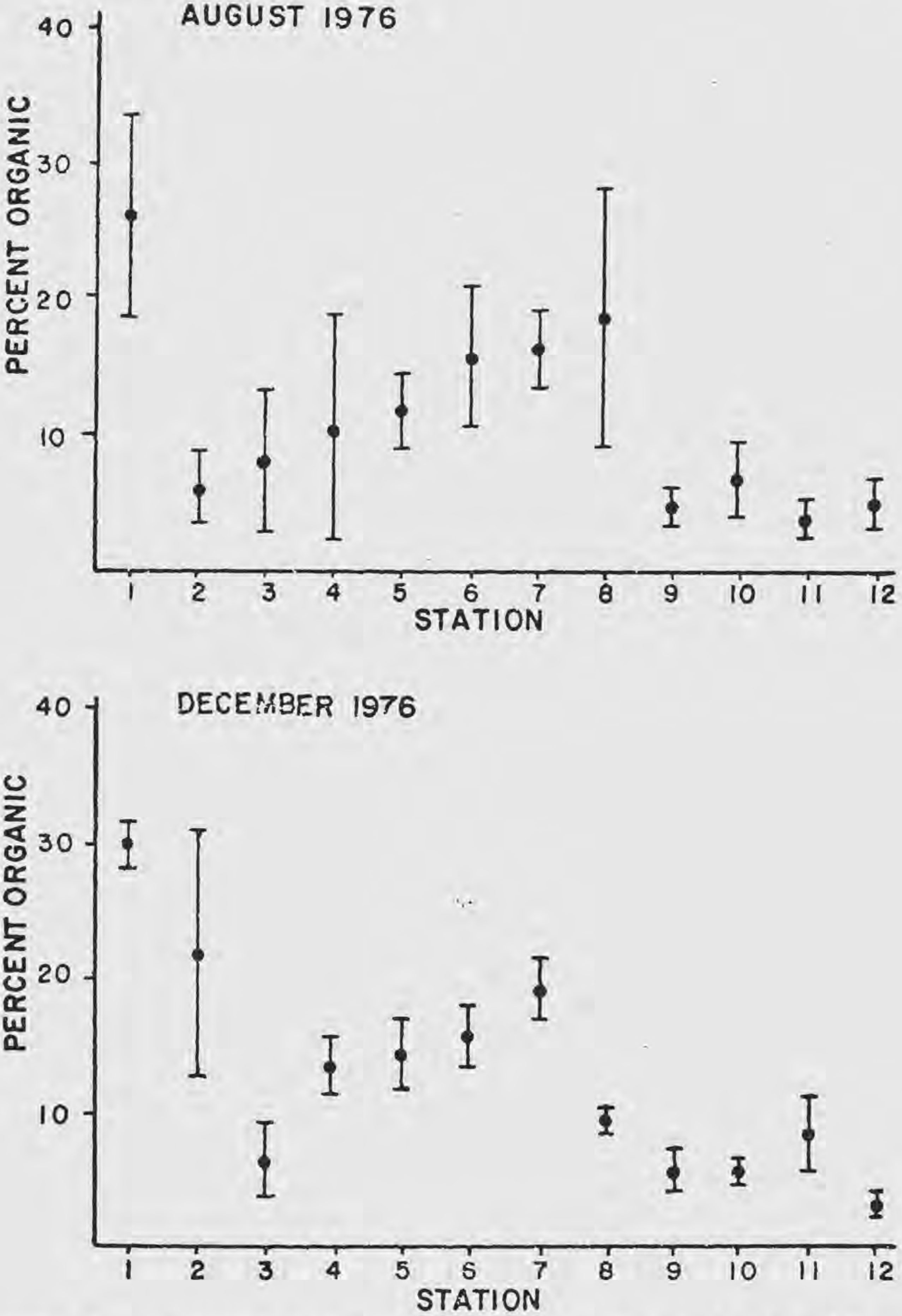

Figure 2. Organic content of bottom sediments in the Wekiva River in August and December, 1976. Error bars are standard errors of the mean.

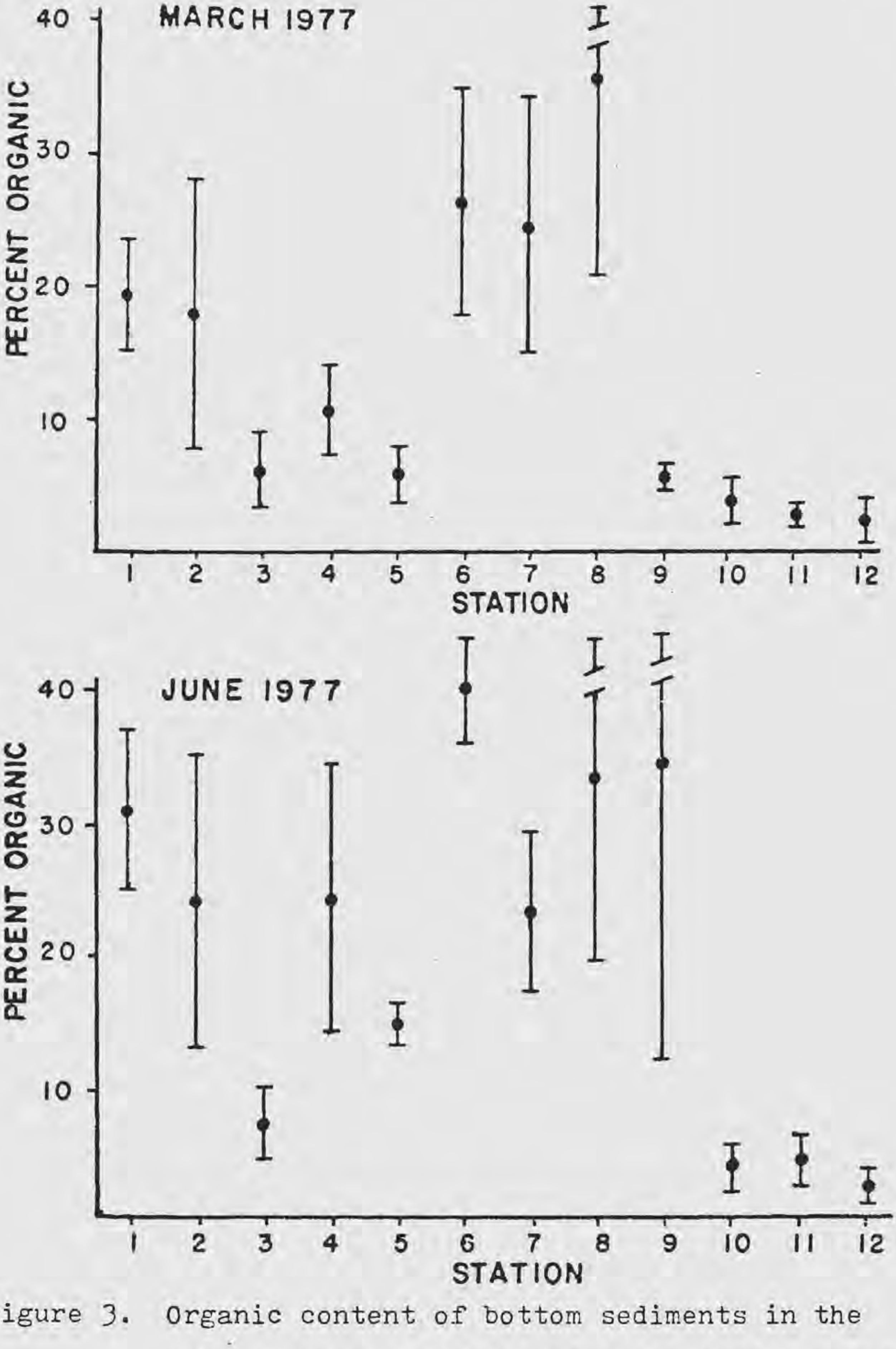

Figure 3. Organic content of bottom sediments in the Wekiva River in March and June, 1977. Error bars are standard errors of the mean.

Table 5. Particle size of bottom sediments at twelve stations in the Wekiva River for June 1977, expressed as a percent by weight of sample.

	Particle Size (mm)					
Station	fine		medium		course	
	0.11-0.21	0.21-0.42	0.42-0.77	0.77-1.43	1.43-2.5	2.5
1	13.0	38.8	25.6	10.4	3.4	9.9
2	11.8	53.7	6.0	5.6	3.0	19.9
3	4.0	56.2	19.9	9.2	1.5	3.0
4	19.4	48.8	14.1	7.4	0.8	7.1
5	13.9	55.8	12.0	5.5	1.4	5.2
6	21.4	40.5	5.5	7.2	3.6	21.8
7	12.7	47.7	4.3	13.8	5.2	16.3
8	18.4	42.6	11.6	11.9	15.6	12.2
9	12.6	70.7	6.4	2.3	1.5	6.6
10	11.3	68.8	14.1	3.4	0.3	2.3
11	12.6	75.1	11.1	1.2	0.4	3.6
12	9.3	73.4	11.7	1.2	0.4	3.9
$\overline{X}$	13.4	56.0	11.9	6.6	3.1	9.2

the organic matter was represented by particles greater than 0.77 mm. Particles greater than 2.5 mm were mainly leaves, bark, and branches. Rocks, stones, and pebbles were rare in the sediments. Much of the 0.11 - 0.21 mm particles were also organic in nature and possibly came from decomposing leaf litter and aquatic plants. This size of particles ranged from 4.0 to 21.4 percent of the sediment taken at all stations.

Distribution and Abundance of Corbicula

Individuals of Corbicula were found at nearly all stations in the Wekiva River. They were never found at station 4, 5, or 6, or at station 7 in August and December, 1976 (Table 6). Individuals were usually found within the first 6 cm of the sediment. Corbicula were unevenly distributed at sample stations and this resulted in high variances for estimated population means.

Corbicula were most abundant at downstream stations where the bottom sediments were sandy. At station 11, fourteen km downstream from the Wekiva Springs, the abundance of Corbicula was 897 per m^2 in December, 1976 and 1210 per m^2 in June, 1977. The abundance of Corbicula at station 10, 13.8 km downstream from the Wekiva Springs, was 560 per m^2 in August, 1976 and 248 per m^2 in June, 1977. Their abundance was usually less than 100 per m^2 at other stations (Table 6).

Table 6. Abundance of *Corbicula manilensis* in the Wekiva River for each sampling period. Abundance expressed as mean numbers per square meter including 95% confidence limits.

Station	August 1976	December 1976	March 1977	June 1977
1	6 ± 6	4 ± 4	29 ± 33	17 ± 22
2	19 ± 24	92 ± 69	69 ± 42	62 ± 51
3	96 ± 63	69 ± 35	66 ± 57	72 ± 56
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0
7	0	0	7 ± 6	6 ± 8
8	6 ± 7	13 ± 21	17 ± 35	75 ± 89
9	86 ± 96	81 ± 101	74 ± 135	252 ± 258
10	560 ± 496	294 ± 220	375 ± 122	249 ± 115
11	1,056 ± 1,131	897 ± 603	997 ± 1,134	1,210 ± 1,257
12	20 ± 21	65 ± 124	148 ± 156	26 ± 21

Few clams were found along the banks of the river or around stands of *Egeria densa*, where low current velocities resulted in the deposition of silts and organic debris. *Corbicula* were not found at stations where the sediments consisted of loosely packed silts and very fine organic matter (stations 4, 5, and 6). *Corbicula* were most abundant in areas where the sediment was primarily composed of 0.21-0.42 mm sand particles with an organic content of less than 8 percent. The effect of other physicochemical factors on the distribution of *Corbicula* is less evident. Linear correlation between the other factors (water temperature, water depth, current velocity, total alkalinity, and pH) and the abundance or the distribution of the clam was not significant.

The morphological and physiological characteristics of *Corbicula* may have limited their distribution in highly silted and organic sediments in the Wekiva River. The distribution of all bivalves may be limited by their inability to ingest fine grained sediments without clogging their gills (Steele-Petrovic, 1975). McMahon (personal communication) believes that *Corbicula* are unable to withstand low dissolved oxygen concentrations common to highly organic sediments.

The mean abundance and the mean individual shell lengths of *Corbicula* in the Wekiva River are presented in Table 7. Significant differences ($p \leq 0.05$) in the mean number of clams collected each sampling period were observed.

Table 7. Mean numbers per m^2 and mean shell lengths of *Corbicula* in the Wekiva River. The 95 percent confidence limits are included.

Date	Numbers per m^2	Mean length (mm)
August, 1976	231 ± 156	13.4 ± 0.1
December, 1976	189 ± 96	13.7 ± 0.2
March, 1977	207 ± 136	13.1 ± 0.2
June, 1977	219 ± 146	13.6 ± 0.2

The abundance of Corbicula was highest in August, 1976 and lowest in December, 1976. Gardner et al. (1976) observed highest densities of Corbicula in the Altamaha River during late summer and early fall. He attributed this phenomenon to low stream discharge. Greater numbers of Corbicula in the Wekiva River in August, 1976 cannot, however, be attributed to low stream discharge since the discharge of the river was high during this month. I suspect that the occurrance of greater numbers of Corbicula during the summer was, in part, a result of the recruitment of immature larvae from the preceding spring into the adult population.

The mean shell length of Corbicula in the Wekiva River was 13.5 mm. Seasonally, the mean shell length was greatest in December, 1976 (13.7 mm) and least in March, 1977 (13.1 mm). The shell lengths of the largest clams ranged from 25.3 mm in August, 1976 to 27.2 mm in June, 1977. The shell lengths of the smallest clams ranged from 1.4 mm in December, 1976 to 3.7 mm in August, 1976. The mean shell lengths of Corbicula collected from the Wekiva River are presented in Figures 4 and 5. Clams collected at stations 1, 2, and 3 tended to be larger than 18 mm. The largest clams were collected from station 3. Larger clams at upstream stations may be indicative of an upstream introduction since larger clams are presumably older. The smallest clams were collected from stations 7, 8, 9, and 12 (Figs. 4 and 5).

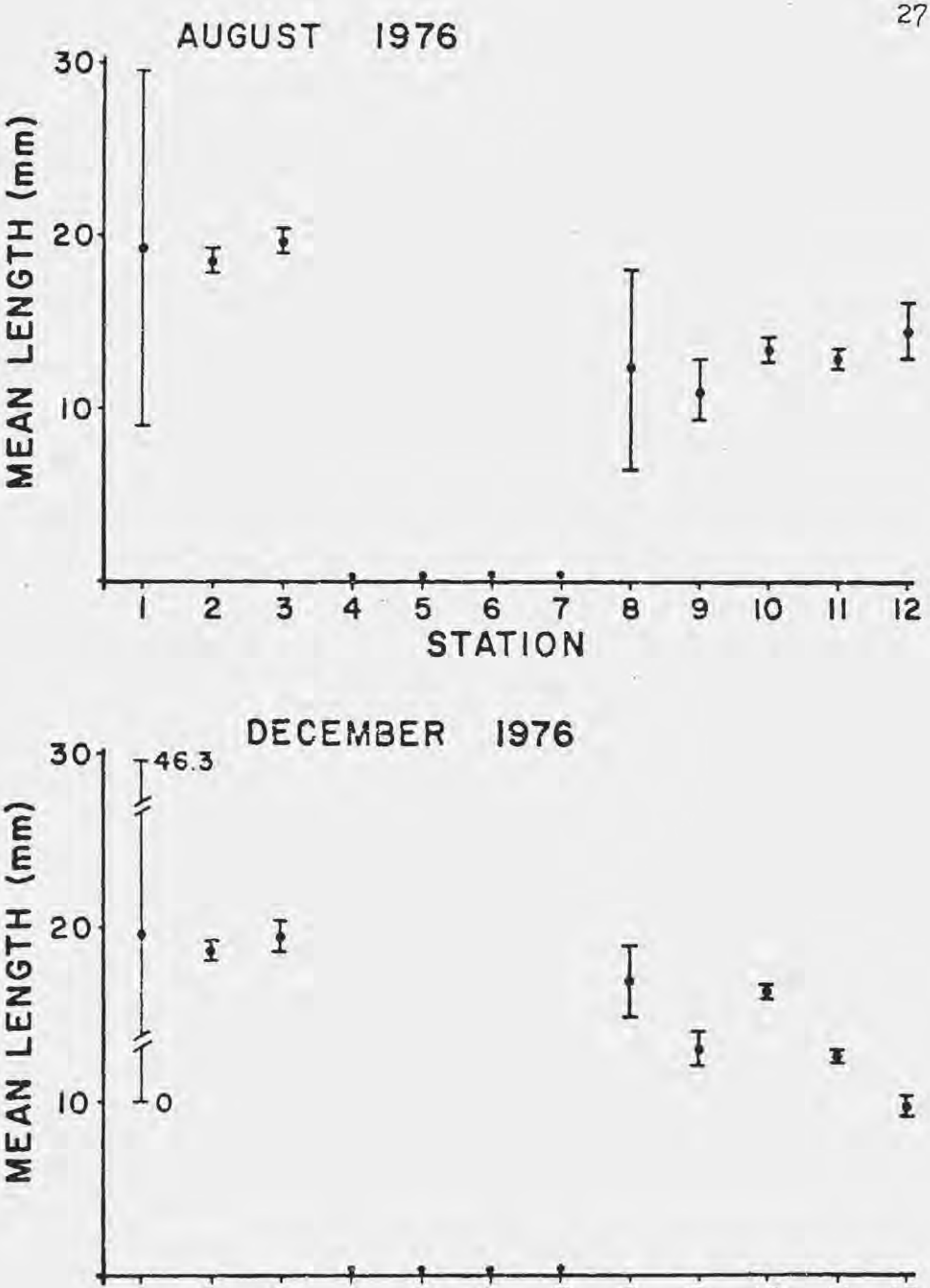

Figure 4. Mean shell length of Corbicula in the Wekiva River at each station in August and December, 1976. Error bars are 95% confidence limits.

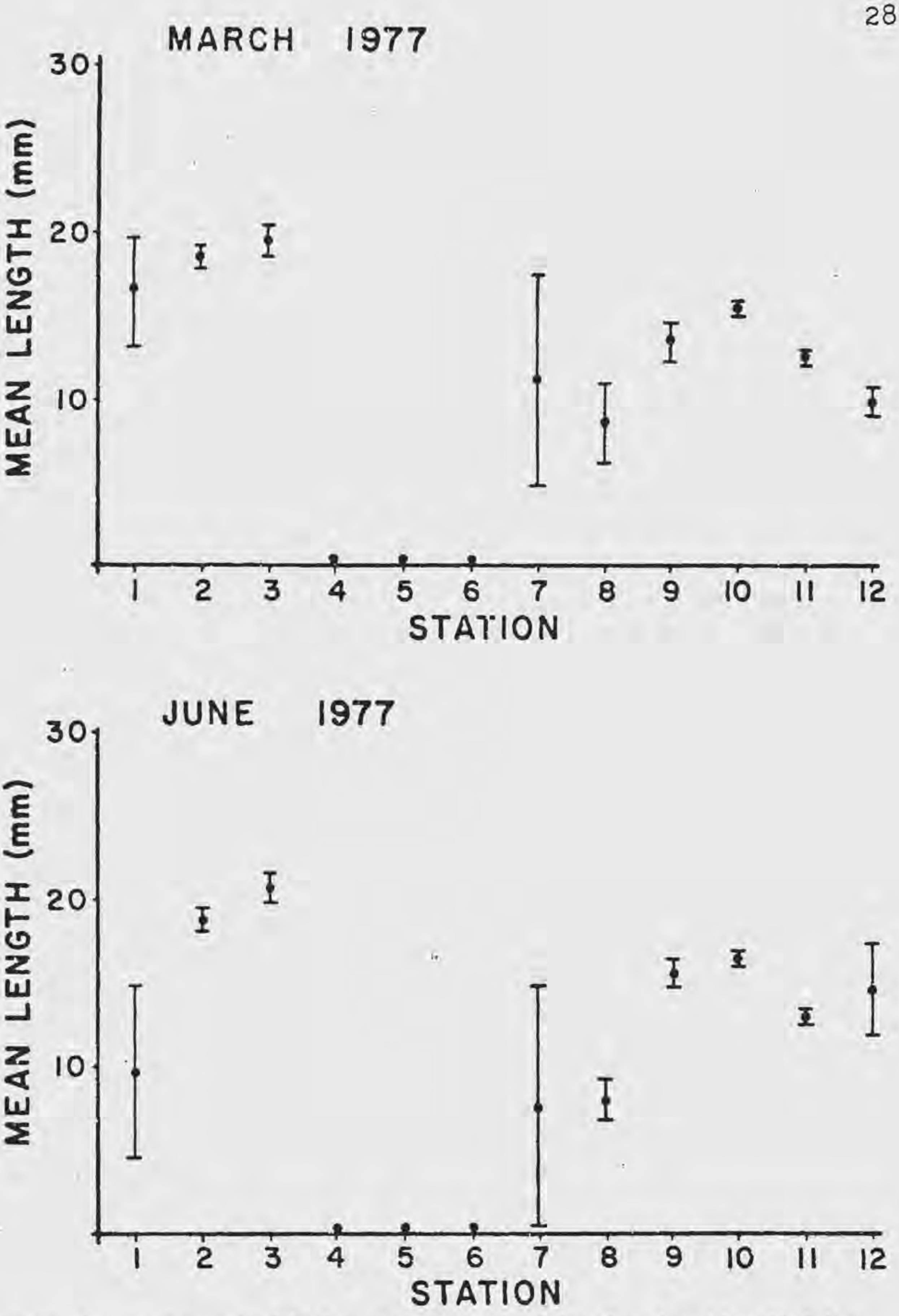

Figure 5. Mean shell length of <u>Corbicula</u> in the Wekiva River at each station in March and June, 1977. Error bars are 95% confidence limits.

The variability in the mean shell length for individuals collected from stations 1 and 7 was probably due to the small sample size at those stations.

Age and Size Classes

Corbicula were arbitrarily divided into six size classes according to the shell length. The number of clams in each size class from the pooled samples is illustrated in Figures 6 and 7. The distribution of clam shell lengths was positively skewed. The greatest number of individuals was in the 10.0-14.9 mm size class, although changes in the percentage of individuals in this group and other size classes occurred seasonally. The percentage of clams in the 10.0-14.9 mm class was highest in August, 1976 and lowest in December, 1976. The 15.0-19.9 mm size class accounted for over half of the remaining individuals. The percentage of clams in this group was lowest in August, 1976 and highest in December, 1976. Individuals in the 0.0-4.9 mm size class were rare in August and December, 1976 and were in greater numbers in March and June, 1977. Seasonal changes in the percentage of individuals in each size class were probably due to the growth of the clams and to increased reproduction and recruitment of immature clams during the spring and summer months.

The shell lengths of *Corbicula* have been an important indicator of the age of individuals in the population (Sinclair and Isom, 1963; Keup et al., 1963; Fast, 1971; Gardner

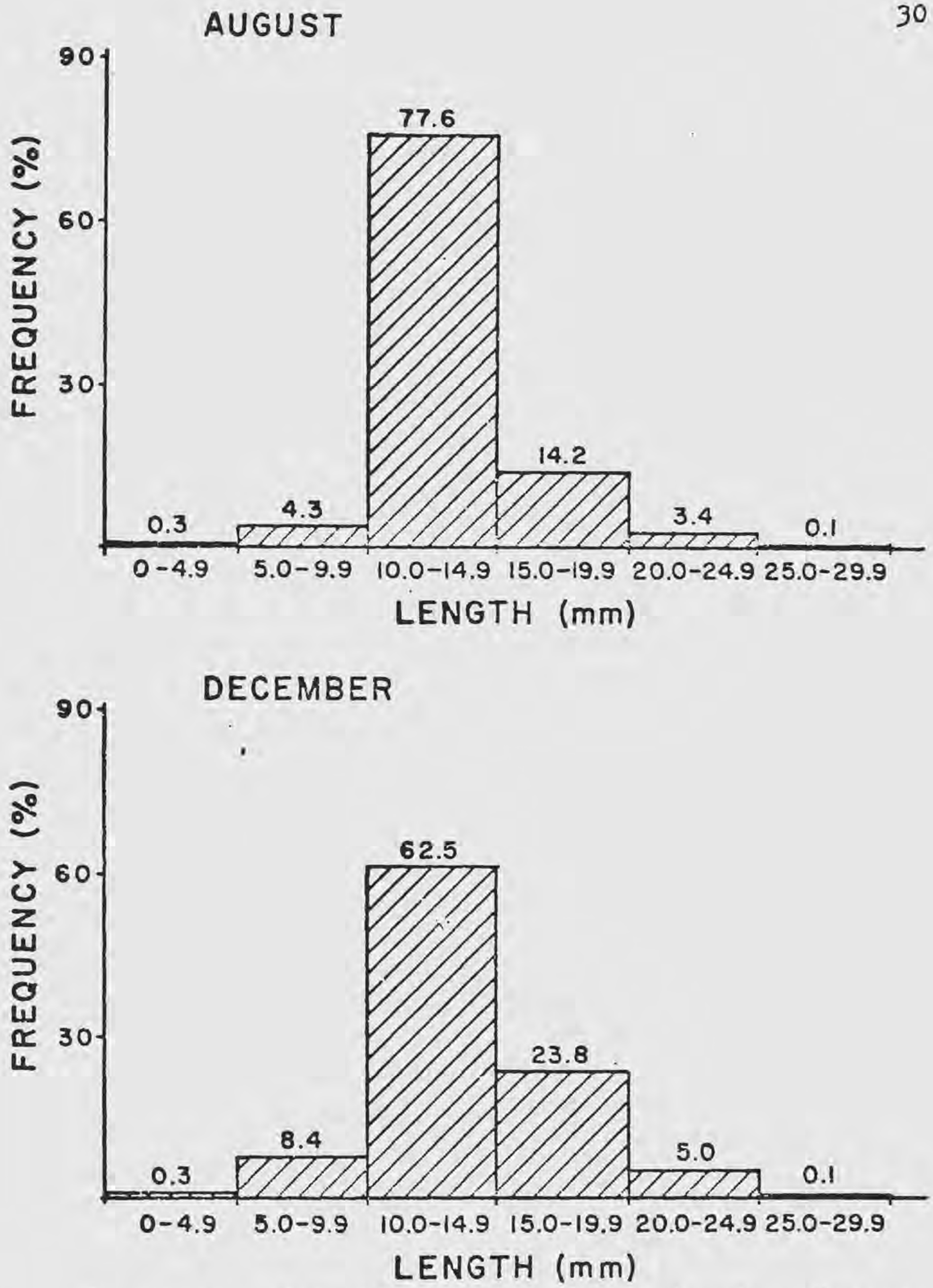

Figure 6. Number of Corbicula in each of six size classes in the Wekiva River in August and December, 1976. Numbers expressed as a relative frequency.

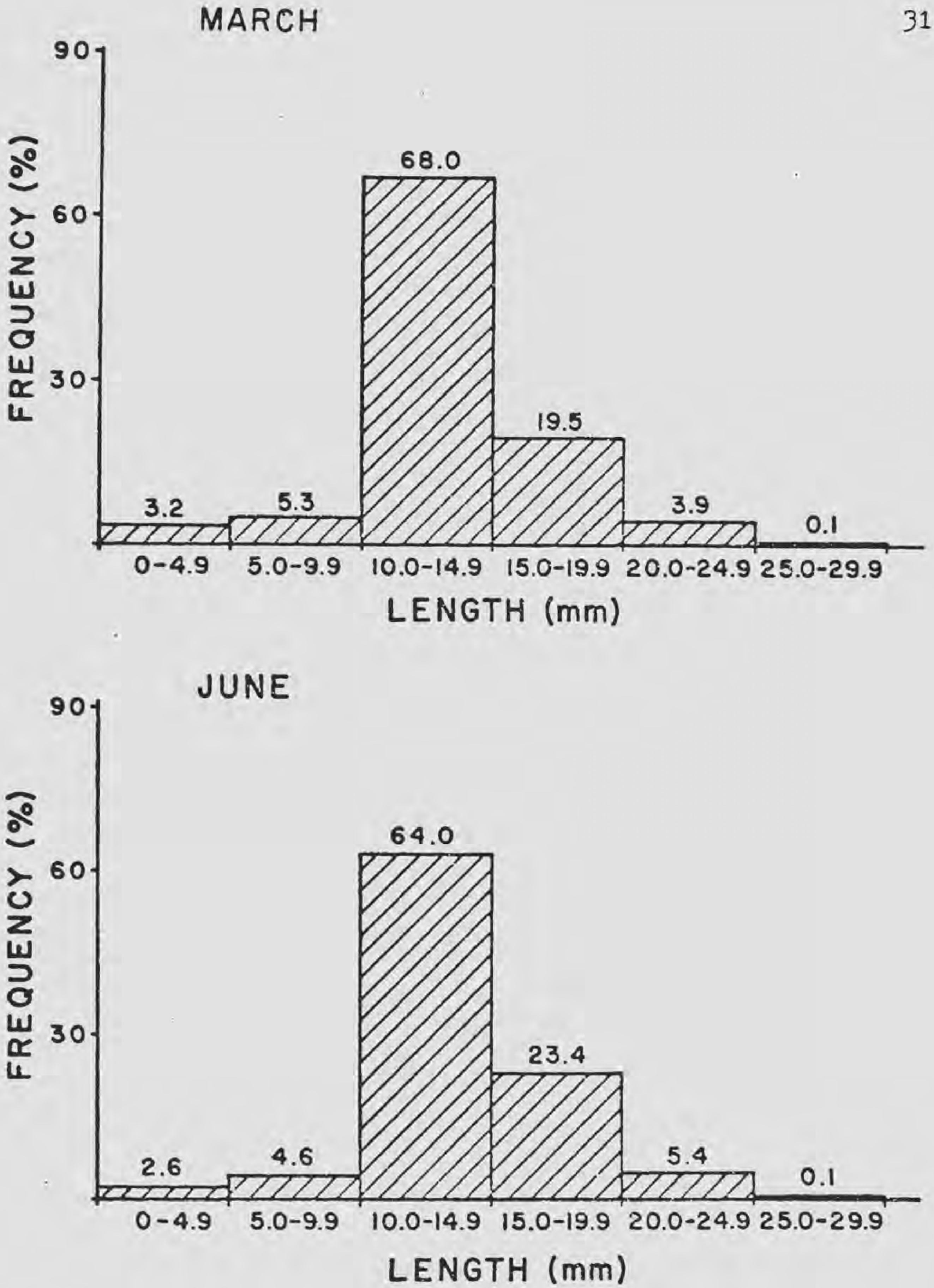

Figure 7. Number of Corbicula in each of six size classes in the Wekiva River in March and June, 1977. Numbers expressed as a relative frequency.

et al., 1976). Individuals are believed to be sexually mature after reaching a length of 6.5 mm. Individuals over 29 mm in length, collected in the Tennessee River, were assumed to be at least four years old (Sinclair and Isom, 1963). A comparison of size and year classes is presented in Table 8, which was first published by Gardner et al. (1976). According to this data, most of the clams in the Wekiva River would be approximately one to two years old since most of the population was in the 10.0-14.9 mm size class. The age of the clams at the upstream stations 1, 2, and 3 would be three to four years,since most of the clams collected there were over 18 mm in shell length. The largest clam collected in the Wekiva River during the study (27.2 mm) could have been three to four years old. Therefore, I conclude that the population in the Wekiva River is young and most likely newly established. More conclusive data are necessary to confirm this suposition since much larger two year old clams have been observed.

A simple linear regression program was used to determine the strength of the relationship between the shell width, shell breadth, number of rings on the shell and the shell length. The correlation coefficient, a measure of the linear association between these variables, was highest for whell width and shell length ($r = 0.98$). This relationship was observed by Joy and McCoy (1975) and Gardner et al. (1976) to permit a rapid method for determining size and

Table 8. Shell lengths retained by sieves and approximate age classes (after Gardner et al., 1976).

Sieve Size (mm)	Shell length retained (mm)	Approximate Age
2.00	7.5	1 yr. (sexually immature)
4.75	7.5-13.5	1 yr. (sexually mature)
9.50	13.5-18.5	2 yrs.
12.50	18.5-28.0	3 yrs.
19.00	28.0	4 yrs.

age classes. Linear association was also observed between shell length and shell breadth ($r = 0.96$) of clams collected in the Wekiva River.

Linear association between shell length and the number of rings on the shell was less (r ranged from 0.68 to 0.88) although significant ($p - 0.05$). Clams with larger rings (fewer rings per unit length) were typically found at upstream stations where abundance was low, while clams with smaller rings (more rings per unit length) were found at downstream stations where abundance was high. I suspect that the number of rings on the shell is not totally dependent on shell length, but is also dependent upon such factors as population density and the availability of resources. Competition for food, space, and oxygen may act to limit growth and, inturn, ring development in densely populated regions of the river. This would reduce the correlation between shell length and the number of rings. The length of the shell probably does not reflect the age of the clam. The age-size relationship is probably dependent upon the habitat type and, therefore, is different between rivers.

Regression analysis generated coefficients of determination (R^2) and prediction equations for shell length at each sampling period (Figs. 8, 9, and 10). The analysis indicated that shell width was a better measure of prediction of shell length (R^2 ranged between 0.95 and 0.99) than shell breadth ($R^2 = 0.92$ to 0.97) or the number of shell rings

(R^2 = 0.68 to 0.88).

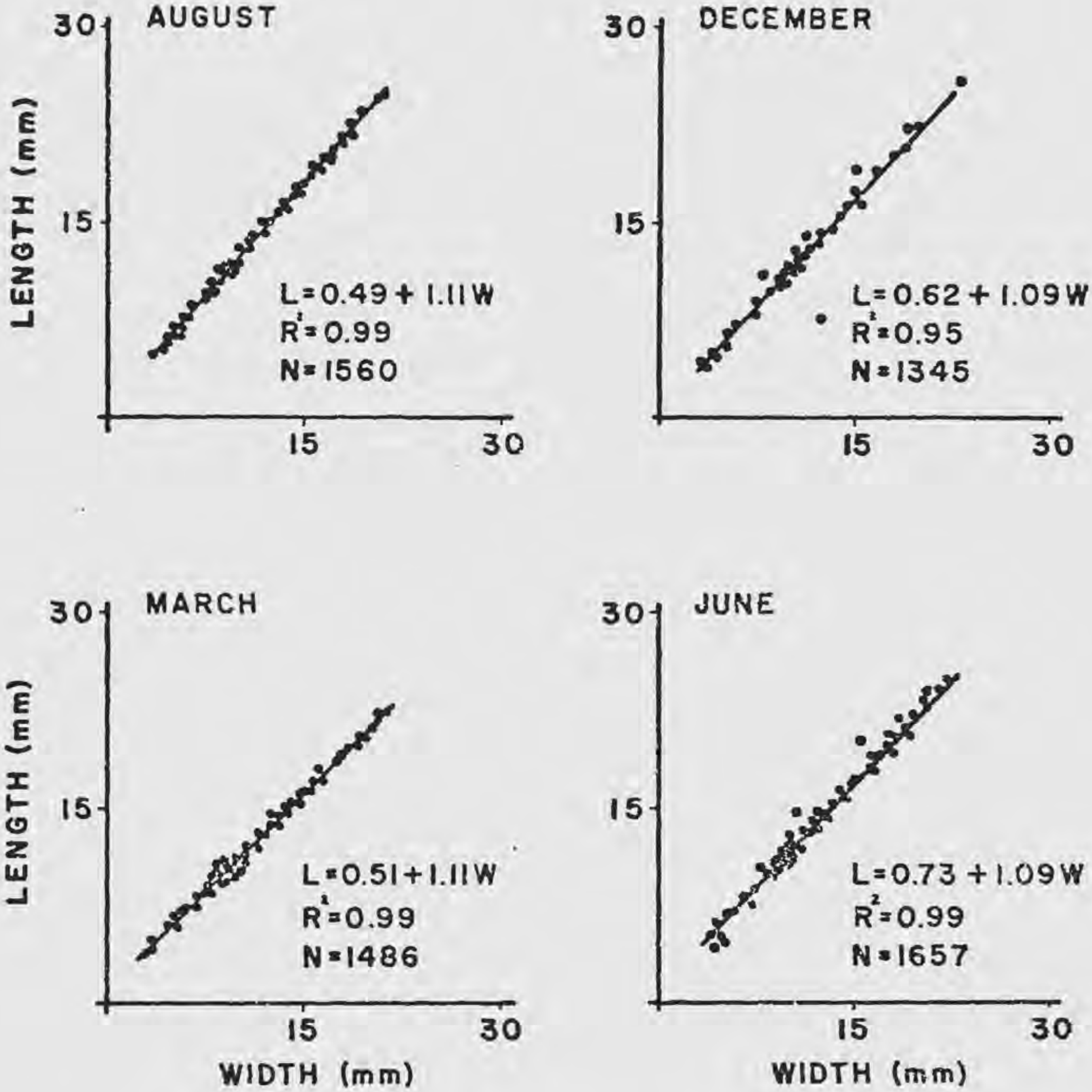

Figure 8. Linear regression of shell length and shell width of Corbicula in the Wekiva River.

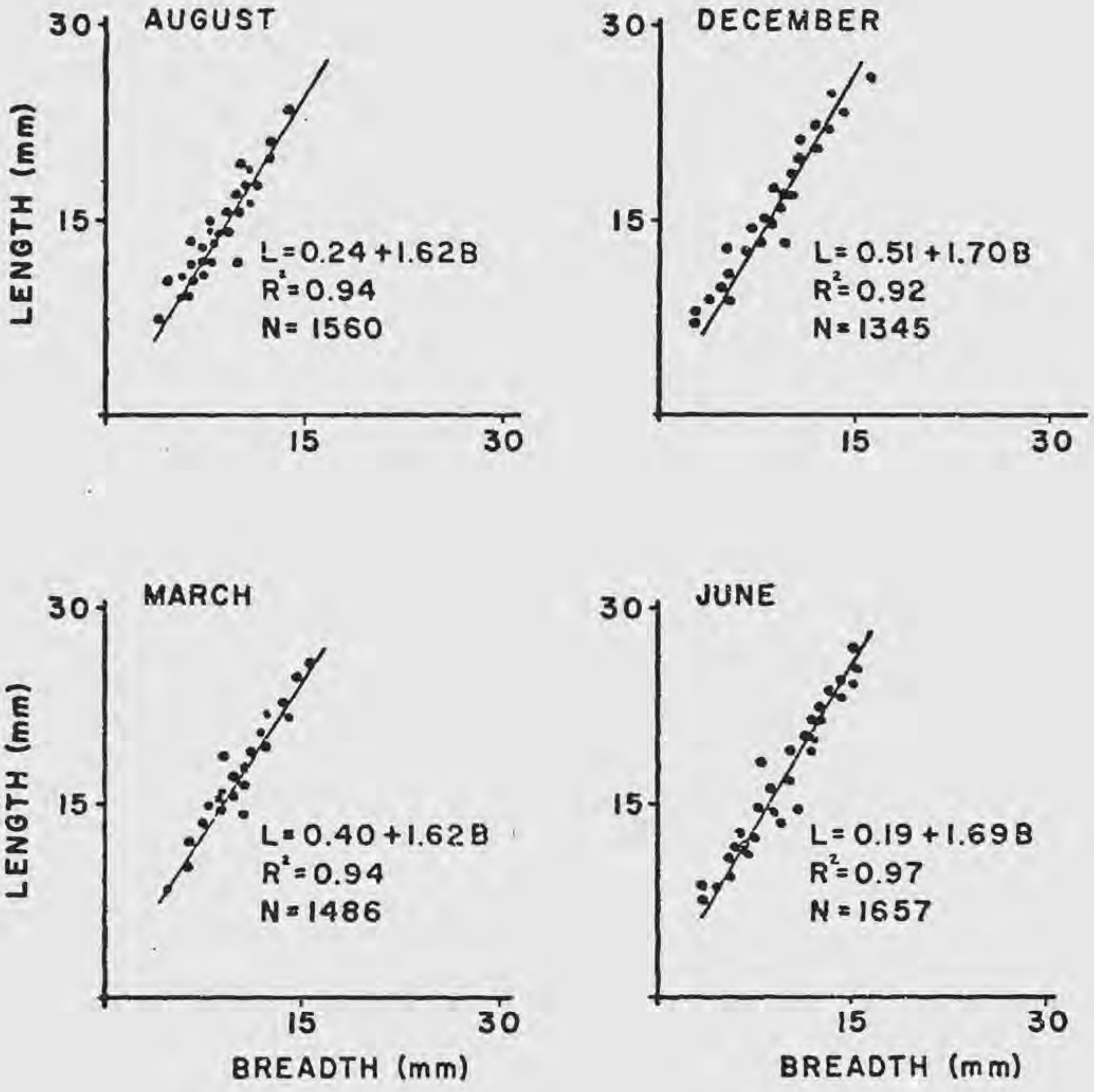

Figure 9. Linear regression of shell length and shell breadth of *Corbicula* in the Wekiva River.

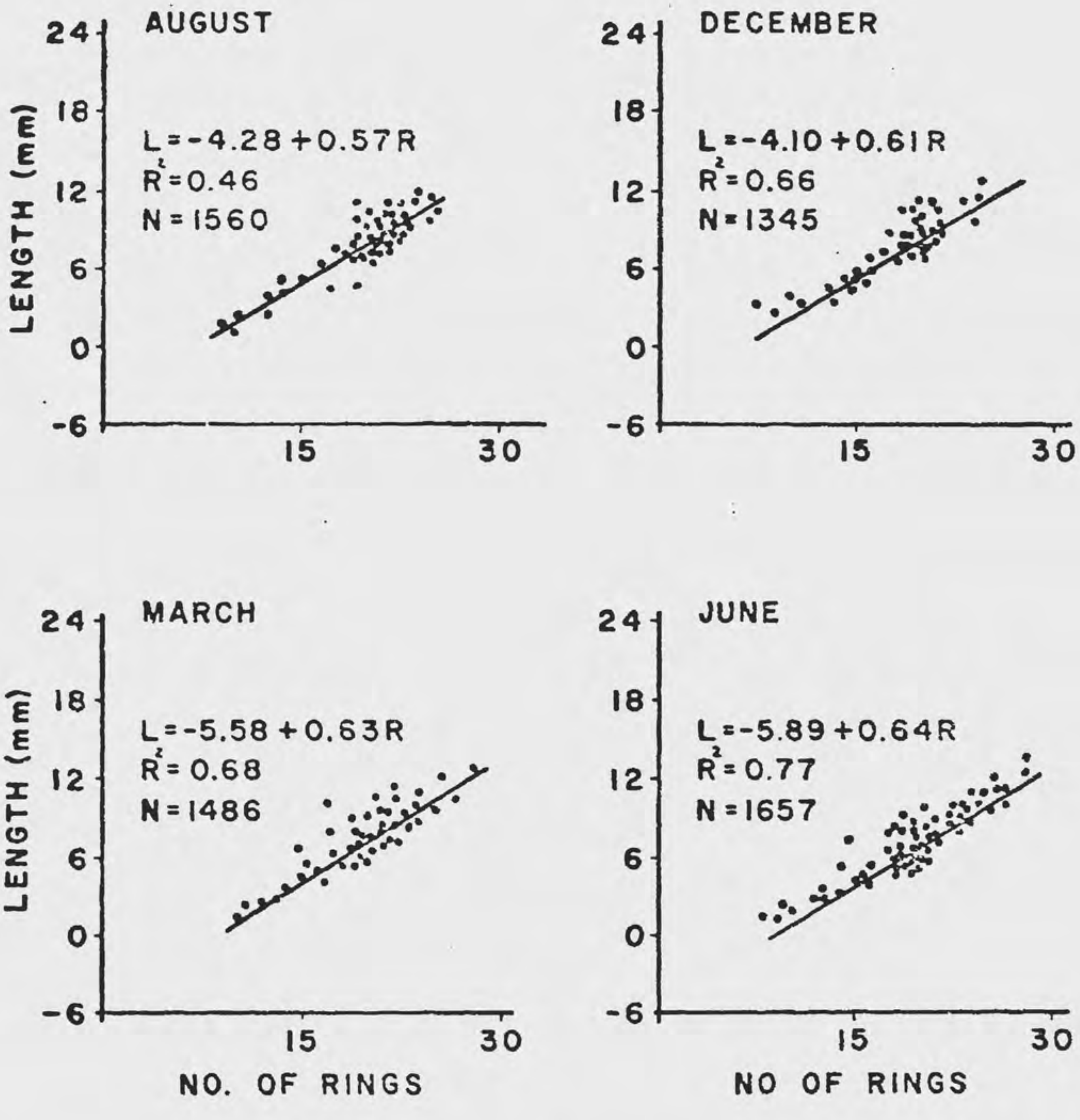

Figure 10. Linear regression of shell length and the number of rings on the shell of <u>Corbicula</u> in the Wekiva River.

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