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Population Characteristics, Food Habits and Spawning Activity of Spotted Seatrout, *Cynoscion nebulosus*, in EVER

NATIONAL PARK SERVICE
DEPARTMENT OF THE INTERIOR

Everglades National Park, South Florida Research Center, P.O. Box 279, Homestead, Florida 33030

Population Characteristics, Food Habits and Spawning Activity of Spotted Seatrout, *Cynoscion nebulosus*, in Everglades National Park, Florida

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Edward Rutherford, Edith Thue and David Buker

National Park Service
South Florida Research Center
Everglades National Park
Homestead, Florida 33030

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ABSTRACT

Age, growth, mortality, stomach content and spawning activity of 570 spotted seatrout taken from sportfishermen catches in Everglades National Park were studied from November 1978 to January 1980. Fish ranged in length from 220-680 mm and in weight from 0.10-2.24 kg. Ages of fish, determined from scale readings, were mainly 3, 4 and 5 year olds. Fish were fully recruited by age 4. Males lived to at least age 6; females to at least age 7. The sex ratio favored females (1.67/1).

Fish lengths at age were back calculated from scale annuli. Fish length varied between sexes and among areas of capture and year classes. Males were larger than females at age 1, but smaller at ages 3-6. Calculated fish length and length at capture were greatest in seasonally brackish areas, and smallest in a hypersaline area of the park. Calculated lengths of year classes were significantly smaller in 1978 than in 1974-77.

Annual mortality of all fish was 0.77. Annual mortality, exploitation ratio and conditional fishing mortality (0.75) were higher for males than for females.

Spotted seatrout in Everglades National Park were carnivorous, eating shrimp and fish. Their diet changed with size; small adults ate proportionately more shrimp than fish while large adults ate more fish than shrimp.

Spotted seatrout spawned nearly year round in Everglades National Park with peaks in spring and late summer. Most ripe fish were collected in seasonally brackish areas of the Park. Age 2, 3 and 4 fish contributed most to the spawn. Size at first maturity was 230 mm for males and 237 mm for females.

Comparison of the results of this study with an earlier study of park spotted seatrout (Stewart, 1961) showed apparent changes in age distribution, age at full recruitment and mortality since 1959, although mean sizes at age of fish have not changed. Dominant ages shifted from 2 and 3 year olds, to 3 and 4 year old fish. Age at full recruitment shifted from age 3 to age 4. Annual mortality of males decreased slightly since 1959, while annual mortality of females increased slightly. Exploitation ratios of both males and females remained constant. Ratios of conditional fishing to conditional natural mortality increased slightly for males and females.

INTRODUCTION

Fishery harvest from Everglades National Park has been monitored through fishermen surveys nearly continuously from 1958 to the present (Higman, 1966; Davis, 1980). Examination of catch and effort data has shown changes in the relative abundance of some gamefish species. Catch rates of red drum, Sciaenops ocellata, appear to have increased since 1958 while those of spotted seatrout, Cynoscion nebulosus, have declined.

The total harvest of major fish and shellfish species from park waters has declined from 2.2 million organisms in 1972 to 1.7 million organisms in 1977 (NPS Fishery Assessment, 1979). The decline in harvest appears to be related to a decline in fishing effort but may also be environmentally related. Annual fluctuations in temperature and rainfall, hurricane incidence, boating activity and alteration of the historic flow of freshwater into the park all may have affected fishery harvest.

Concern over the decline in fishery harvest from Everglades National Park prompted the South Florida Research Center to initiate, in 1978, a study of the population biology, spawning activity, and food habits of the four most popular gamefish species in the park: spotted seatrout, red drum, snook (Centropomus undecimalis), and gray snapper (Lutjanus griseus). Knowledge of the population biology of these species may offer insight into the reasons behind the decline in catches and provide a basis for measuring future changes in the estuary. This paper, the first in a series of reports on the four gamefishes mentioned above, describes the results of these studies for spotted seatrout.

The spotted seatrout is an estuarine sciaenid fish that ranges from Cape Cod, Massachusetts to Mexico (Welsh and Breder, 1924). It is one of the most important recreational and commercial fishes in the Gulf of Mexico (Arnold, Lasswell, Bailey, Williams and Fable, 1976). Spotted seatrout and red drum have always been the two most popular gamefish in Everglades National Park as determined by sport-fishermen interviews (Davis, 1980). Spotted seatrout is also fished commercially in the park.

Tagging studies conducted elsewhere in Florida indicate that spotted seatrout are relatively nonmigratory (Moffett, 1961; Iversen and Tabb, 1962; Beaumariage, 1969). Ninety-five percent of all recaptured fish tagged at Pine Island, Florida were taken within 30 miles of the tagging site (Moffett, 1961; Iversen and Tabb, 1962). Electrophoretic analyses of spotted seatrout collected from different locations in Florida and the Gulf of Mexico have identified distinct subpopulations (Weinstein and Yerger, 1976). Analysis of calculated length at age data has indicated that growth of spotted seatrout varies among estuaries in Florida (Iversen and Tabb, 1962.) It is therefore important for management purposes to study each stock of spotted seatrout individually.

Spotted seatrout have been studied previously in Everglades National Park. Stewart (1961) described its age, growth, spawning activity and food. Higman (1966) correlated catches of spotted seatrout with rainfall and temperature data. Clark (1970) studied the distribution of fishes (including spotted seatrout) in

Whitewater Bay in relation to environmental factors. The relative abundance of fishes (including spotted seatrout) was studied in relation to environmental variables by Roessler (1967) in Buttonwood Canal, and by Jannke (1971) in Buttonwood Canal and the Shark River. Davis (1980) noted changes in length frequency distributions of spotted seatrout, red drum and gray snapper from 1959-1977. The park spotted seatrout fishery has been described in detail by Higman (1966) and Davis (1980).

Description of the Study Area

The mainland shoreline of Everglades National Park extends from the Florida Keys to Everglades City on Florida's west coast. It contains numerous bays, inlets and rivers which lie at the terminus of the historically immense Everglades and Big Cypress swamp drainages. Price (1954), and Tabb, Dubrow and Manning (1962) have described the animal and plant communities of park waters and identified distinct ecological zones. Their work provided the basis for delineating fishing areas used in this study and other Everglades National Park fishery investigations since 1960 (Higman, 1966) (Fig. 1). These areas vary in their topographical, hydrological and biotic characteristics.

METHODS

Data Collection

Data were collected from sportsfishermen catches at the Everglades National Park Flamingo boat ramp from November 1978 through June 1980. Flamingo is a central departure point for fishermen in the park (Fig. 1). Samples collected from Flamingo represent the central part of the fishery but may not adequately represent two other significant areas: the Florida Bay side of the Florida Keys within the park (Areas 1 and 2), and the western part of the park including Everglades City and the lower 10,000 islands (Area 6). Special effort was made to sample fish caught in the inland waters of the park (Areas 4 and 5) in order to compare food analysis results with concurrent studies of benthic organism availability in these areas. Therefore, the number of fish sampled from various park areas probably does not reflect their true relative abundance.

Scale samples for age and growth determinations were taken from behind the pectoral fin on the left side of the fish. The scales from each fish were placed in a coin envelope on which the following information was recorded: species, sample number, location of catch, date, time collected, time caught, gear type used (bait and/or artificial), weight (kg), standard length (mm), sex, reproductive condition and observer.

Aging Methods

Spotted seatrout have previously been successfully aged using scale annuli in Everglades National Park (Stewart, 1961), in eastern Florida (Tabb, 1961), and elsewhere in the Gulf of Mexico (Pearson, 1928; Klima and Tabb, 1959; Moffett, 1961). In this study, the following criteria (Bagenal, 1979) were used to evaluate the validity of age determinations from annular marks on spotted seatrout scales:

1. Fish body growth is proportional to scale growth.

2. Scale annular formation is seasonal and occurs only once each year.

3. Back calculated lengths of fish at age N are between observed lengths at capture of fish aged N-1 and N.

4. Lengths at capture of fish aged by scales agree with modal lengths of age groups determined by the Petersen length frequency method.

Scales were prepared for age analysis by pressing them into plastic slides with an Ann Arbor fish scale press and photographing the slide impressions with a Model 500 3 M microfilm reader printer. The enlarged (20X) scale pictures were examined for number of annuli. The distance from the focus was measured for each annulus and for the total scale radius. Fish body length was regressed on total scale radius for each area of capture and sex to determine the proportionality of fish body growth to scale growth. The y intercept of this regression was used as the correction factor "a" in the Dahl-Lea (Bagenal, 1979) formula to back calculate fish length at each annulus. The Dahl-Lea formula is:

$$l_t = \left(\frac{St}{S}(L - a)\right) + a$$

where l_t is length at age t, St is the distance (mm) to annulus t, S is the total scale radius and L is the observed fish length (mm) at capture.

Seasonality of scale annulus formation was estimated by plotting scale radius marginal increment against month of capture. Year class of fish was determined by subtracting the number of annuli from the date of capture.

Sex was determined by inspection of the gonads. Developmental stages of the gonads were classified according to Lagler (1956).

<u>Growth</u>

Possible differences in back calculated fish lengths and lengths at capture among sexes and areas of capture were analyzed using two factor Analysis of Variance (Zar, 1974). Differences in calculated annual fish growth among year classes were analyzed using three factor (year class, sex, area of capture) Analysis of Variance. A student Neuman-Keuls test was used to determine which specific differences were significant. Growth data (mean back calculated lengths at age) were fitted to the von Bertalanffy growth equation (Bayley, 1977). Length-weight relationships were calculated for each sex according to the formula:

$$W = a L^b$$

where W= weight (decagrams), L= length (mm S.L.), and a,b are empirically determined constants. The length-weight regressions were logarithmically (base 10) transformed and compared using analysis of covariance (Zar, 1974).

Survival

Annual survival was estimated for fully recruited fish from the age distribution of the catch (Robson and Chapman, 1961). Age at full recruitment was determined according to Robson and Chapman's (1961) method. Total instantaneous mortality coefficients (Z) were calculated from the estimates of annual survival (S) using the relationship $Z = -\ln S$. Natural mortality coefficients (M) were estimated from variables (K, L_∞) obtained from the von Bertalanffy equation and from mean water temperatures ($T^{o}c$) recorded in the study area according to Pauly's (1980) equation:

$$\log 10\, M = -0.0066 - 0.2790 \log 10\, L_\infty + 0.6543 \log 10\, K + 0.4634 \log 10\, T$$

Estimates of fishing mortality coefficients (F) were then obtained by subtracting the estimated natural mortality coefficient from the coefficient of total mortality. These mortality coefficients also permitted calculation of exploitation ratios (E), conditional fishing mortalities (m), and conditional natural (n) mortalities.

Exploitation ratios measure the fraction of total mortality in a stock due to fishing when fishing and natural mortality occur simultaneously. Conditional mortalities measure the mortality due to either fishing or natural causes in a stock assuming it is the only form of mortality occurring at that time (Ricker, 1975).

Food Analyses

Stomach samples for the food study were removed by cutting open the body cavity from the throat to the anal pore. The stomach was removed by clamping the esophagus and cutting above the clamp. Stomachs were immediately placed in 10% buffered formalin for later examination.

Food items of stomach samples were identified to the species level when possible. For analysis of percent frequency and percent volume, prey species were grouped into six categories: shrimp, fish, crabs, mollusks, algae + plants and other. The percent volume of each food item was taken by blotting dry the item, measuring its volume (mL) by water displacement and expressing this as a percentage of the total volume of food in a designated series (individuals of a species; by area, sex and month). The percent frequency of a food item was calculated as the number of stomachs in which it occurred, divided by the total number of stomachs in the series.

RESULTS

Seven hundred and forty eight spotted seatrout were collected for analysis from Florida Bay (Areas 1, 2, 3) and the Whitewater Bay-Shark River areas (Areas 4, 5). No fish from the lower Ten Thousand Islands areas (Area 6) were sampled. Five hundred and seventy of the fish were examined for information on age and growth, reproductive condition and stomach content. An additional 178 spotted seatrout were measured for length frequency information and 154 fish examined for stomach content. Fish ranged in length from 220-680 mm (S.L.) ($\bar{x} = 330 \pm 4$ mm) and in weight from 0.10-2.24 kg ($\bar{x} = 0.57 \pm .02$ kg).

Length Frequency

The mean length of all fish in the catch was 330 mm (Fig. 2). Females (x = 341 $\pm$ 6 mm) were significantly larger ($p \leq .001$) than males (x = 314 $\pm$ 6 mm). Females ranged in length from 220-530 mm, while males ranged in length from 230-465 mm (Fig. 3).

Significant (x^2 = 21.53; $P < .05$) seasonal differences in length frequency distributions were noted for spotted seatrout (combined sexes). Small fish (<280 mm) occurred proportionately more often in winter than in other seasons. The mean length of fish was greatest in spring and declined steadily in summer, fall and winter. Female length distributions also differed significantly (x^2 = 22.993; $P < .05$) among seasons. Large females (>400 mm) occurred proportionately more often in spring than in summer, fall or winter. Mean length of females was greatest in spring and least in fall and winter. Male length distributions were not significantly different among seasons. Because no consistent seasonal progression in mean length of fish or length modes was noticed, recruitment into the fishery was considered continuous.

Significant ($.01 < P < .025$) differences were found in length frequency distributions of male spotted seatrout among areas of capture. Mean fish length was significantly larger ($P < .025$) and sample size smaller in North Florida Bay than in the Whitewater Bay and Cape Sable areas. Fish from south Florida Bay (Area 2) were not included in the analysis of variance because of inadequate sample size (n = 4) although their mean length was largest ($\bar{x}$ = 412 mm) of all. Length frequency distributions of females and combined sexes, considered separately, were not significantly different among areas.

Verification of Aging Technique

Scales from 570 spotted seatrout were analyzed for annular marks. Tabb (1956) gives an excellent description of spotted seatrout scales and their annuli which proved to be invaluable in finding annular marks:

> "The circuli and normal checks are concentric with the scale margin. There is no appreciable crowding of circuli in the zones designated as annuli. Annuli are characterized by a slight dip in the scale surface and a disconformity of the circuli in the lateral posterior angle of the scale. New radii often originate in the immediate vicinity of annuli, hence are useful in locating an annulus in large scales with coarsened surface features. The ctenii inside and outside the first annulus differ in size and regularity, and form the best single clue to the location of the first annulus, a mark that may be overlooked."

We verified age analysis of spotted seatrout by scale annuli by meeting all criteria listed in the Methods section except age analysis by the Petersen length frequency method.

Scale margin increments were plotted by season for age 3 and 4 fish in the catch to determine time of annulus formation (Fig. 4). Most minimal scale increments (0-2 mm) occurred in spring (March, April and May), indicating that spotted seatrout form annuli at this time (Fig. 4). The mean marginal increment increased during the year. It was lowest in spring and rose steadily to a peak in winter. The occurrence of a few fish with minimal scale margin increments in fall may be due to mistaking spawning checks on the scales of these fish for annular marks.

Fish body length was significantly ($P<.001$) correlated with scale growth for each sex in each area of capture. The regressions of fish body length on total scale radius were found to be significantly ($P<.001$) different among sexes and areas by analysis of covariance. Regression plot elevations of males and females in the Cape Sable area (Area 3) differed significantly from each other and from all other fish. Therefore, three groups were formed: males from Cape Sable, females from Cape Sable, and males and females from North Florida Bay, South Florida Bay, Whitewater Bay and the Shark River Area (Areas 1, 2, 4, 5) (Fig. 5). The y intercept of each group was used as the standard correction factor "a" to back calculate lengths at previous ages.

Figure 6 and Appendices 1-3 show the distribution of back calculated lengths and observed lengths at capture for 539 spotted seatrout. Mean observed lengths at annulus are similar to, but larger than, back calculated lengths because of growth since annulus formation.

To compare the age-length key derived from the Petersen method with the age-length key derived from scale readings, modal lengths of fish in the length frequency distributions were separated by Cassie's (1954) method and compared with lengths at capture of scale-aged fish (Table 1). Only at age 3 were lengths at capture of scale aged fish and modal lengths of the length distributions similar. No modal lengths were observed below 280 mm S.L. because of the 12 inch T.L. (258 mm S.L.) minimum size limit. Based upon lengths at age reported for other spotted seatrout stocks (Pearson, 1928; Tabb, 1961), young of the year and age 1 fish were underrepresented in the catch. It was therefore impossible to determine ages of spotted seatrout from length frequency analysis without a representative sample of small fish.

Age Composition and Sex Ratio of the Catch

The sportfish catch in Everglades National Park consisted mainly of 3 and 4 year old fish, which comprised 45% and 29% of the catch, respectively (Fig. 7). Recruitment to the fishery began at age 1 and was complete by age 4 as determined by a Robson and Chapman (1961) chi square analysis. The number of fish caught dropped sharply after age 4; no males over 6 years old and no females over 7 years old were observed. The small number of age 1 fish examined (4) was primarily due to the minimum legal size limit of 12 inches (305 mm T.L.); sport-fishermen report catching small fish frequently and releasing them.

The mean age of all fish in the catch was $3.3 \pm .1$ yrs. The mean age ($\bar{x} = 3.4 \pm .1$ yrs.) of females was significantly ($.005 < P < .01$) older than mean age ($\bar{x} = 3.1 \pm .1$ yrs.) of males. Mean ages of males, females and combined sexes did not vary among areas.

The overall sex ratio of the catch favored females by 1.67/1. The sex ratio remained constant with age as indicated by chi square tests for heterogeneity. The sex ratio appeared to be different at ages 1 (0.33/1) and 6 (3.5/1) because sample size was small; the ratio remained constant at ages 2 through 5 where sample size was larger. No significant differences were found in sex ratio among areas.

Growth

Back calculated lengths based on scale annuli indicate that growth of spotted seatrout is greatest in the first year of life when growth averages 212 mm (Fig. 8). Yearly growth increments are smaller (40-50 mm) from ages 1-5 but are uniform from year to year. The smallest mean length increment (22 mm) occurred in the sixth year. The large increase in growth in the seventh year (71 mm) may be an artifact of the small sample size of large fish available for back calculation in this year.

Significant sexual differences in length at capture and back calculated length were found for spotted seatrout. Females were significantly ($P < .001$) larger in observed length at capture at ages 3, 4 and 5. Males were larger ($P < .05$) in back calculated length than females at age 1 but were again smaller ($P < .01$) at ages 3, 4 and 5, indicating that females grew significantly ($P < .001$) more than males in the second, third, fourth and fifth growth years (Fig. 9).

Significant ($P < .025$) area differences in fish length were found at ages 1 through 4. Mean lengths at capture of fish in the Shark River area were largest and lengths of fish in the Cape Sable area smallest at age 4. Mean back calculated lengths of fish in the Cape Sable area were smallest at ages 1-4 (Fig. 10), although these differences in fish length were detected by a SNK test only at ages 3 and 4. Back calculated growth rate of fish differed significantly ($P < .025$) between areas in the first, third and fifth growth years. In the first and fifth growth years, fish in North Florida Bay grew most and fish in Cape Sable grew least. In the third growth year fish in the Shark River area grew most and fish in Whitewater Bay grew least. Fish taken from South Florida Bay were excluded from the analyses because of small sample size (N = 10).

Differences in calculated annual growth rate of year classes were noticed for spotted seatrout. Year classes of fish increased in length at significantly ($P < .001$) different rates in the second, third and fourth growth years (Fig. 11). In these growth years, year classes grew significantly less in calendar year 1978 than in any other calendar year.

Interaction effects between area of capture, sex and year class on fish length were examined but no clear differences were found.

Growth Equation

The regression of G, the instantaneous growth coefficient, on the reciprocal of mean length was significant ($.025 < P < .05$) for both males, females and combined sexes (Fig. 12). The von Bertalanffy equations derived from this regression appeared to fit calculated length data at ages 1-6 well. Figure 13 compares lengths estimated by the von Bertalanffy equation with mean back calculated length data. The von Beralanffy equations were:

males	$L_t = 591 (1 - e - .12 (t + 2.95))$
females	$L_t = 656 (1 - e - .13 (t + 2.04))$
combined sexes	$L_t = 774 (1 -e - .09(t + 2.54))$

Confidence intervals (95%) around K, L_∞ and t_o for males, females and combined sexes are listed in Appendix IV. Confidence intervals calculated for L_∞ were negative because of the poor fit, and subsequent high variance, of the length weight regression to very small (age 1) and very large (age 7) fish. The high variance created wide confidence intervals around $1/L_\infty$, and thus L_∞; confidence intervals around k and t_o were smaller.

The von Bertalanffy estimates of L_∞, the maximum theoretical length of a species, are smaller than the size of the largest spotted seatrout reported for Florida, a 860 mm (15 lb, 6 oz) fish (Lorio and Perret, 1980).

Length-weight relationship

Figure 14 shows a length-weight relationship calculated for 567 spotted seatrout. A logarithmic (base 10) transformation of the data provided the best fit ($P < .001$) to the relationship for males, females and combined sexes. There was no difference in length-weight relationship between sexes or among areas of capture.

Survival

Survival rates of spotted seatrout were calculated from the age composition of the catch. All fish were fully recruited by age 4 (as determined by the Robson and Chapman (1961) method, therefore survival estimates were calculated for spotted seatrout older than age 3.

Annual survival of all fish was $S = 0.23 \pm 0.05$. Male survival ($S = 0.18 \pm .10$) was lower than female survival ($S = 0.25 \pm 0.07$) (Table 2). The natural mortality coefficients calculated from Pauly's equation for males ($M = 0.35$) and females ($M = 0.36$) were nearly identical; natural mortality coefficient of both sexes combined was 0.27. These coefficients, when subtracted from total mortality coefficients estimated by the Robson and Chapman method, yielded fishing mortality coefficients that were higher for males ($F = 1.37$) than for females ($F = 1.02$). Consequently, the exploitation ratio (E) and ratios of conditional fishing to natural mortality (m/n) were higher for males than for females (Table 2). Conditional fishing mortality rates were at least twice as high as conditional natural mortalities for each sex.

Food Analyses

Figure 15 shows the results of the analysis of 724 seatrout stomachs. Two hundred thirty eight (32.5%) of the fish analyzed contained food items. A species list of all identifiable food items is given in Appendix V.

Spotted seatrout consumed mainly shrimp of the family Penaeidae, primarily *Penaeus duorarum*. Shrimp appeared in 72.7% of all stomachs and totalled 53.8% of the food volume. Other common shrimp species in the diet were *Alphaeus heterochaelis* and *A. armillatus*.

Fish were the next most important prey, occurring in 42.4% of the stomachs and comprising 43.5% of the volume. The most common identifiable families were Sparidae, particularly *Archosargus rhomboides*, Batrachoidadae and Gerreidae, particularly *Eucinostomus* spp.

Algae and marine plants ranked third in frequency (17.2%) and volume (2.0%) in the diet but may have been consumed accidentally along with other food items. Commonly consumed marine plants were *Thalassia testudinum*, *Halodule wrightii*, *Ruppia maritima*, and *Udotea flabellum*.

Molluscs and crabs constituted a very small portion of the diet, occurring in 8.8% and 3.8% of the stomachs and comprising 0.3% and 0.07% of the volume, respectively. Molluscan prey included *Ceritheum eburneum*, *Modulus modulus*, *Brachidontes exustus*, *Marginella apicina*, and *Bulla striata*. The most commonly consumed crab species was *Pagures annulipes*.

The last prey category, "other", contained tunicates, serpulid worms, amphipods and unidentifiable organic matter.

Differences in food consumption by area of capture, season, sex and size (length) of the predator were tested by chi-square analysis of prey frequencies in the diet. There were no significant differences in food consumption by area, season or sex.

Food consumption did differ significantly ($P<.01$) by size of predator (Fig. 16). The percentage frequency and volume of fish prey species increased with the size of the predator. Fish prey species occurred in stomachs of small ($<$271 mm) spotted seatrout only 20% of the time and occupied 11.6% of the volume, whereas in large ($>$371 mm) spotted seatrout, fish were predominant (58.3% frequency, 64.2% volume) in the diet. Conversely, shrimp were most common (88.3%) and occupied the most volume (87.2%) in the diet of small spotted seatrout but were less prevalent (58.3% frequency, 35.2% volume) in the diet of large predators. The consumption of other prey categories did not change with predator size.

The use of shrimp (*Penaeus duorarum*) and fish (*Mugil cephalus*) as bait did not significantly distort their relative abundance as food items in the analyses. The frequencies of all prey categories consumed by fish caught on all bait types was not significantly different from those consumed by fish caught on artificial bait. The size of fish caught on all bait types and on artificial lures was approximately the same, discounting the possibility of size influence on food consumption by the 5 groups.

Spawning Activity

Spotted seatrout were found to spawn nearly every month of the year in Everglades National Park. However, spawning peaks occurred in spring and late summer. Most females examined (46%) spawned in late summer with a secondary peak (37%) in spring. Most males examined (33%) spawned in spring with a secondary peak (29%) in summer (Fig. 17). The seasonal difference in spawning peaks among males and females was slight and probably does not represent distinctly different spawning peaks by sexes.

Ripe fish of both sexes were collected in all areas of the park. Most fish in spawning condition were caught in the Shark River and Whitewater Bay areas during the year (Fig. 18); in Shark River and North Florida Bay during the late summer peak, and in Shark River, Whitewater Bay and North Florida Bay during the spring peak.

The smallest ripe male spotted seatrout collected was 237 mm; the smallest ripe female collected was 230 mm. The age distribution of all ripe fish (Table 3) shows that age 3 and age 4 fish numerically contributed most to female spawning effort, while male spawning effort came primarily from age 2, 3 and 4 fish.

DISCUSSION

Length Frequency

Distinct annual modes in length frequency distributions of the park spotted seatrout population were difficult to discern because of the species' extended spawning season; fish spawned in April grow almost a full season more than fish spawned in October, creating a bimodal distribution (Guest and Gunter, 1958). After 2 years, when most fish start recruiting into the fishery, modes become even less distinct. The lack of distinct modes in the length distributions make age analysis by length frequency difficult, if not impossible. Therefore, in Everglades National Park, as has been shown for spotted seatrout in other areas (Pearson, 1928; Klima and Tabb, 1959; Moffett, 1961; Stewart, 1961; Tabb, 1961), scales or otoliths should be used to accurately age the fish.

Seasonal differences observed for mean spotted seatrout length may indicate greater availability of large fish in spring than in other seasons. Fish length decreased steadily after spring, suggesting that these large fish move out of the park during the year. Seasonal inshore-offshore movements have been reported for spotted seatrout in Georgia (Mahood, 1974), Florida (Tabb, 1966), and Texas (Simmons, 1951; Guest and Gunter, 1958).

Sex Ratio

Our findings of an overall sex ratio favoring females agrees with those reported previously (Pearson, 1928; Klima and Tabb, 1959; Moffett, 1961; Stewart, 1961; Tabb, 1961). The sex ratio remained constant with age in this study. However, the sex ratio of park spotted seatrout reported by Stewart in 1961 favored females by a lesser amount (1.3/1), and changed with age, going from near unity at ages 1 and 2 to favor females at ages 3, 4 and 5. Stewart made a special effort to obtain small (young) fish, perhaps making his ratio more representative of the park population.

Age, Growth and Mortality

All studies of spotted seatrout in east Florida and in the Gulf to date have shown sexual differences in growth and longevity (Pearson, 1928; Klima and Tabb, 1959; Moffett, 1961; Stewart, 1961; Tabb, 1961). In some populations, females live longer than males and are larger at every age (Pearson, 1928; Klima and Tabb, 1959; Stewart, 1961; Tabb, 1961). In this study, males were larger than females at age 1, and smaller after age 2. Females lived longer than males. The difference in longevity between the sexes in Everglades National Park might be explained by differences in fishing mortality. Our observations suggest that males experience higher rates of annual mortality and conditional fishing mortality than females but equivalent rates of conditional natural mortality. No estimates of longevity have been made for unfished populations.

Mortality rates of spotted seatrout have been estimated only twice before. Iversen and Moffett (1962), in a tagging study of a Pine Island, Florida population, estimated the total annual mortality rate of all fish to be 41.6%. Conditional natural mortality was 1.3 times greater than conditional fishing mortality. Tatum (1980) estimated the mean total mortality rate of an Alabama population by length frequency analysis to be 50%. Both studies sampled fish of the same length range as the park population.

The calculated growth curve derived for the 1979 Everglades National Park spotted seatrout population was similar at ages 3-7 to those reported for the 1959 park population and other populations in Florida's east coast and the Gulf of Mexico (Fig. 19). Spotted seatrout in the present study were larger at ages 1 and 2 than other populations studied because of the back calculation formula used. Previous investigators back calculated lengths at annulus directly without a correction factor according to the formula $L_t = \frac{s_t}{S} L$, where L_t = length at annulus t, L = length of fish at capture, s_t = scale radius at annulus t, S = total scale radius (Bagenal, 1979). The difference in length resulting from the type of back calculation formula used becomes negligible after age 2 when lengths of the park spotted seatrout population closely parallel lengths reported for other Gulf populations.

Varying growth of spotted seatrout among ecologically different areas in the park may be due to environmental differences among these areas. Fish grew less in the hypersaline Cape Sable area than in the seasonally brackish areas (Whitewater Bay, Shark River, North Florida Bay) of the park. Salinities in Cape Sable are generally the highest of all park areas, ranging from $26-47^{o}$/oo and averaging 35^{o}/oo (Tabb, Dubrow and Manning, 1962). They exceed optimal salinities reported for growth and survival of larval spotted seatrout ($20-35^{o}$/oo) and for metabolic activity and sustained swimming speed of juvenile and adult fish (20^{o}/oo) (Wakeman and Wohlschlag, 1977; Taniguchi, 1980). Since tagging studies have shown that spotted seatrout are relatively nonmigratory (Iversen and Tabb, 1962; Beaumariage, 1969), it is likely that local environmental conditions could have affected their growth.

The y intercepts of the scale radius body length relationships of males and females in Cape Sable were significantly different from each other and from fish in other areas. The differences in y intercepts were probably an artifact of having sampled adult fish. It is unlikely that sexual differences in size at scale formation would exist in the Cape Sable area and not in other areas.

Observed differences in calculated growth of seatrout year classes may be artifacts of Rosa Lee's phenomenon (Bagenal, 1979), in which lengths of a given age group are larger the older the fish from which they were calculated (i.e., fish in their third growing season in 1975 (year class 1973) were largest, and fish in their third growing season in 1978 (year class 1976) were smallest). Lee's phenomenon may be caused by size selective mortality eliminating the smaller members of an age group, leaving a pool of large individuals from which to back calculate fish lengths (Bagenal, 1979). It is also possible that the poor growth of year classes in 1978 may have been caused by unfavorable climatic conditions in that year.

Temperature is one of the most important parameters influencing growth of fish, (Webb, 1978; Brett, 1979). Although spotted seatrout have been observed to survive and feed actively at temperatures between $4-33^{o}C$ when allowed time to acclimate (Simmons, 1957), they survive and grow best at temperatures ranging from $23.1-32.9^{o}C$ for larvae (Taniguchi, 1980) and $15-27^{o}C$ for adults (Tabb, 1966). We examined air temperature data for 1978 for Everglades National Park to see if unusually cold weather had occurred which might have influenced growth. The winter of 1978 was not unusually cold. Mean temperature of $20.5^{o}C$ for the period November 1980 through March 1979 was $3.7^{o}C$ warmer than the long-term average and temperatures dropped below $4^{o}C$ for only 2 days (NOAA, 1978, 1979). Other factors, including salinity and food availability, may have caused the poor growth of year classes in that year.

Food Habits

Results of this food study confirm findings of other food studies of spotted seatrout in the Gulf of Mexico (Pearson, 1928; Moody, 1950; Stewart, 1961; Tabb, 1961; Seagle, 1969). Spotted seatrout are carnivorous, eating mainly fish and shrimp. Their diet changes with size. Seasonal differences found in other investigations (Gunter, 1945; Moody, 1950) of spotted seatrout stomach content were not found in this study.

Spawning Activity

Stewart (1961) also found that park spotted seatrout spawn throughout the year with peaks in spring and fall. Stewart correlated the spawning peaks to a surface water temperature range of 25-30°C. He collected most ripe fish from north Florida Bay and Cape Sable. Over 70% of the ripe fish collected in the present study came from the seasonally brackish Whitewater-Coot Bay and Shark River areas (Areas 4 and 5 combined), although this may reflect sampling bias rather than actual location of spawning activity. Roessler (1967) and Jannke (1971) collected larval and juvenile spotted seatrout in passes and canals leading to the inland waters of the park. They both postulated that spotted seatrout spawn near ocean passes or channels which lead to brackish water. Taniguchi (1980) reported that survival and growth of laboratory reared spotted seatrout larvae were optimal at 23.1-32.9°C and 20-35 °/oo, conditions commonly found in Whitewater Bay and the Shark River area. The ability of spotted seatrout to use the estuarine environment as a nursery area is thought to afford protection from stenohaline competitors and predators (Tabb, 1966).

Elsewhere in the Gulf of Mexico, spotted seatrout spawn from February through October with a peak in May (Pearson, 1928; Klima and Tabb, 1959; Fontenot and Rogilio, 1970). They are known to mature at 1 to 3 years, with the majority of fish reaching maturity in the third year (Miles, 1950; Guest and Gunter, 1958; Klima and Tabb, 1959).

CONCLUSIONS

Comparison of our results with those of Stewart's (1961) earlier study of park spotted seatrout indicates a change in age distribution, age at full recruitment and mortality rate since 1959. Although Stewart did not provide specific figures, estimates from Figure 12 of his thesis indicate that mean lengths at capture at age of males and females do not appear to have changed.

The age distribution of the catch appears to have shifted from a predominance of 2 and 3, to 3 and 4 year old fish (Fig. 20). Age at full recruitment switched from age 3 in 1959 to age 4 in 1979. The apparent shift in age structure may be an artifact of sample bias. Stewart (1961) stated that he made a special effort to collect juvenile fish in the 1959 study. Therefore, the relative proportions of 1 and 2 year old fish in his study may not reflect their true abundance in the recreational catch.

Mortality rates of fully recruited spotted seatrout have also changed from 1959 to 1979. Annual mortality rates of all fish and of females taken separately increased slightly. These changes in mortality rates were not affected by sample bias. If one assumes that spotted seatrout were fully recruited at age 4 in 1959, thereby eliminating Stewart's sample bias for smaller fish, mortality rates still increased from 1959 to 1979. These changes in mortality rates were due to corresponding changes in both fishing mortality and natural mortality (Table 4).

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Table 1. Median lengths at capture of scale aged fish compared with medians of modes of length frequency (L - F) distributions for spotted seatrout males, females, and combined sexes.

	Age 1	2	3	4	5	6	7
Males							
Median lengths at capture of scale aged fish	231	283	305	340	394	415	
Median of L - F Modes (mm)		257	302	348			
Females							
Median lengths at capture of scale aged fish	237	280	321	369	427	421	505
Median of L - F Modes (mm)		255	312	383	451		
Combined Sexes							
Median lengths at capture of scale aged fish	233	282	314	359	416	420	505
Median of L - F Modes (mm)		250	305	377			

Table 2. Estimates of annual survival (S) and monthly (A), instantaneous fishing (F) and natural mortality (M) coefficients, exploitation ratio (E), and ratio of conditional fishing mortailty (m) to conditional natural mortality (n) for spotted seatrout males, females and combined sexes in Everglades National Park.

	S[1]	A	M	F	m/n	E
Combined Sexes	.23 ± .05	.77	.27	1.21	2.92	.82
Males	.18 ± .10	.82	.35	1.37	2.52	.80
Females	.25 ± .07	.75	.36	1.02	2.11	.74

[1] Survival rates with 95% confidence intervals.

Table 3. Age distribution of ripe spotted seatrout in Everglades National Park by number and percentage.

	Males		Females		All Fish	
Age	N	%	N	%	N	%
1	0	0.0	1	1.1	1	0.8
2	7	25.0	5	5.5	12	10.1
3	12	42.9	41	45.1	53	44.5
4	8	28.6	36	39.6	44	37.0
5	1	3.6	6	6.6	7	5.9
6	0	0.0	1	1.1	1	0.8
7	0	0.0	1	1.1	1	0.8
Total	28	100.1	91	100.1	119	99.9

Table 4. Annual survival (S), and mortality (A) rates, instantaneous fishing (F) and natural (M) mortality coefficients, exploitation ratio (E) and ratio of conditional fishing (m) to conditional natural (n) mortality for spotted seatrout males, females and combined sexes in 1959 and 1979, Everglades National Park.

	S	A	M[1]	F[1]	m/n[1]	E[1]
Combined Sexes						
1959 =	0.28	0.72	0.43	0.83	1.61	0.66
1979 =	0.23	0.77	0.45	1.03	1.77	0.69
Males						
1959 =	0.15	0.85	0.54	1.36	1.78	0.72
1979 =	0.18	0.82	0.46	1.26	1.94	0.73
Females						
1959 =	0.34	0.66	0.39	0.68	1.40	0.63
1979 =	0.25	0.75	0.50	0.88	1.50	0.64

[1]For purposes of comparison these estimates were made from lengths back calculated from the same formula, without a correction factor.

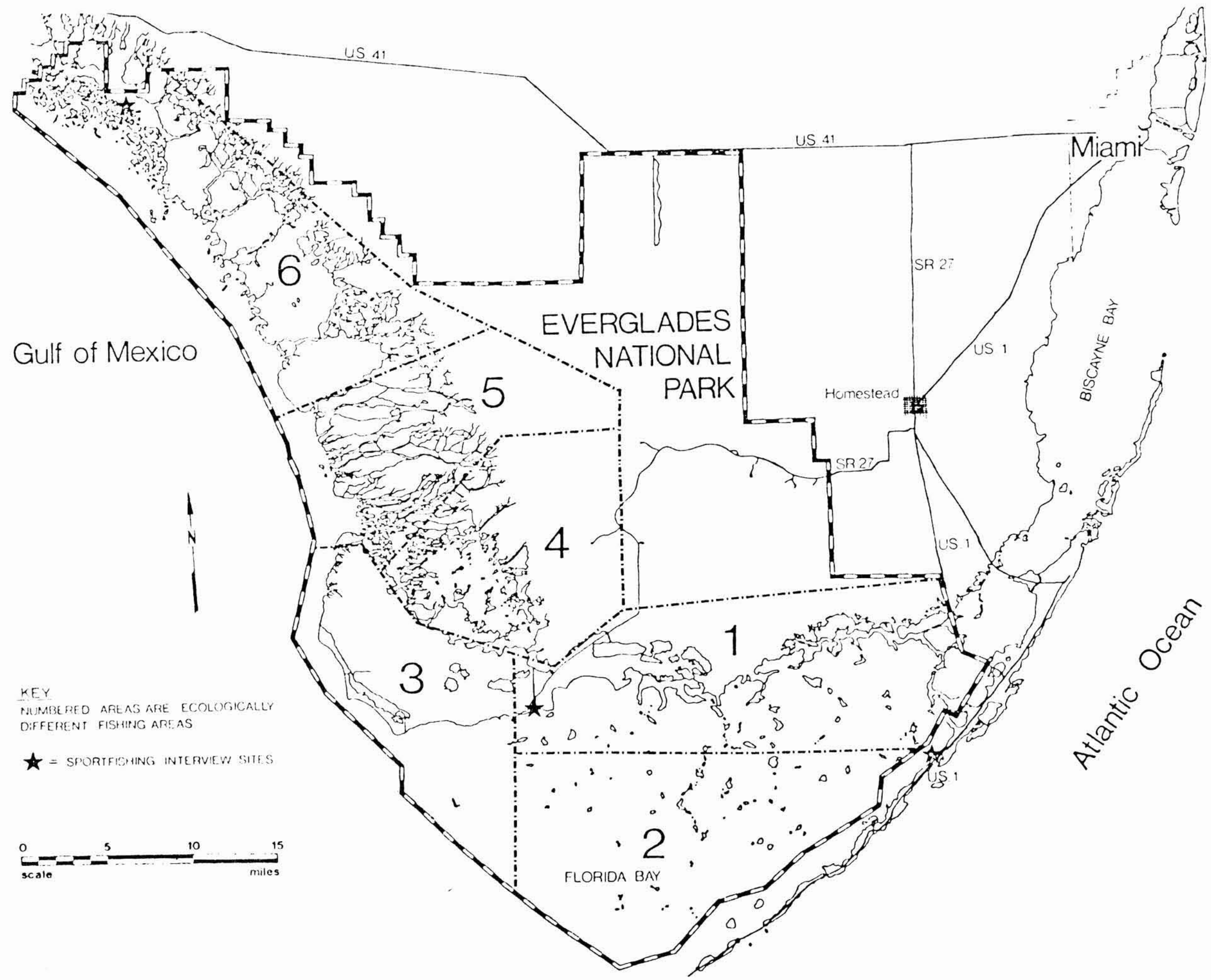


Figure 1. Fishing areas in Everglades National Park, Florida. Numbered areas are: North Florida Bay (1), South Florida Bay (2), Cape Sable (3), Coot-Whitewater Bays (4), Shark River area (5), Ten Thousand Islands (6).

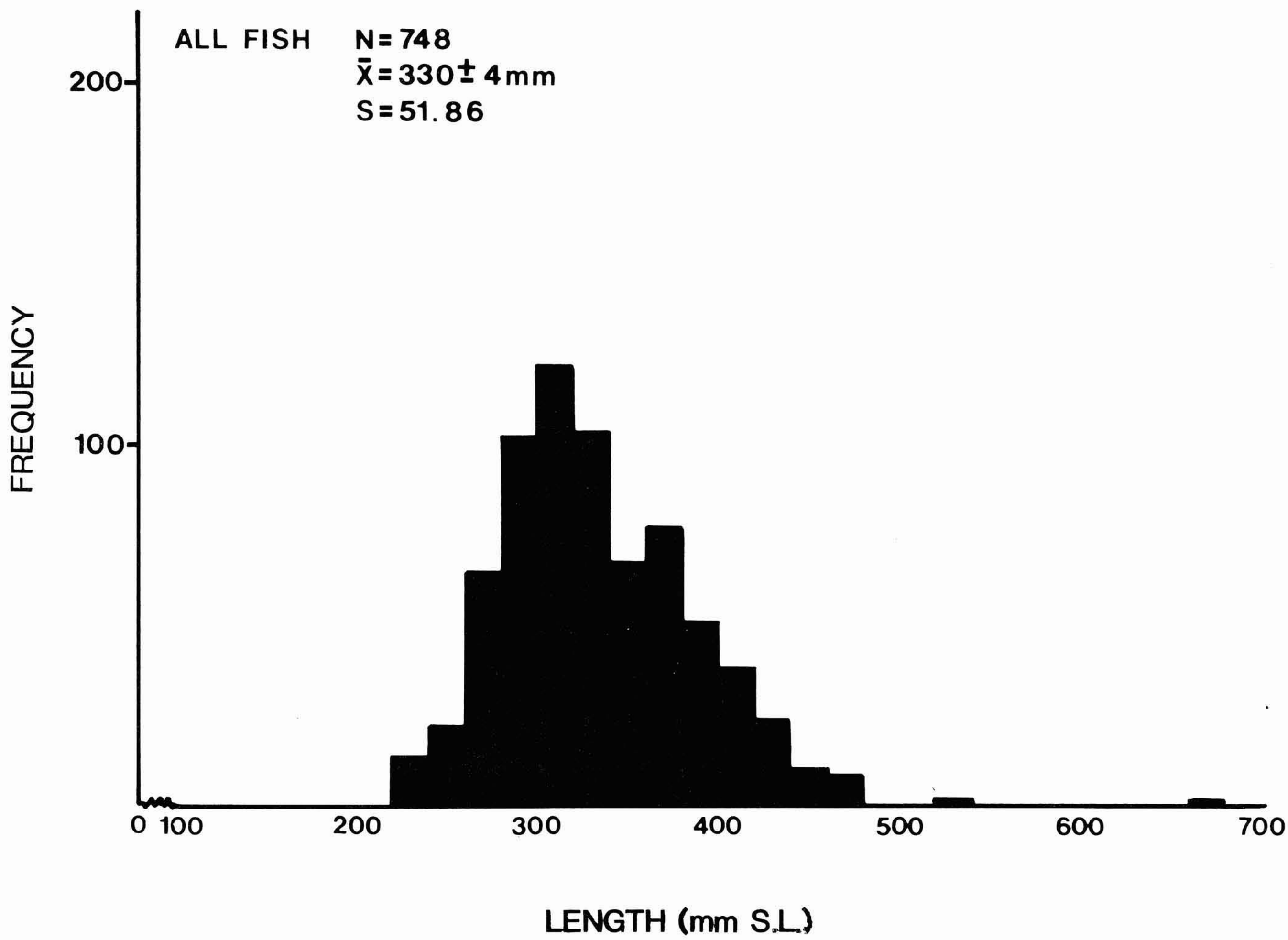
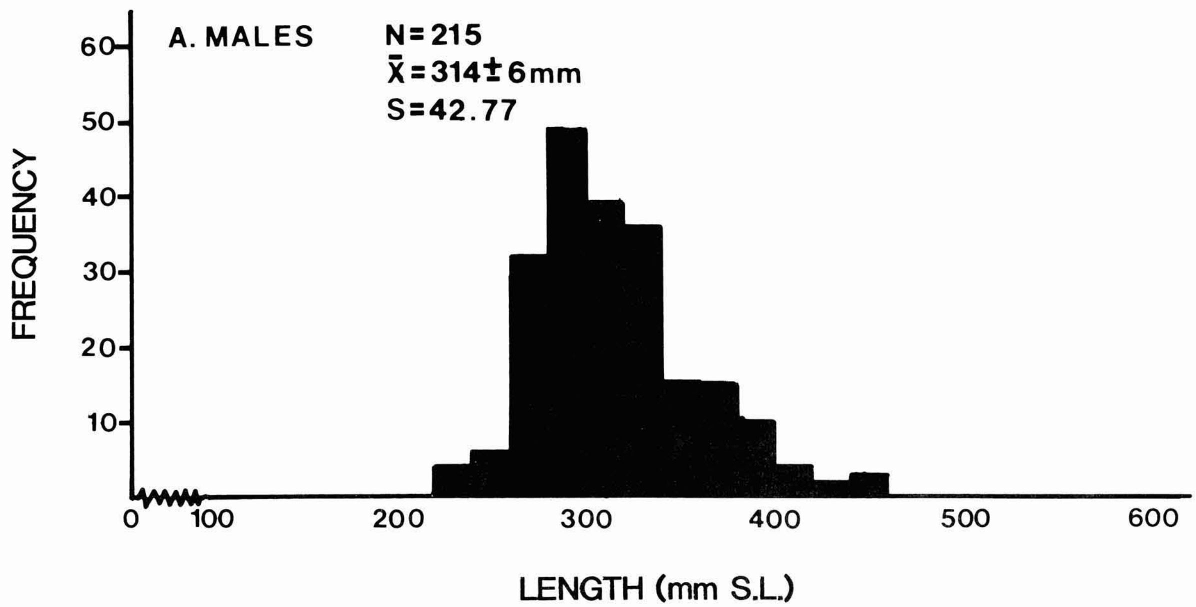


Figure 2. Length-frequency distribution of all spotted seatrout collected from sportfishermen catches in Everglades National Park, Florida. Means with ± 95% confidence intervals.



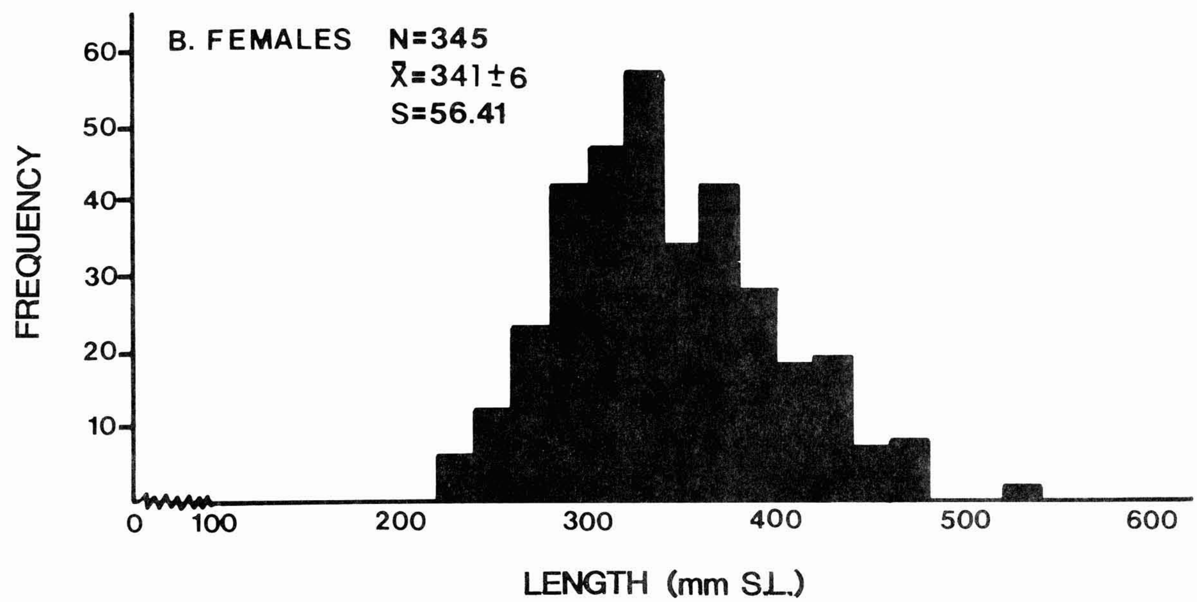


Figure 3. Length-frequency distributions of male and female spotted seatrout collected from sportfishermen catches in Everglades National Park, Florida. Means with ± 95% confidence intervals.

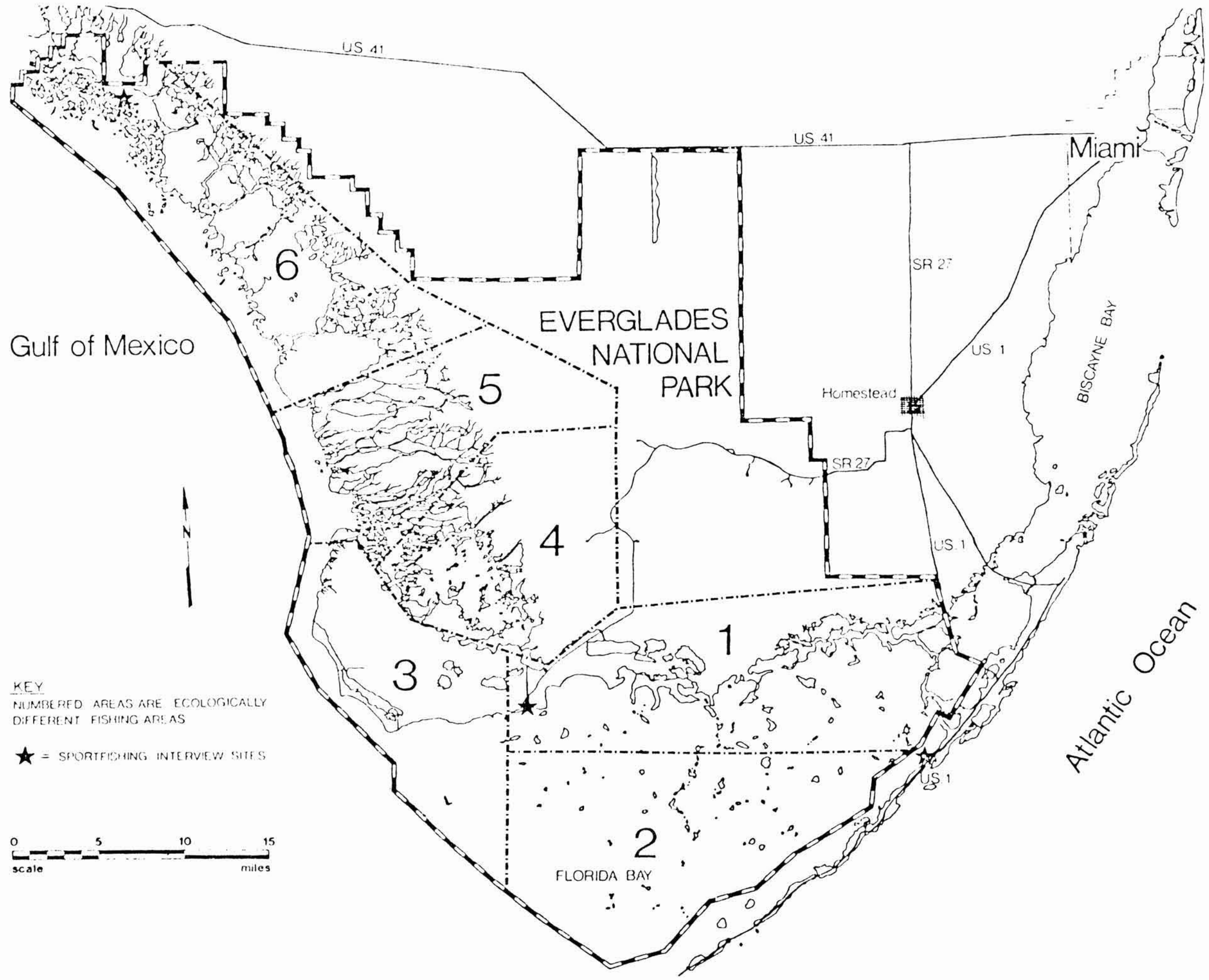


Figure 1. Fishing areas in Everglades National Park, Florida. Numbered areas are: North Florida Bay (1), South Florida Bay (2), Cape Sable (3), Coot-Whitewater Bays (4), Shark River area (5), Ten Thousand Islands (6).

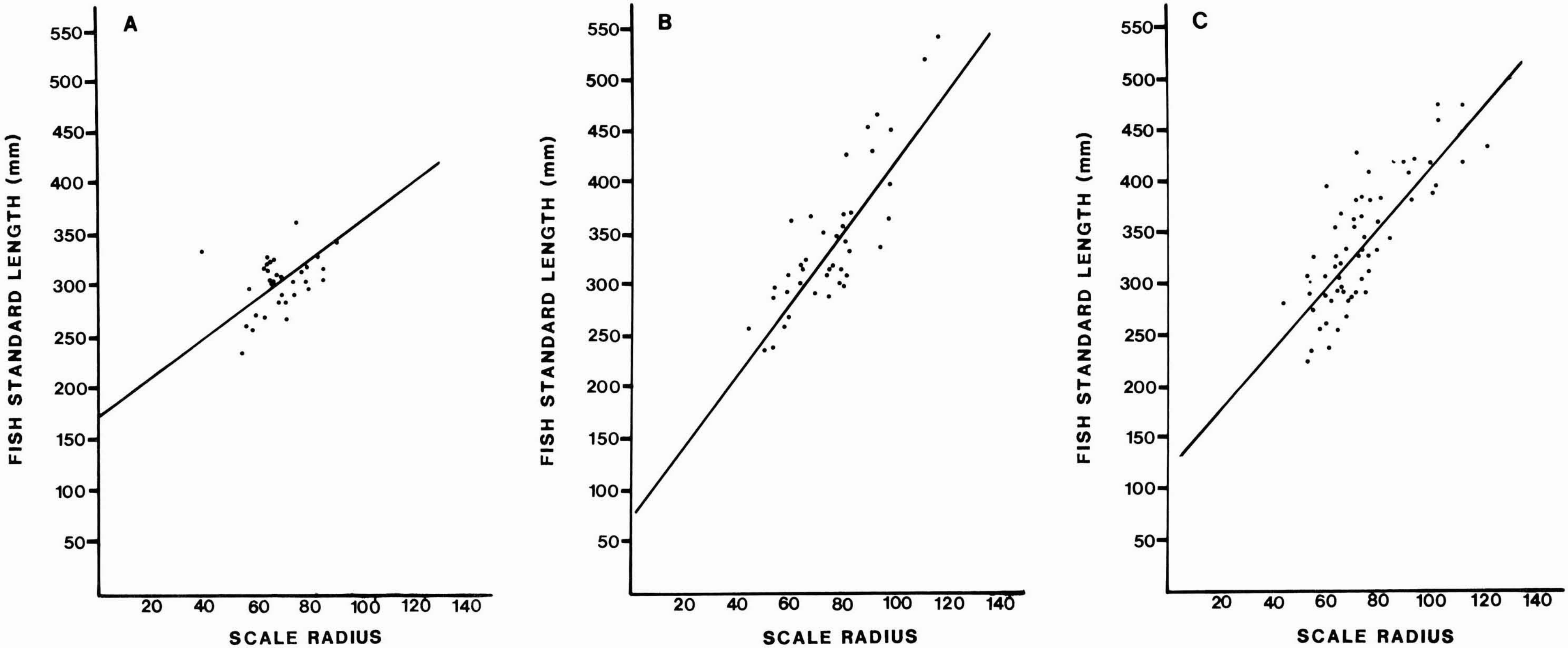


Figure 5. Body length - scale radius regressions for spotted seatrout in Everglades National Park, Florida : Males, Cape Sable (length = 171.42 + 1.93(scale radius), n = 63, r = 0.59 (A)); Females, Cape Sable (length = 72.62 + 3.49(scale radius), n = 88, r = 0.79 (B)); Males and females, Coot - Whitewater Bays, Shark River, North and South Florida Bays (length = 119.13 + 2.99(scale radius), n = 387, r = 0.75 (C)).

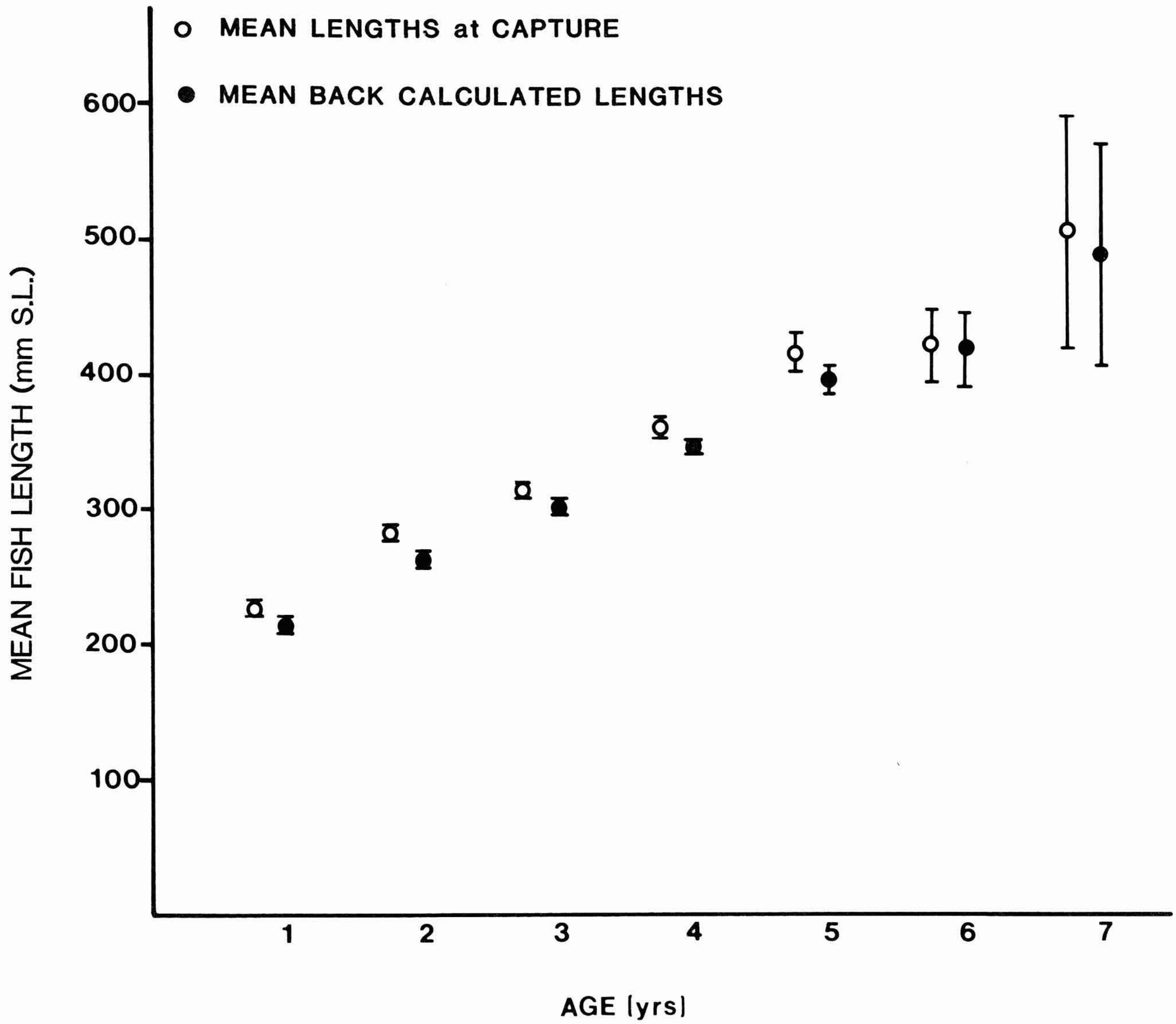


Figure 6. Mean back-calculated lengths and lengths at capture at age of all spotted seatrout in Everglades National Park, Florida. Bars indicate 95% confidence intervals.

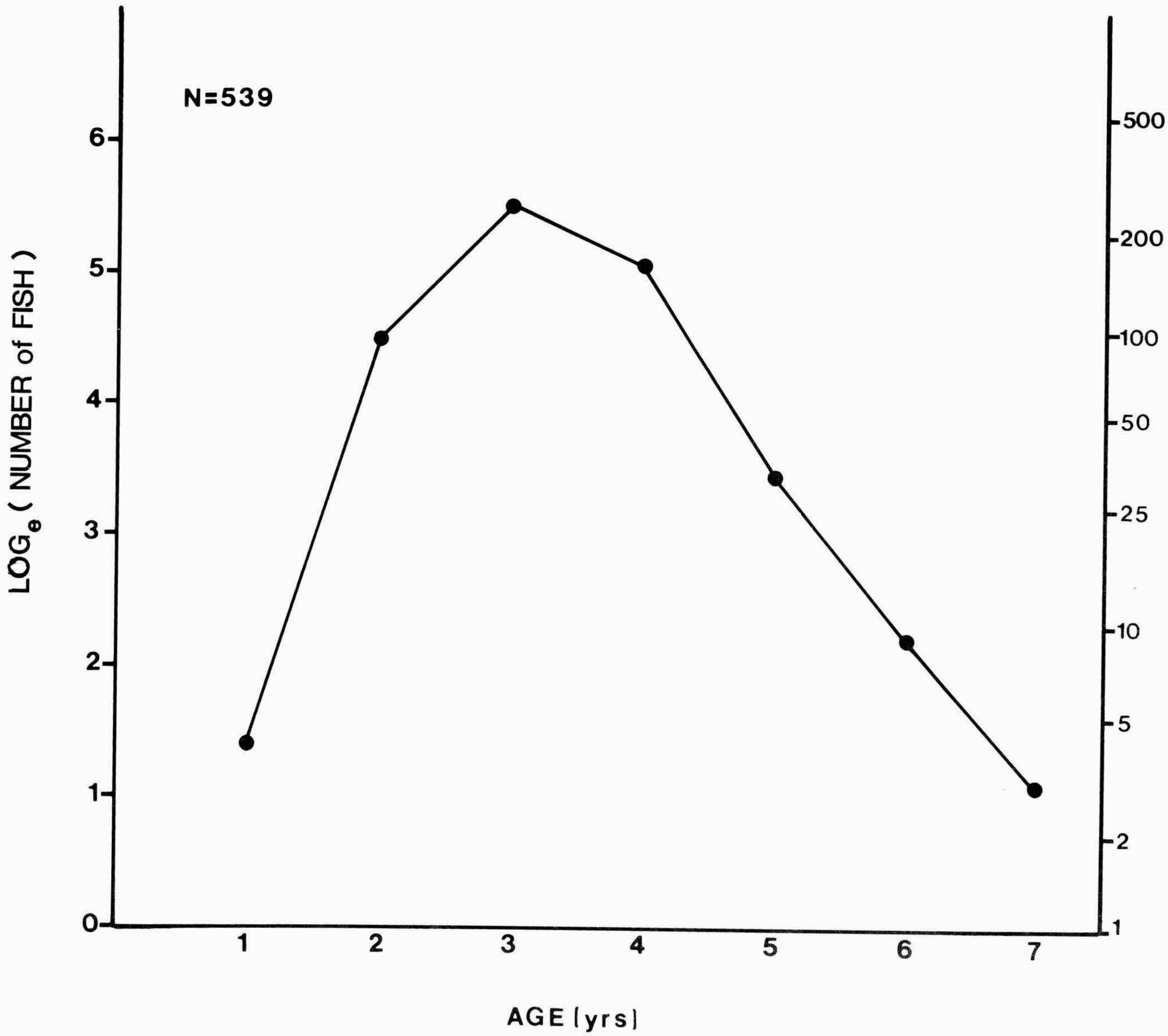


Figure 7. Catch curve of all scale-aged spotted seatrout collected from sportfishermen catches in Everglades National Park, Florida.

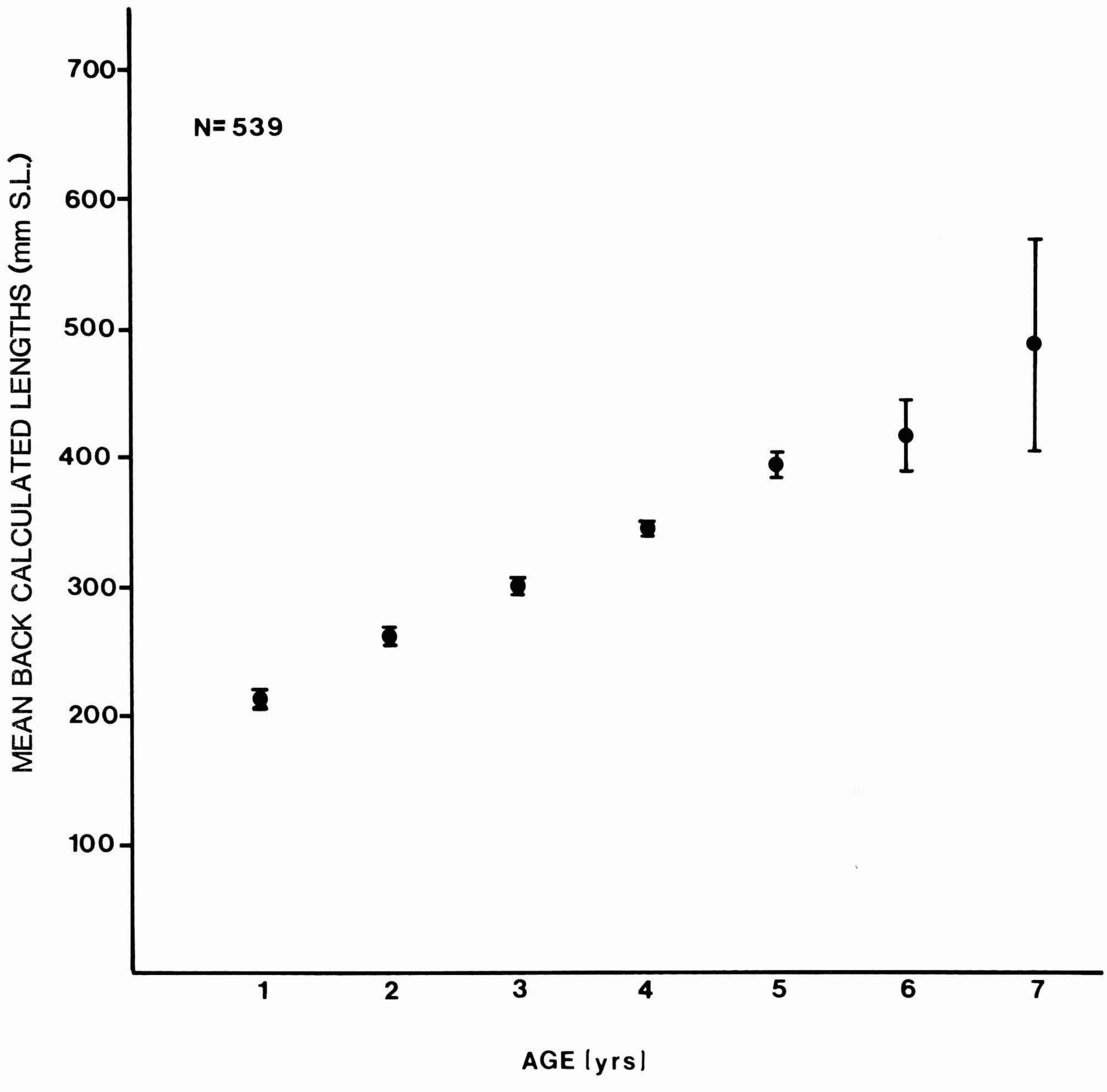


Figure 8. Mean back-calculated lengths at age of all spotted seatrout in Everglades National Park, Florida. Bars indicate 95% confidence intervals.

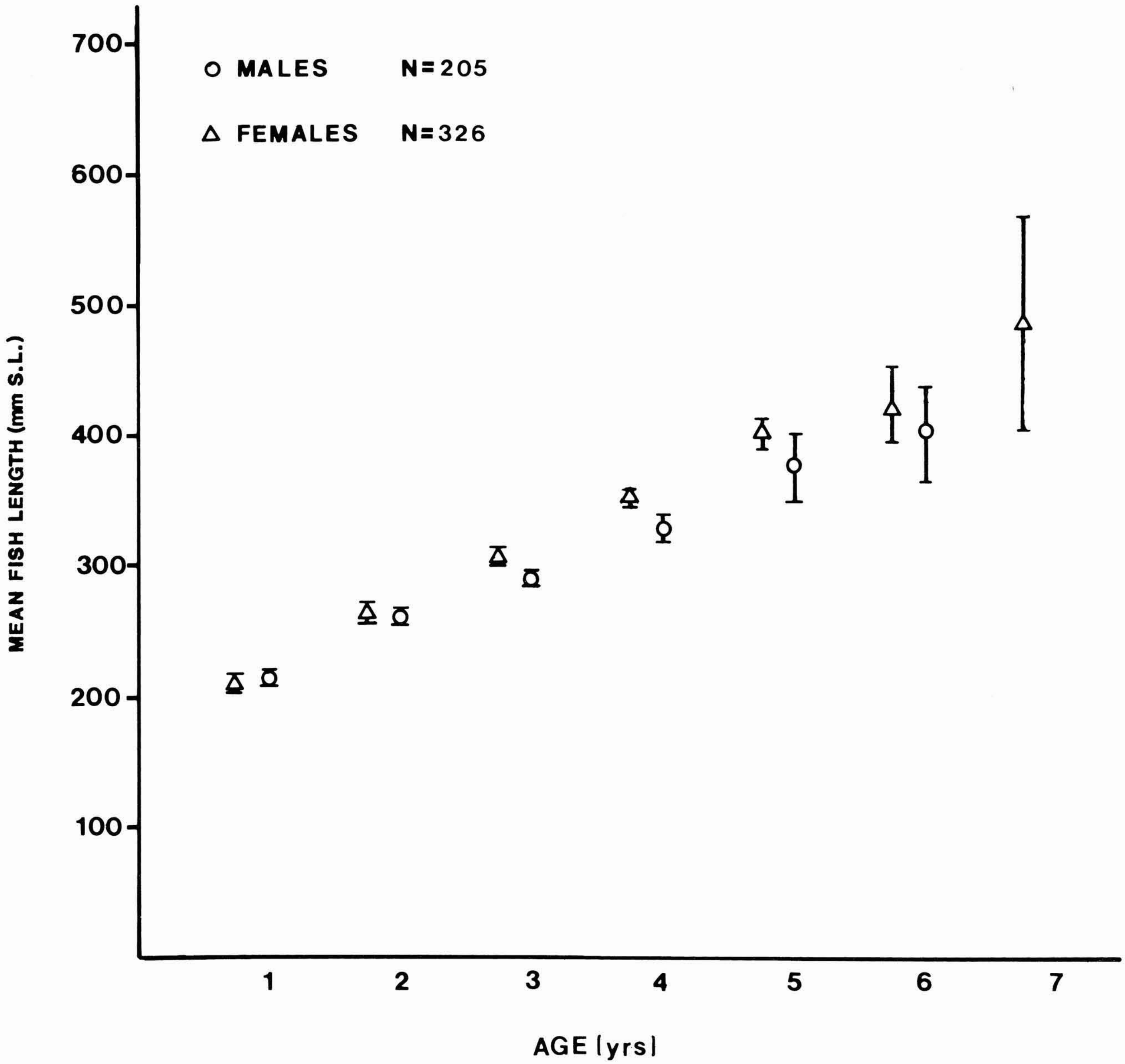


Figure 9. Mean back-calculated lengths at age of male and female spotted seatrout in Everglades National Park, Florida. Bars indicate 95% confidence intervals.

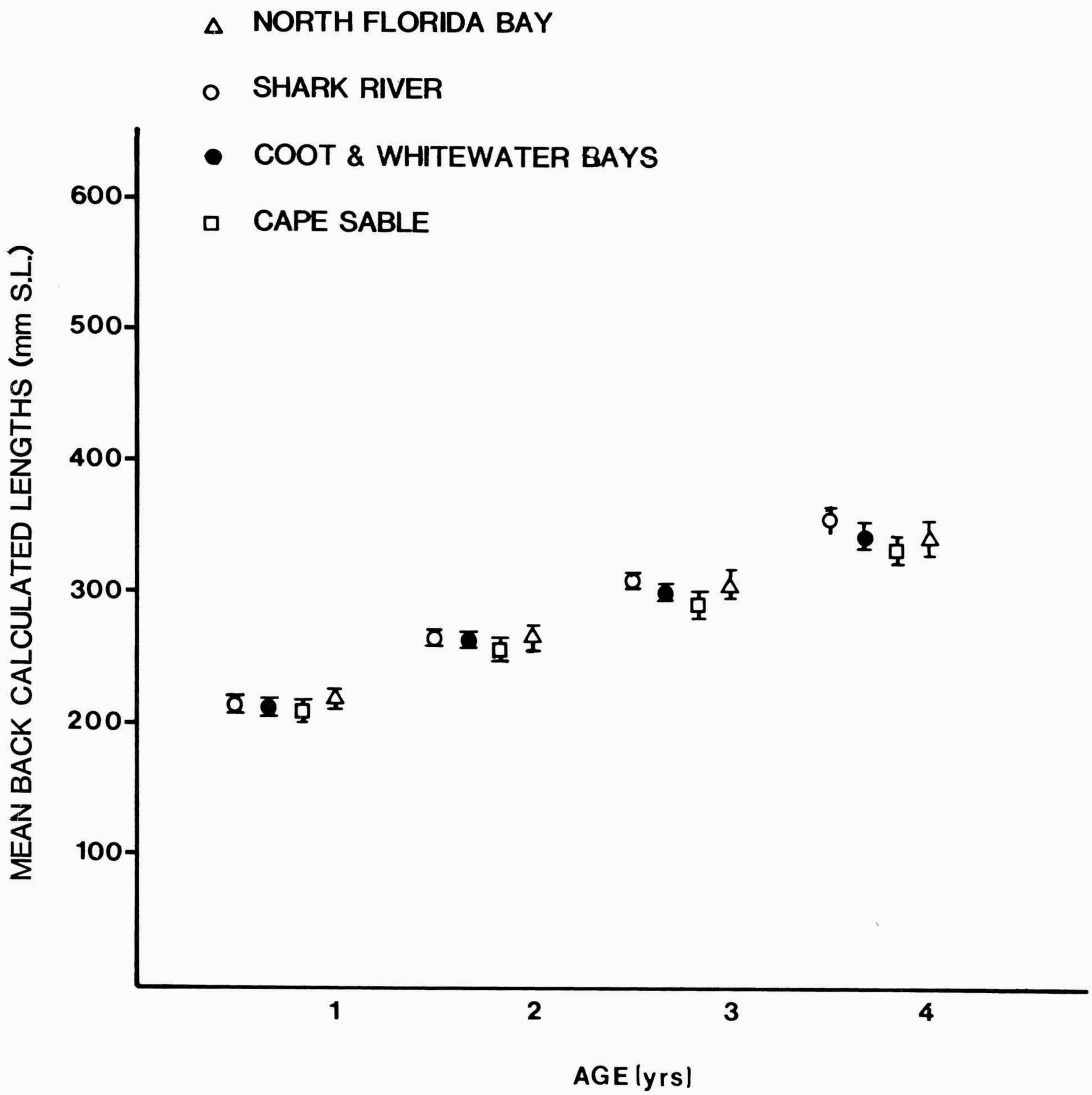


Figure 10. Mean back-calculated lengths at age of all spotted seatrout collected among fishing areas in Everglades National Park, Florida. Bars indicate 95% confidence intervals.

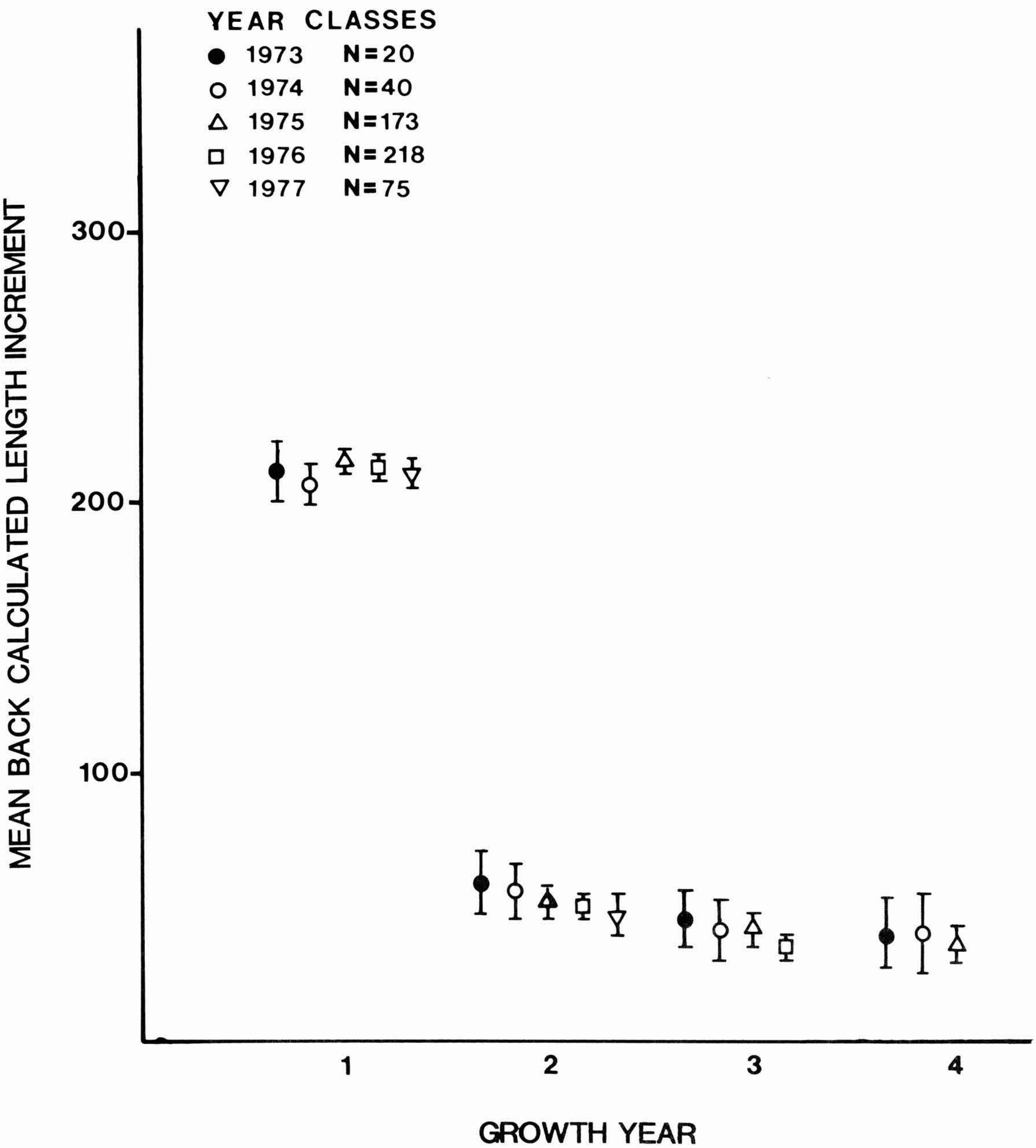


Figure 11. Mean back-calculated annual length increment of spotted seatrout year classes in Everglades National Park, Florida. Bars indicate 95% confidence intervals.

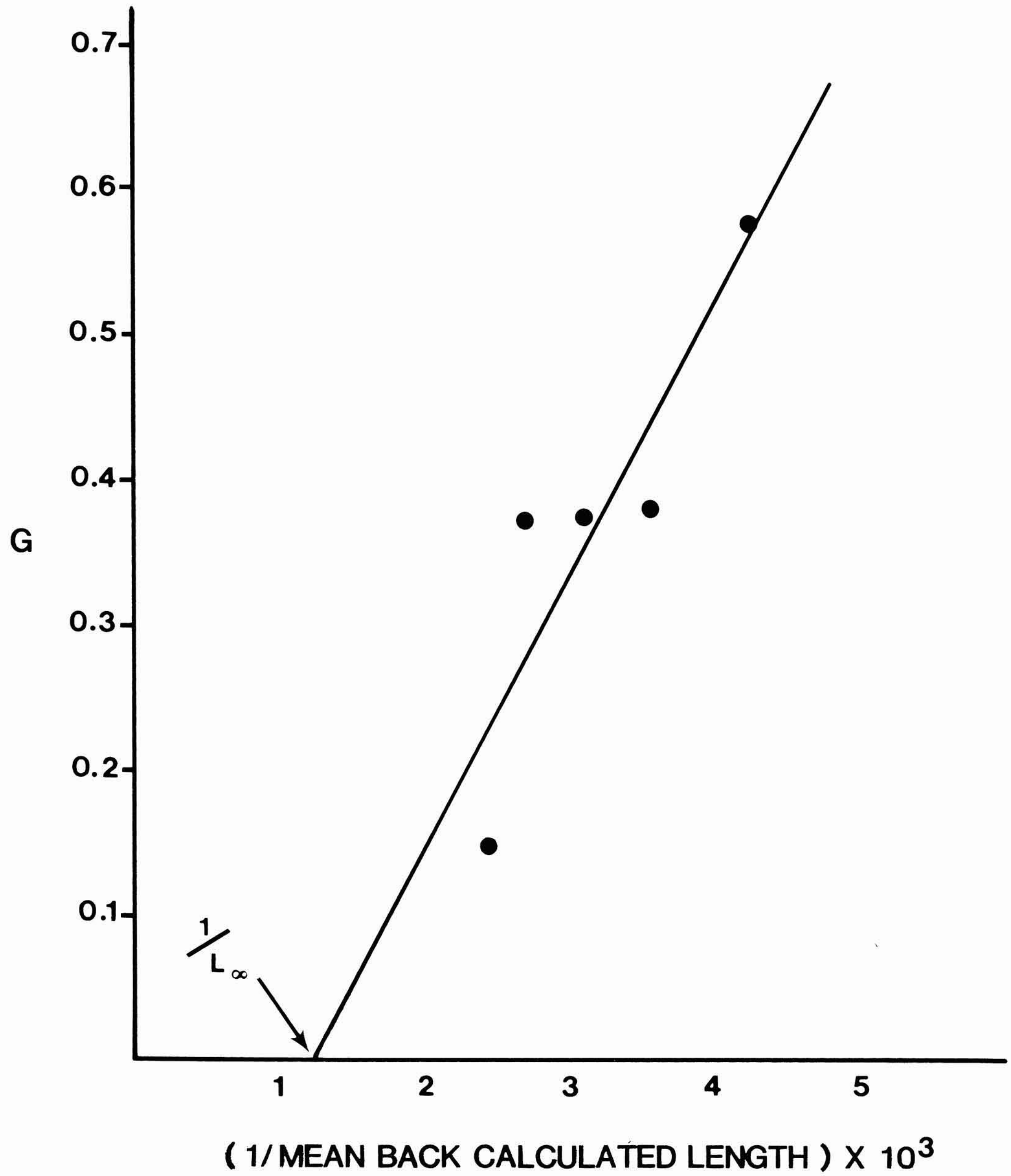


Figure 12. Regression of instantaneous growth coefficient G on reciprocal of mean back-calculated lengths at age for all spotted seatrout in Everglades National Park, Florida. $G = -0.2501 + 0.1936(1/L \times 10^3)$, $n = 5$, $r = 0.89$. $L_\infty = 774$, $K = 0.09$, $t_o = -2.54$.

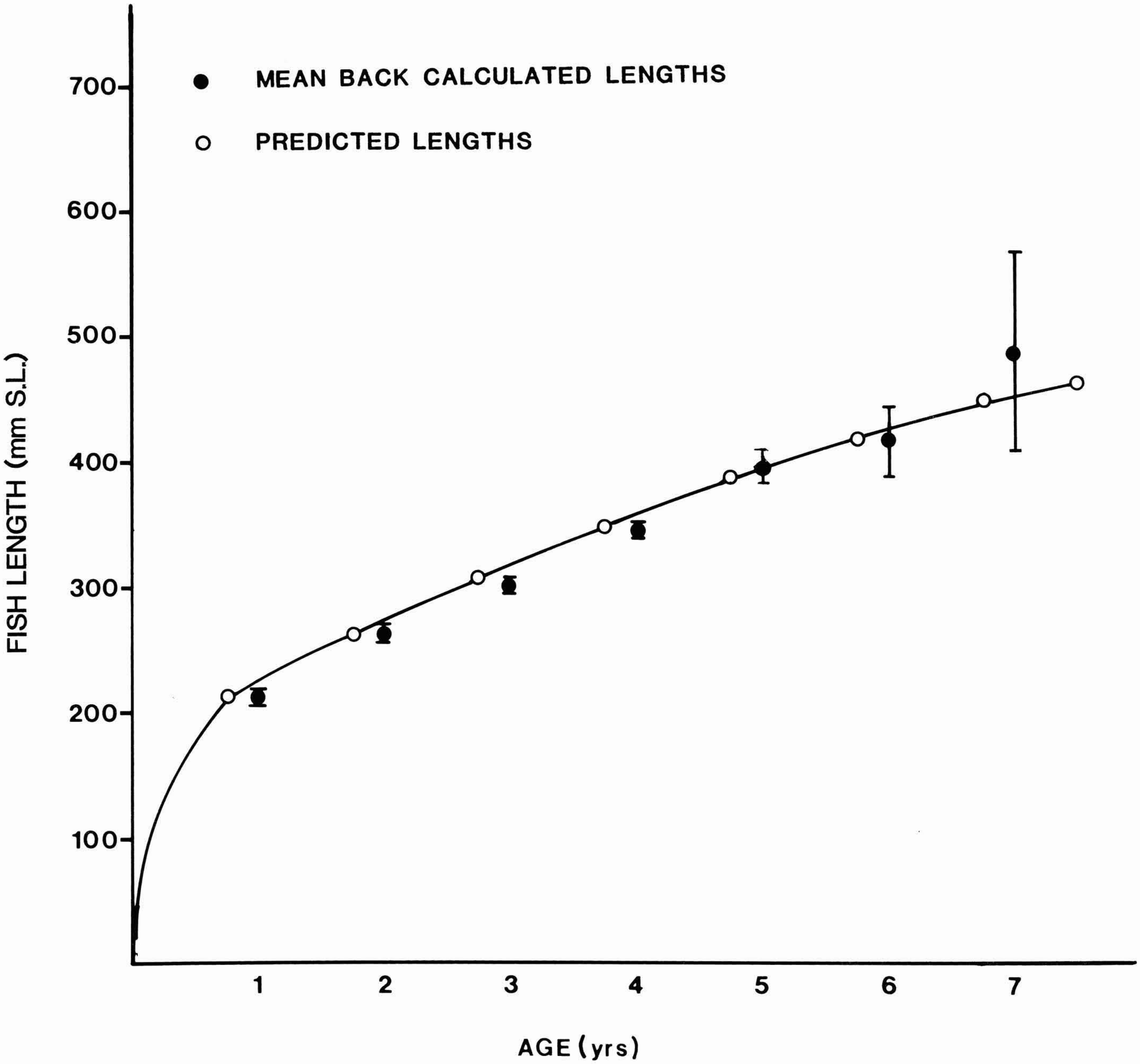


Figure 13. Mean back-calculated lengths at age and lengths predicted by the von Bertalanffy equation for all spotted seatrout in Everglades National Park, Florida:

$$L_t = 774(1-e^{-0.09(t = 2.54)})$$

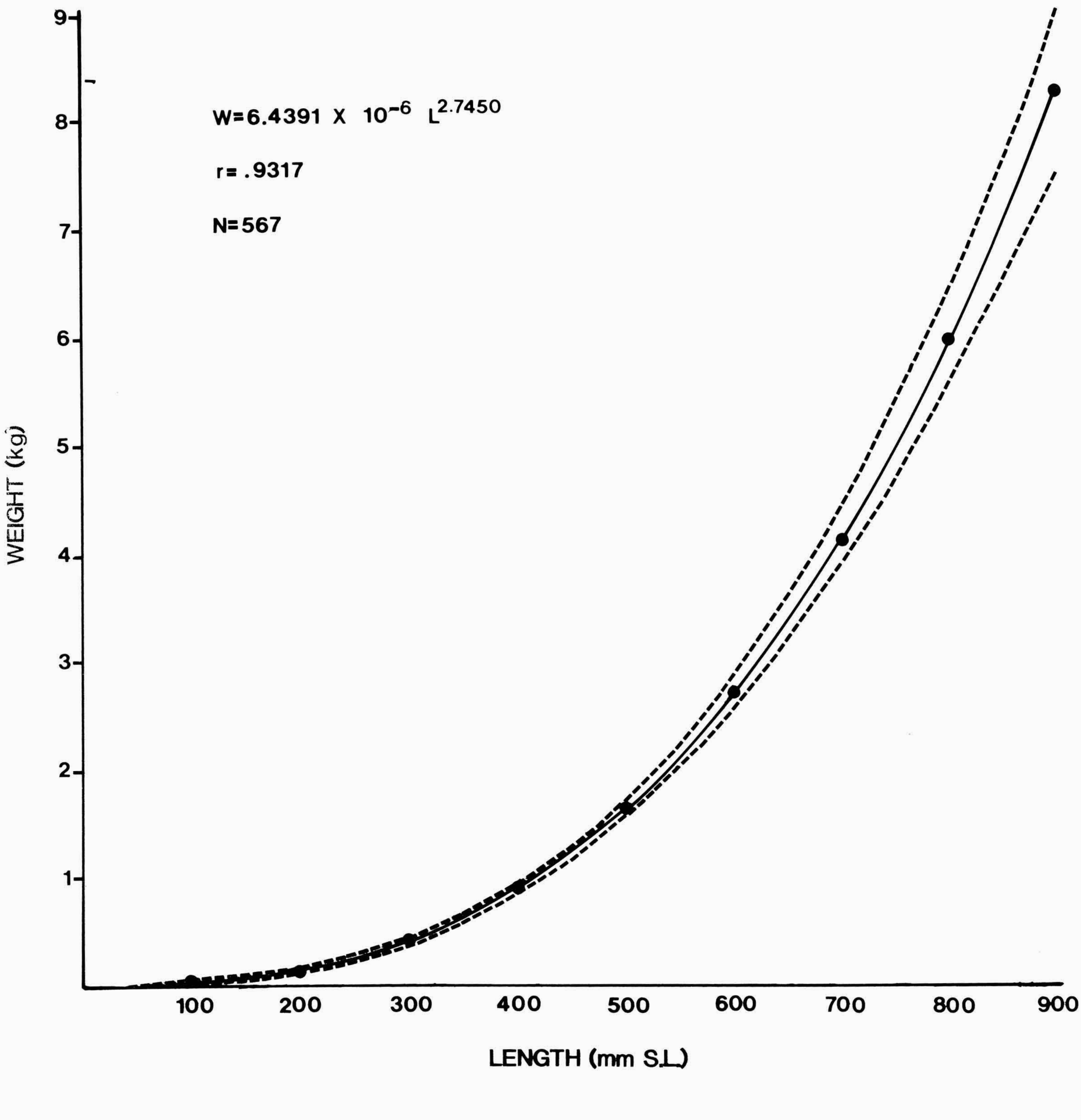


Figure 14. Length-weight relationship for all spotted seatrout in Everglades National Park, Florida. Dashed lines indicate 95% confidence intervals. Weight predicted by this equation is in decagrams.

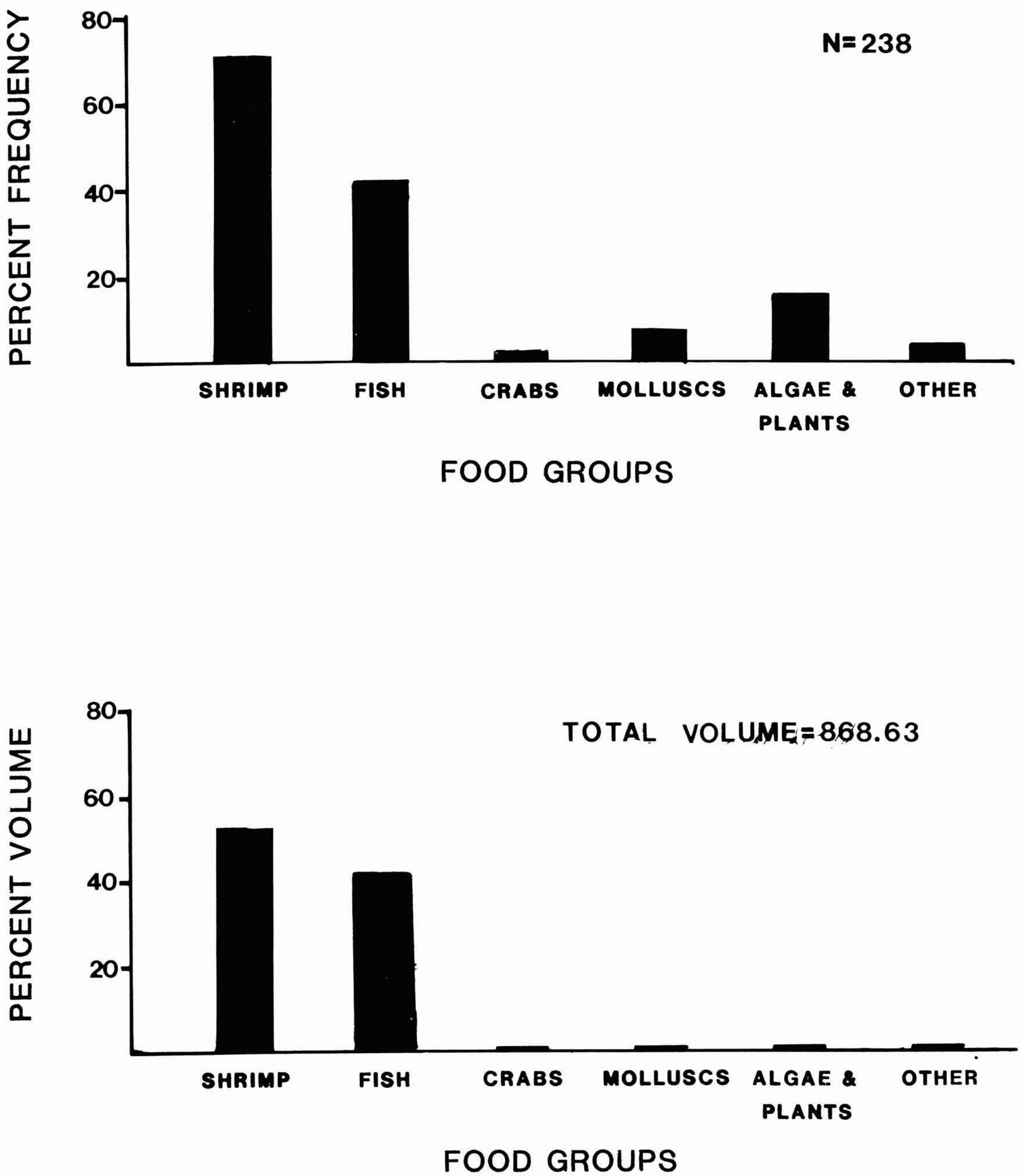


Figure 15. Percent frequency and volume of prey consumed by all spotted seatrout in Everglades National Park, Florida.

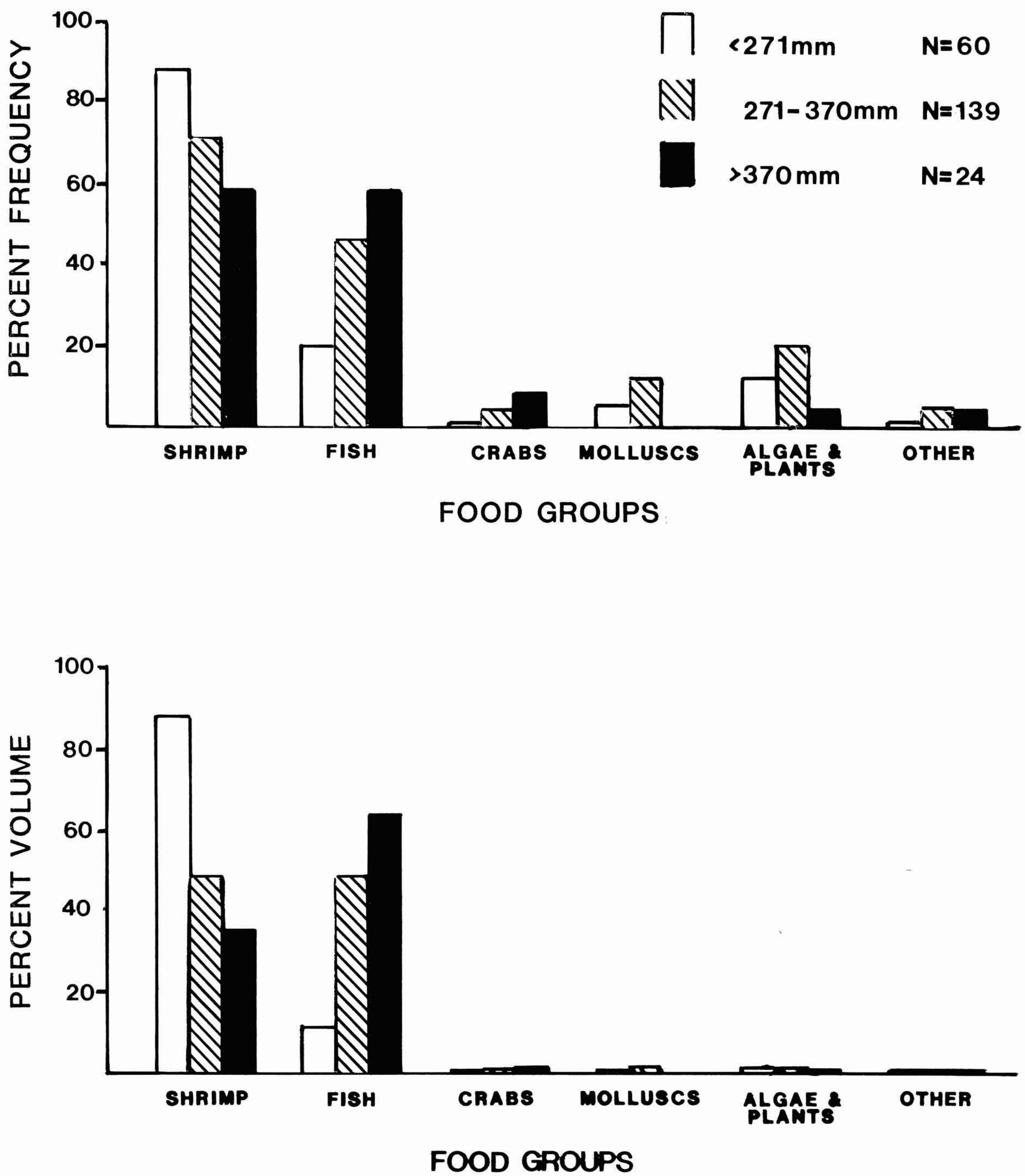


Figure 16. Percent frequency and volume of prey consumed by size class of spotted seatrout in Everglades National Park, Florida.

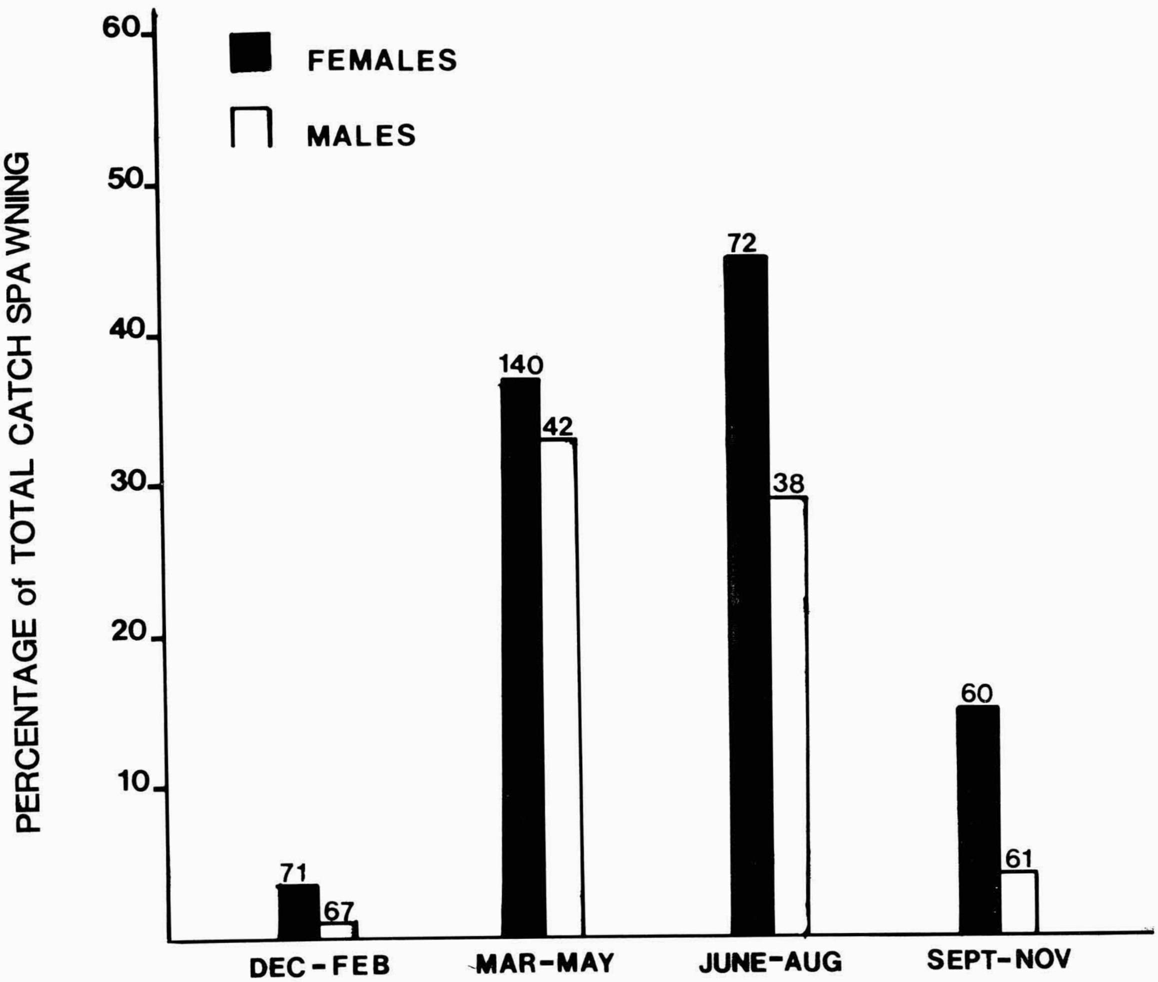


Figure 17. Percentage of total number of spotted seatrout examined that were spawning in Everglades National Park, Florida. Numbers above graphs are total numbers of fish examined in a season.

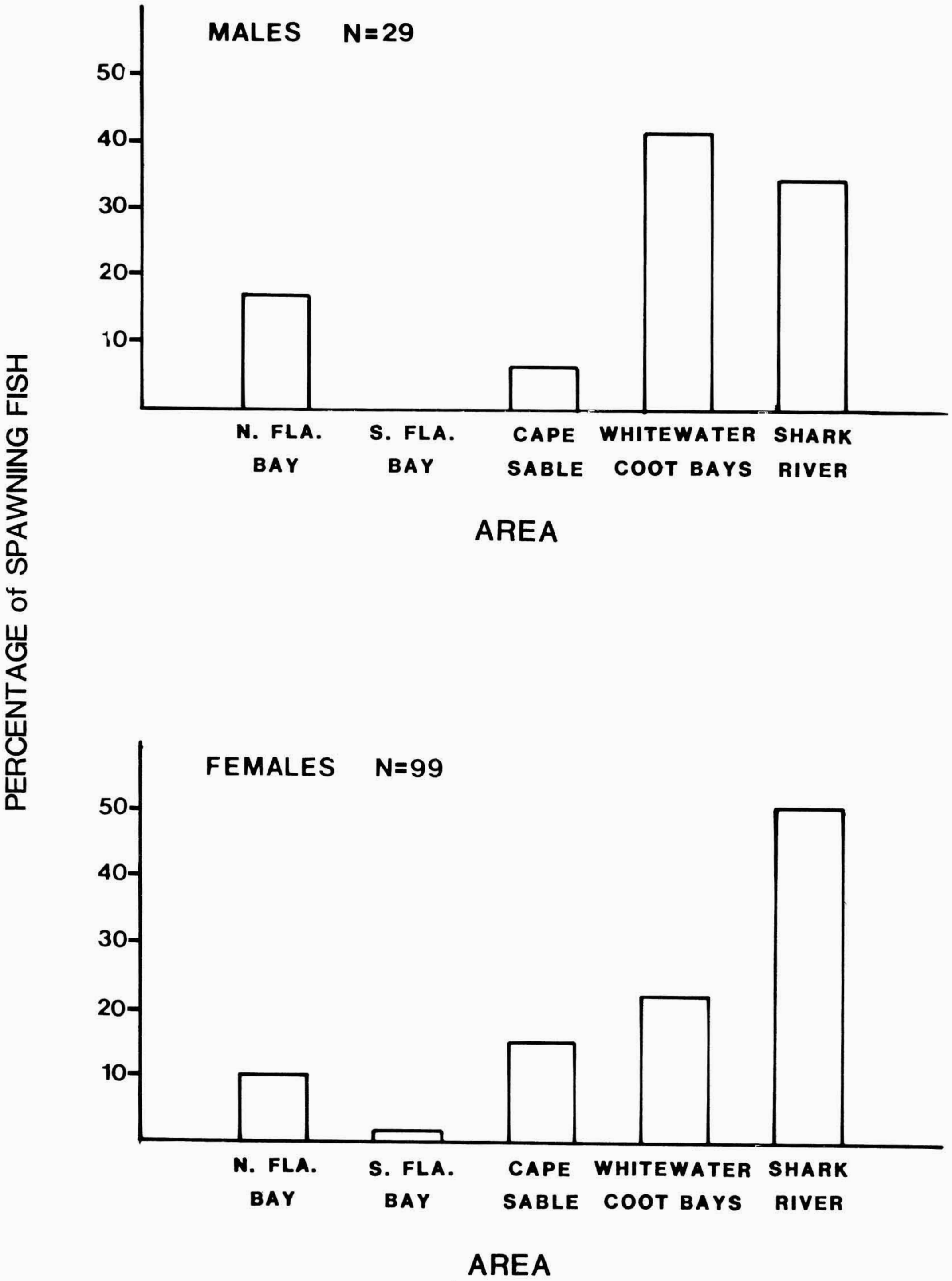


Figure 18. Percentage of ripe male and female spotted seatrout among areas in Everglades National Park, Florida.

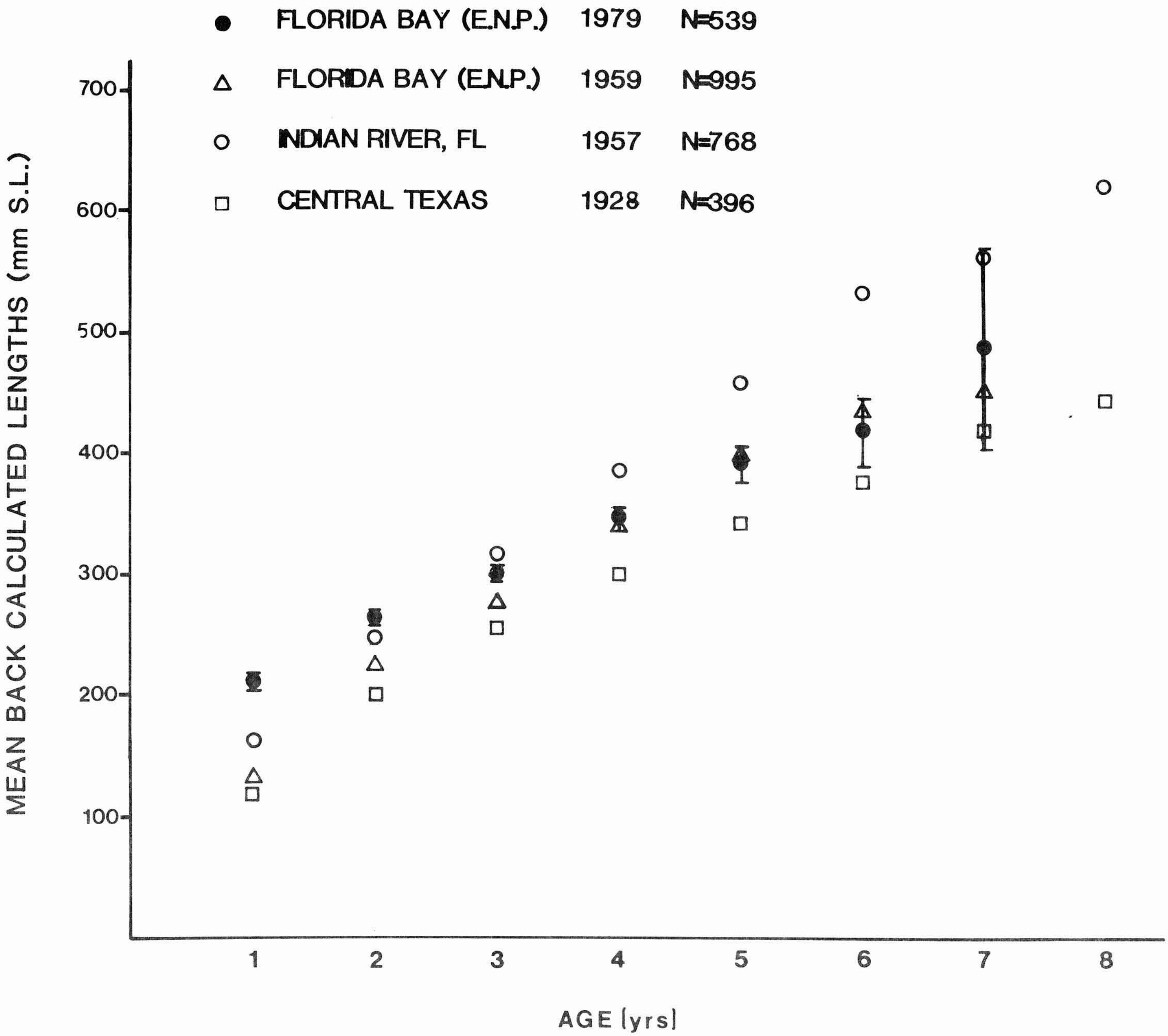


Figure 19. Mean back-calculated lengths at age for park spotted seatrout and other selected populations in eastern Florida and the Gulf of Mexico. Bars indicate 95% confidence intervals. Data taken from Tabb (1961) for Indian River, Florida; from Pearson (1928) for central Texas; and from Stewart (1961) for Florida Bay, 1959.

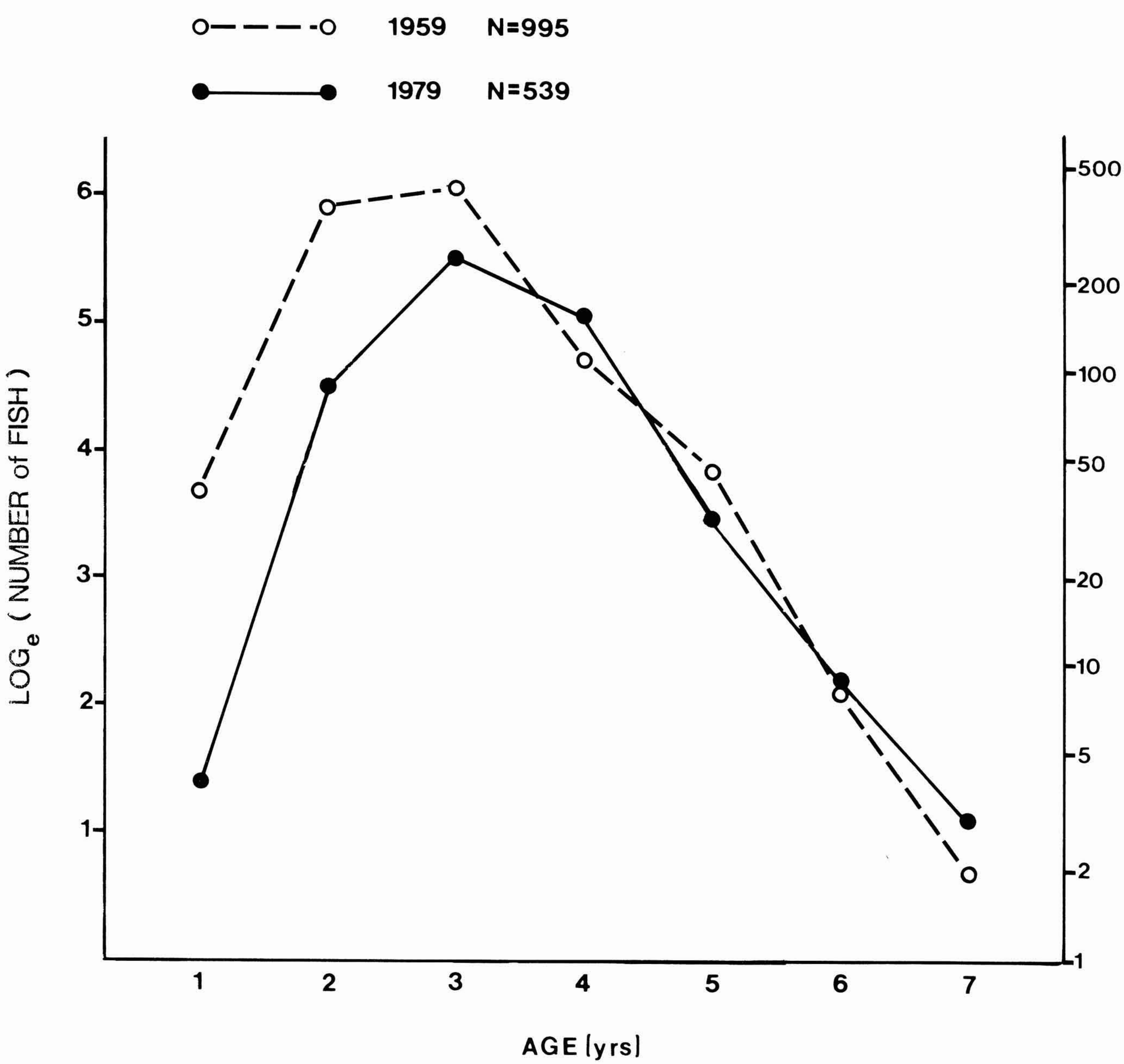


Figure 20. Catch curves of all scale-aged spotted seatrout taken from sportfishermen catches in Everglades National Park, Florida, 1959 (Stewart, 1961) and 1979.

Appendix I. Distribution of males, females and combined sexes of spotted seatrout back-calculated lengths (C) and lengths at capture (O) for ages I to VII in Everglades National Park, Florida.

Age	I		II		III		IV		V		VI		VII	
Length mm	C	O	C	O	C	O	C	O	C	O	C	O	C	O
120-139														
140-159	9													
160-179	36													
180-199	115		1											
200-219	185		23											
220-239	139	4	78	6	7									
240-259	43		162	9	34	7								
260-279	10		138	27	74	25	9							
280-299	2		92	28	114	48	17	10						
300-319			33	9	94	63	35	15	2					
320-339			7	8	74	53	26	28	3	2	1			
340-359			1	2	34	22	37	23	5	1	1			
360-379					11	23	40	28	2	2	0	2		
380-399					4	3	23	27	8	5	0	0		
400-419						1	11	13	13	4	5	2		
420-439							3	11	7	6	1	3		
440-459								1	4	9	2	0	1	
460-479								1		3	1	2	0	1
480-499											1		1	0
500-519													1	0
520-539													0	2
n	539	4	535	89	446	245	201	157	44	32	12	9	3	3
$\bar{x}$	212	233	262	282	301	314	345	359	395	416	417	420	488	505
s	22.77	3.11	26.09	27.68	31.06	31.32	37.44	39.77	36.90	41.11	43.77	36.27	33.04	34.43

Appendix II. Distribution of male spotted seatrout back calculated lengths (C) and lengths at capture (O) for ages I to VII in Everglades National Park, Florida.

Age	I		II		III		IV		V		VI		VII	
Length mm	C	O	C	O	C	O	C	O	C	O	C	O	C	O
120-139														
140-159														
160-179	9													
180-199	42													
200-219	70		6											
220-239	60	3	28	1	1									
350-369	20		77	3	18	2								
260-279	3		51	15	38	15	7							
280-299	1		31	10	51	28	7	8						
300-319			9	5	31	29	18	5	2					
320-339				3	13	14	12	15	0	2				
340-359				1	10	2	9	11	2	0				
360-379					2	9	6	6	1	0				
380-399							3	5	4	4				
400-419							3	1	1	1	2	2		
420-439								2	2	0				
440-459										3				
460-479														
480-499														
500-519														
n	205	3	202	38	164	99	65	53	12	10	2	2		
$\bar{x}$	215	231	260	283	292	305	327	340	377	394	403	415		
s	20.77	1.0	22.41	25.47	27.33	28.68	34.68	36.29	39.80	46.78	3.97	2.12		

Appendix III. Distribution of female spotted seatrout back-calculated lengths (C) and lengths at capture (O) for ages I to VII in Everglades National Park, Florida.

Age	I		II		III		IV		V		VI		VII	
Length mm	C	O	C	O	C	O	C	O	C	O	C	O	C	O
120-139														
140-159	9													
160-179	27													
180-199	71		1											
200-219	110		17											
220-239	78	1	50	5	6									
240-259	23		81	6	16	5								
260-279	7		84	12	34	9	2							
280-299	1		60	17	60	19	10	2						
300-319			24	4	61	32	17	10						
320-339			7	5	61	38	13	12	3		1			
340-359			1	1	24	20	27	12	3	1	1			
360-379					9	14	34	22	1	2	0	2		
380-399					4	3	20	21	4	1	0			
400-419						1	8	12	12	3	3			
420-439							3	9	5	6	1	3		
440-459								1	4	6	2		1	
460-479								1		3	1	2		1
480-499											1		1	
500-519													1	
520-539														2
n	326	1	325	50	275	141	134	102	32	22	10	7	3	3
$\bar{x}$	210	237	264	280	307	321	354	369	402	427	420	421	488	505
s	23.92	0	28.31	29.63	32.04	31.68	35.86	38.14	34.08	34.76	47.80	41.72	33.04	34.43

Appendix IV. Von Bertalanffy growth parameters K, L_{∞} and t_o with confidence levels (95%) for spotted seatrout males, females and combined sexes in Everglades National Park, Florida.

	K	L_{∞}		t_o
Males	0.12 ± .10	591	340 -85	-2.95 ± .73
Females	0.13 ± .13	656	357 -188	-2.04 ± .34
Combined Sexes	0.09 ± .11	774	357 -27	-2.54 ± .33

Appendix V. Prey species of spotted seatrout in Everglades National Park. Occurrence of prey in greater than 5% of the stomachs is noted as common (C) and less than 5% as rare (R).

MARINE PLANTS

Algae

Chlorophyta

Udotea flabellum	R
Caulerpa spp.	R

Rhodophyta

Acanthophora specifera	R
Bostrychia spp.	R

Phanerograms

Thalassia testudinum	C
Halodule wrightii	R
Ruppia maritima	R
Cymodacea manatorum	R

MARINE ANIMALS

Polychaeta

Serpulidae spp.	R

Mollusca

Gastropoda

Modulus modulus	R
Cerithium eburneum	R
Ceritheum muscarum	R
Marginella apicina	R
Bulla striata	R

Pelecypoda

Brachidontes exustus	R
Anomalocardia cumimeris	R
Lucinidae spp.	R

Arthropoda

Crustacea

Corophidae spp.	R
Parapenacus longirastris	R
Penacus attecus	R
Dynamene spp.	R
Penaeus duorarum	C
Penaeus setiferus	R
Alpheus armillatus	R
Alpheus heterochaelis	R
Tozeuma carolinensis	R
Leander tenuicornis	R
Thor floridanus	R
Periclimenes longicaudatus	R
Pagurus spp.	R
Sesarsma spp.	R
Petrolistes galathinus	R

Tunicata (Urochordata)

Ascidiacea

Molgula spp.	R

Vertebrata (Chordata - Pisces)

Clupeidea

Unknown spp.	R

Perciformes

Lutjanus griseus	R
Eucinostomus spp.	R
Bairdiella chrysura	R
Microgobius spp.	R
Archosargus rhomboidales	R
Opsanus beta	R

Rutherford, Edward, Edith Thue, and David Buker. 1982. Population Characteristics, Food Habits and Spawning Activity of Spotted Seatrout, *Cynoscion nebulosus*, in Everglades National Park, Florida. South Florida Research Center Report T-668. 48 pp.