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ASPECTS OF THE BIOLOGY OF THE SPOTTED SEATROUT, *CYNOSCION NEBULOSUS*, IN MISSISSIPPI

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ABSTRACT About 3,000 specimens of the spotted seatrout from Mississippi Sound and adjacent water grouped by males and females had a nearly identical standard length (SL) versus total length (TL) relationship, although the equation for males in winter differed from that for those in other seasons. When investigating the SL-weight relationship, some differences occurred both among seasons and between sexes. Therefore, condition coefficients (K) were calculated to compare male and female groups according to their length and state of maturation on a seasonal basis. The hepatosomatic index (HSI) tended to increase with fish length, with relatively high values occurring in winter compared to low ones in summer when livers exhibited an abundance of lipid. Seasonal values of gonosomatic index (GSI) were typically less than those for HSI, except for ripe or nearly ripe fish. Males and females often concurrently exhibited contrasting values for both HSI and GSI. Females matured as short as 189 mm SL and males by 201 mm, and the percentage of gravid females in summer increased with increasing SL. By the time fish reached 40 cm, females constituted 85.7% of the sample from Mississippi Sound, not counting additional samples in 1982 that contained more males between 350 and 475 mm than females. Ovaries contained more oocytes than indicated in the literature. The largest estimate of oocytes over 30 μ m in diameter per female was ten and one-half million using a simple volumetric displacement method, or fifteen and one-half million when calculated using a gravimetric technique. Based on histological and other evidence, most individual fish in Mississippi apparently spawned periodically from April to September and even longer during years with appropriate temperature conditions. When gravid, fish tended to group in schools composed primarily of males or females. Tagging studies indicated that neither *C. nebulosus* nor *C. arenarius* moved farther than 25 km from their location of release. Both seatrouts hosted parasites that harm the host in natural water and culture conditions, that adversely affect their respective fisheries, and that potentially cause human distress. Several listed parasites had not been reported previously from the fishes.

INTRODUCTION

The spotted seatrout, *Cynoscion nebulosus* (Cuvier), supports an important commercial and recreational fishery in the southeastern United States. It constitutes one of the few commercially important fishes in that region that can spawn, develop, and spend its entire life in an estuarine environment. Consumers eat both the flesh and the ripe roe. Several aspects of the biology of this essentially nonmigratory fish that occurs from New York to Mexico depend on the fluctuating salinity and temperature, and, as pointed out by Tabb (1966), details of its biology from different estuaries are needed. Fish from different estuaries apparently spawn in their respective estuary, and few individuals migrate from those areas. Different growth-rates and tagged fish support that premise, as do blood-serum polymorphisms and, to a lesser extent differences in eye-lens proteins. Weinstein and Yerger (1976b) distinguished a separate subpopulation in each of seven estuaries from Texas to the east coast of Florida using electrophoretic methods and showed that the difference in those subpopulations increased with geographic distance. Because evidence favors distinct subpopulations from each estuarine system, because estuaries are vulnerable to environmental alterations detrimental to those subpopulations, and because the biological characteristics of the stock in Mississippi Sound are minimally understood (Etzold and Christmas 1979), this study was undertaken to assess the

Mississippi stock.

Most of the data for this study was collected from mid-1978 to mid-1980. Atypically low salinity levels over long periods, low temperatures occurring suddenly, and possibly other factors resulted in few available fish during much of the study period. In fact, local fish houses and restaurants had no local spotted seatrout for many continuous months. Nevertheless, collections were made and data from these are compared and often combined with previously collected data. I include also some data on tagged and infected *C. arenarius* Ginsburg, possibly a subspecies of *C. regalis* (Bloch and Schneider) (see Weinstein and Yerger 1976a). Information on food contents of three seatrout species in Mississippi occurs separately (Overstreet and Heard 1982). References to comparative biological data on *C. arenarius* are listed by Moffett et al. (1979), and Shlossman and Chittenden (1981) provided the most extensive report on that species.

MATERIALS AND METHODS

Samples of the spotted seatrout were gill-netted, trammel-netted, seined, or caught by hook and line on a monthly basis from August 1978 to December 1980. Added to data describing those samples are data on fish previously collected for investigations on specific parasites and stomach contents (Overstreet 1977, Deardorff and Overstreet 1981, Overstreet and Heard 1982). Those fish not measured, tagged, and released were covered with ice and transferred to the laboratory for detailed analyses. Reliable commercial and recreational fishermen caught some individuals, and Gulf Coast

Research Laboratory (GCRL) personnel collected the rest. Most came from Mississippi Sound; those from other localities are specified in the text.

Fish tags used on a few fish before 1978 were commercially-produced dart tags inserted with a Dennison tagging gun, but these apparently were expelled, or the glue binding the labeled streamer to the anchor did not hold, or the base of the tubing split. Sackett and Hein (1979) noted that after 90 days in a pond, only about 60% of tagged seatrout retained that type of tag, and 27% of the remaining tags were broken or split. Consequently, internal anchor tags were used exclusively after 1977. Two sizes of labeled, laminated, cellulose, acetate anchors directed those who found them to provide GCRL pertinent information (Figure 1). The large anchor, 26 by 7 mm, had red, green, or yellow strips of size 18 polyvinyl chloride insulation tubing about 13 cm long inserted through a centrally located hole. For small fish, 15 by 5 mm labels (both sizes produced by Howitt Plastic Company, now Floy Tag & Manufacturing, Inc.) were fitted with about 8 cm of size 24 tubing. This pliable tubing trailed from a fish after the unit was inserted through the wall of the body cavity. The proximal end of the tubing was expanded on a hotplate, the distal oblique end pulled through the hole in the anchor, and any remaining hole in the proximal end plugged with paraffin. After being inserted through a ventral incision in the fish, the tag, by means of the tubing, was twisted until the anchor lay perpendicular to the slit without binding any internal organs against the cavity wall. This incision paralleled the fish's vertebral column, was located slightly off-midline and a short distance anterior to the anus, and measured about 1 mm wider than the width of the tag. If conditions were unsafe to release tagged fish because of nets, predators, or other reasons, personnel temporarily retained them in large, aerated, plastic containers.

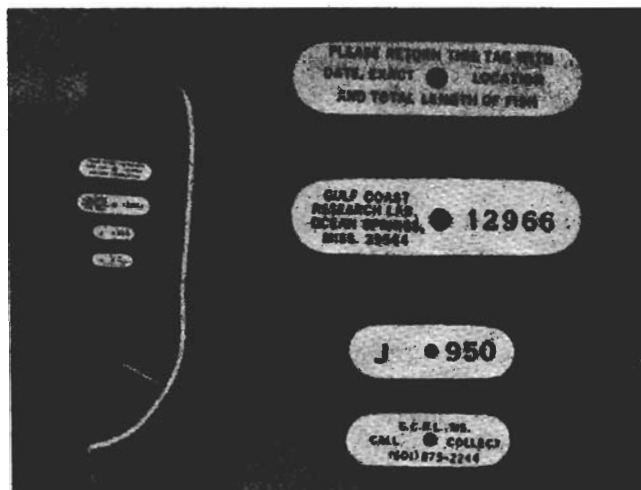


Figure 1. Internal body-cavity anchor tags and close-up of two-sided label. The small-sized tag is used for juvenile seatrouts as well as individuals of shorter fishes.

Striped bass, Atlantic croaker, and other fishes properly tagged and held in GCRL raceways did not shed tags after several months, their incisions healed rapidly, and they showed no complications from the tagging operation.

Once the standard length (SL) and total length (TL) were measured to the nearest millimeter (mm) and weight obtained to the nearest 0.05 grams (g), the fish was cut open, its viscera removed, and the fish reweighed. Unless indicated otherwise, all lengths are SL even though SL is occasionally stipulated. Gonads and liver were each blotted to remove excess liquid and weighed to the nearest 0.01 g; also, their volumetric displacement of water was noted to the nearest 0.1 milliliter (ml) using 5 to 2000 ml graduated cylinders. For females, an aliquot of ovarian tissue including a small amount of tunic approximating 0.06 or 0.12 g was weighed to the nearest 0.002 g (a few weighed to the nearest 0.001) and its displacement of water in a 5 ml cylinder recorded to the nearest 0.01 ml. That tissue was fixed and stored in Gilson's fluid (Simpson 1951).

To estimate fecundity, the Gilson's fluid was decanted from the vial with the ovarian aliquot and replaced with 1/3 vial of distilled water. After being stored in Gilson's fluid for at least 3 to 5 months, the eggs easily separated from each other without modifying their shape when shaken for about 30 to 60 seconds in a mechanical vibrator. Eggs were then spread evenly over a gridded, 88 mm-diameter petri-dish and counted within five 10.89 mm² grids (including those eggs overlapping two sides). If the counts were not similar, the eggs were respread more evenly and counted again. If counts were similar, their sum was used to calculate the estimated number in the aliquot which in turn was used to calculate the estimated number in the ovaries (density of oocytes appeared similar in both ovaries from a fish) using both volumetric displacement and gravimetric techniques. The ratio between the number of eggs in the aliquot and the total number in both ovaries was assumed to be roughly proportional to both the measured displacement of aliquot to that of ovaries or the measured weight of aliquot to that of ovaries.

After fecundity was estimated from an aliquot of representative fish, approximately 100 of the oocytes were measured using an ocular micrometer at 40X magnification. These values for oocytes from each fish were grouped by stage of maturation of fish and used to construct length-frequency graphs. Table 1 defines the arbitrary stages of maturation for both males and females determined by gross examination.

Representative tissues of gonads and suspected diseased tissues were fixed in 10% phosphate-buffered formalin, processed for paraffin-embedded sections, and routinely stained using Harris's hematoxylin and eosin Y. Occasionally, special staining methods (Luna 1968) were used to assess specific features.

The location of each fish was recorded as precisely as

TABLE 1.
Gross appearance of gonads in *Cynoscion nebulosus* relative to arbitrary stages of maturity.

| Stage | Gonad | Fresh color | Color after 6 to 15 hr | Length of gonad as % of body cavity | Amount of adjacent lipid deposit | Remarks (without use of microscope) |
|-----------------------------|--------|------------------------|------------------------|-------------------------------------|----------------------------------|---|
| I. Virgin | ovary | colorless to grey | light orange to rust | 10-15 | very little | appears similar to mesentery |
| | testes | very light grey | same | 10-15 | none | |
| II. Maturing Virgin | ovary | colorless to grey | dark orange | 15-25 | very little | |
| | testes | light grey | same | 20-30 | none | |
| III. Developing and resting | ovary | grey or light orange | very dark orange | 45-55 | moderate | blood vessels conspicuous |
| | testes | grey to creamy | same | 45-55 | little | |
| IV. Developing | ovary | dark orange | reddish | 65-70 | more than in III | blood vessels wider than in III |
| | testes | creamy | same | 60-70 | small | blood vessels very thin or not conspicuous |
| V. Gravid | ovary | yellow to light yellow | same | 85-95 | less than in IV | blood vessels maximal diameter |
| | testes | creamy | same | 50-95 | small | blood vessels not apparent, testes wide |
| VI. Spawning | ovary | yellow | same | 85-95 | little or none | blood vessels still large and reddish, ovary widest |
| | testes | creamy to white | same | 55-95 | small | blood vessels not apparent, testes widest |
| VII. Spent | ovary | light yellow | same | 75-80 | none | blood vessels brownish, ovary flaccid, fluid expelled with pressure |
| | testes | creamy to grey | same | 55-95 | small | width reduced, a little fluid can be expelled |

possible as was the temperature and salinity of the water at that location. Additionally, biweekly or triweekly measurements of temperature and salinity of water were monitored from off the GCRL pier at about 8:00 a.m. Initially, measurements were taken with a hand-held thermometer and an American Optical Co. temperature-compensated refractometer, but later in the study they were taken with a Yellow Spring Instrument Co. conductivity meter (YSI model 33, S-C-T).

Different indices and statistical methods are indicated or explained in the text under the appropriate sections. Procedures for the analysis of covariance (ANOC) follow those by Snedecor and Cochran (1967) and Dixon and Massey (1957) and those to test for homogeneous variances are for Cochran's test (Dixon and Massey 1957) and Bartlett's test (Ostle and Mensing 1975).

RESULTS AND DISCUSSION

Temperature and Salinity Data

Biweekly or triweekly measurements of temperature and

salinity of Davis Bayou were grouped on a monthly basis, and the average values are graphed in Figure 2. They usually represented well both surface and bottom water from the northern Mississippi Sound nearshore areas as determined by comparisons with data collected by others at GCRL. To accentuate the severity of environmental conditions that took place during the primary period of this study, winter temperatures dropped below freezing in 1978, 1979, and 1980. Between 22 February and 13 August 1979 recorded salinity values remained below 10 ppt, seldom surpassed 6 ppt, and mostly stayed at 1 ppt or less in April, May, and part of July. Hurricane Bob passed through on 11 July 1979 and Hurricane Frederic on 12 September 1979. In 1978, readings did not surpass 10 ppt until mid-July and then rarely until September. The low salinity probably acted as the single most influential factor in the low availability of spotted seatrout during most of the study.

Standard Length-Total Length Relationship

To predict total length (TL) from standard length (SL), the general regression equation $TL = a(SL)^b$ was used. To

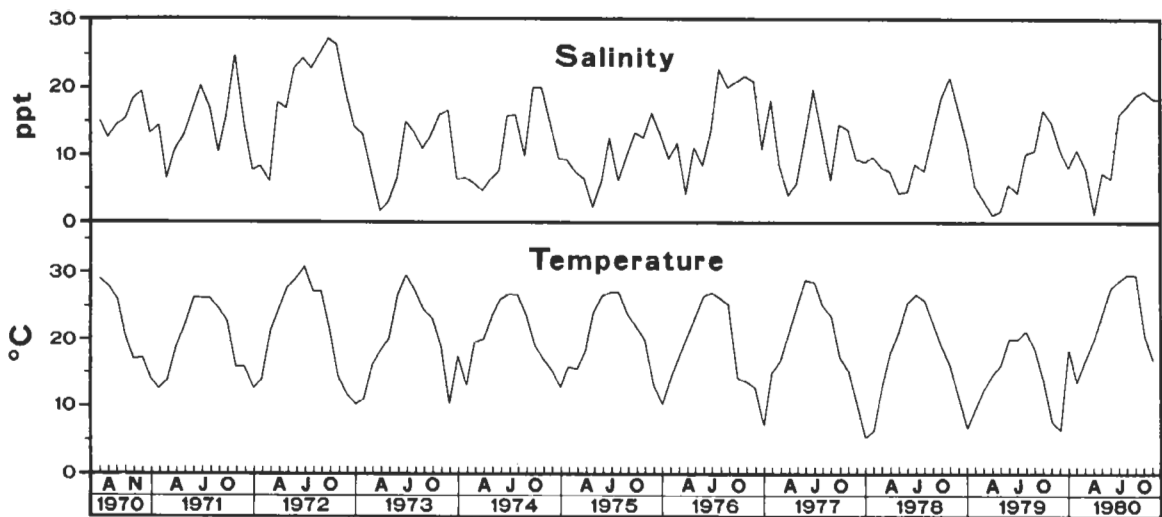


Figure 2. Monthly averages of temperature and salinity of water from 1970 through 1980 monitored bi- or triweekly from GCRL.

determine if equations differed according to sex and season, I used two methods. In the first, estimates of differences among equations were apparent by comparing calculated measurements of specific-sized individuals from each different group. The total length (TL) values calculated for a 300 mm SL fish in each group revealed some differences as shown in Table 2. In the second method, analysis of covariance (ANOC) was used to compare regression equations (Table 2) for males versus females on a seasonal basis and to compare equations for paired combinations on a seasonal basis for males and for females. When comparing equations between sexes, only those representing winter data had homogeneous variances. Even during this season when differences between sexes appeared greatest, the means did not differ ($F = 2.72 < F_{.05[1,401 \text{ df}]} = 3.86$) and a single regression line could represent data for both sexes ($F = 2.25 < F_{.05[2,400 \text{ df}]} = 3.02$). In contrast, the means for males in winter differed from those for males during other seasons ($F = 4.66 - 7.24 > F_{.05[1,424 - 1,245 \text{ df}]} = \sim 3.86$) and one regression line would not represent any of the specific pairs ($F = 4.70 - 5.69 > F_{.05[2,423 - 1,244 \text{ df}]} = \sim 3.00$), even though variances for data in winter versus summer were not homogeneous. The slopes differed for regression lines in winter versus spring and autumn, but not for that line representing all seasons combined ($F = 4.70, 4.35 > F_{.05[1,423 - 537 \text{ df}]} = 3.86$, $F = 2.54 < F_{.05[1,1244 \text{ df}]} = 3.85$). Differences for means of data comparing males in winter with those for all seasons combined can be explained. The slopes were the same, but their intercepts along the Y (TL) axis differed ($F = 6.84 < F_{.05[1,1245 \text{ df}]} = 3.85$). A similar explanation can describe the regression lines for females in spring versus autumn. The means differed ($F = 4.83 > F_{.05[1,1058 \text{ df}]} = 3.85$) and separate regression lines were necessary to represent them ($F = 3.54 > F_{.05[2,1057 \text{ df}]} = 3.00$), but the linear slopes ($F = 0.003 < F_{.05[1,1058 \text{ df}]} = 3.85$) did not differ ($F = 2.23 < F_{.05[1,1057 \text{ df}]} = 3.85$). The difference in means can be explained by a difference in intercepts ($F = 4.83 > F_{.05$

$[1,1058 \text{ df}] = 3.85$). Variances were homogeneous for data representing females in spring versus winter (and all seasons combined) and for males in spring versus autumn (and all seasons combined), but their means did not differ and a single regression line could be used to represent all data for the pairs. Variances were not homogeneous for the other combinations.

In addition to calculating the regression equations with TL as the dependent variable, I calculated and listed them using SL as the dependent variable and TL as the independent one (Table 2). These do not differ considerably from their counterparts as can be seen by calculated values for 300 mm SL fishes, but they should be used by those conducting comparative studies based on SL as the dependent variable. Also, for comparative assessments, equations are listed using logarithmically transformed data. Like their nontransformed counterparts, these also have high correlation coefficients and narrow confidence limits about the slopes.

Large samples of spotted seatrout have been measured also from Louisiana and Texas, and values for the fitted equations for those data occur also in Table 2. Calculated TL values for a 300 mm SL fish from those collections are slightly larger than for fish in the Mississippi collection. That calculated value for a fish in a collection from Georgia is considerably larger, but it is an extrapolation because the small sample included no fish over 60 mm. Moffett (1961), mostly on the basis of fish between 11 and 32 cm, found a linear relationship for corresponding data from the spotted seatrout in west Florida. He calculated TL by multiplying SL by 1.22; using that method, a 300 mm SL fish would be 366 mm long, or much longer than the average TL of a fish in Mississippi. In the above cases, probably neither method produces reliable comparisons.

Standard Length-Weight Relationship

The general regression equation of the form $\text{Log } W = \text{Log } a + b (\text{Log } \text{SL})$ to make data linear was fitted to data according to sex, stage of maturity, length group, season, and

TABLE 2.

Standard length-total length relationships for *Cynoscion nebulosus* collected in Mississippi Sound from 1972 through 1980 compared with those from other localities (N = number of fish examined; a = TL (or SL) axis-intercept; b = slope; and r = correlation coefficient).

| Sex | Standard length range in mm | N | TL = a + b (SL) | 95% confidence interval of b | r | Calculated TL for a 300 mm SL fish in mm | Geographical locality | Reference |
|------------------|-----------------------------|------|-------------------------------------|------------------------------|--------|--|-------------------------|-----------------------------|
| Female | 39-544 | 1680 | Log TL = 0.1608+0.9620 (Log SL) | 0.9599-0.9640 | 0.9990 | 349.8 | Mississippi Sound | Present study |
| Male | 40-465 | 1089 | Log TL = 0.1623+0.9611 (Log SL) | 0.9576-0.9646 | 0.9981 | 349.2 | Mississippi Sound | Present study |
| Female | 39-544 | 1680 | TL = 10.6586+1.1284 SL | 1.1250-1.1317 | 0.9981 | 349.2 | Mississippi Sound | Present study |
| Male | 40-465 | 1089 | TL = 10.1648+1.1292 SL | 1.1239-1.1344 | 0.9970 | 348.9 | Mississippi Sound | Present study |
| Female Winter | 75-460 | 245 | TL = 9.7670+1.1290 SL | 1.1252-1.1328 | 0.9996 | 348.5 | Mississippi Sound | Present study |
| Male Winter | 92-418 | 159 | TL = 11.4230+1.1168 SL | 1.0946-1.1391 | 0.9921 | 346.5 | Mississippi Sound | Present study |
| Female Spring | 92-544 | 427 | TL = 10.7260+1.1258 SL | 1.1183-1.1333 | 0.9976 | 348.5 | Mississippi Sound | Present study |
| Male Spring | 100-419 | 268 | TL = 7.7890+1.1386 SL | 1.1315-1.1456 | 0.9987 | 349.4 | Mississippi Sound | Present study |
| Female Summer | 39-453 | 374 | TL = 14.3090+1.1183 SL | 1.1053-1.1314 | 0.9935 | 349.8 | Mississippi Sound | Present study |
| Male Summer | 40-412 | 280 | TL = 15.7770+1.1099 SL | 1.0928-1.1271 | 0.9915 | 348.7 | Mississippi Sound | Present study |
| Female Autumn | 82-518 | 634 | TL = 9.8480+1.1321 SL | 1.1277-1.1365 | 0.9988 | 349.5 | Mississippi Sound | Present study |
| Male Autumn | 76-465 | 382 | TL = 9.3000+1.1336 SL | 1.1292-1.1380 | 0.9993 | 349.4 | Mississippi Sound | Present study |
| Female | 39-544 | 1680 | SL = -8.3544+0.8828 TL ¹ | 0.8802-0.8854 | 0.9981 | 349.3 | Mississippi Sound | Present study |
| Male | 40-465 | 1089 | SL = -7.4654+0.8802 TL ¹ | 0.8762-0.8843 | 0.9970 | 349.3 | Mississippi Sound | Present study |
| Combined | 8-60 | 20 | TL = 1.020+1.224 SL | | | 368.2 ² | Coastal Georgia | Jorgenson and Miller (1968) |
| Combined | 21-629 | 1208 | SL = -3.8832+0.8653 TL ¹ | | 0.9946 | 351.2 | South-central Louisiana | Hein et al. (1980) |
| Combined | 36-744 | 9857 | TL = 11.804+1.138 SL | 1.136-1.140 | 0.997 | 353.2 | Texas bays | Harrington et al. (1979) |

¹Note TL and SL reversed. ²Sample-range did not include fish 300 mm long.

year. Values for fitted equations of data grouped by sex and season regardless of year, as well as by sex regardless of season, had a correlation coefficient (r) of at least 0.99 and appear in Table 3. Because readers may wish to compare those data with those from other reports and methods, other available equations are presented. The same data used for Table 3 are additionally transformed with natural rather than common logarithms, and the corresponding equations are listed in Table 4. Also listed there are equations from non-transformed, curvilinear data to illustrate the considerable difference in correlation coefficients and calculated weights when compared with those from linear data. Additionally, listed comparative equations for fish from other geographic areas suggest Mississippi fish may be heavier than fish of the

same length from most cited collections.

Table 3 shows that both males and females of a given length weigh more during spring when rapid development for reproduction occurs. Also in spring, but not in other seasons, calculated weight for a 300 mm female is greater than that for a corresponding male.

Corresponding equations calculated using natural logarithms had similar correlation coefficients, with calculated weights for a 300 mm fish differing by +1.3 to -1.5 g and averaging only -0.1 g. When SL rather than weight served as the dependent variable, correlation coefficients for the corresponding equations were identical, but calculated weights for a 300 mm fish were consistently more, ranging from 0.8 to 5.8 g and averaging 2.3 g. Most of that difference,

TABLE 3.

Standard length-weight relationships for 2,770 individuals of *Cynoscion nebulosus* collected in Mississippi Sound from 1972 through 1980 by sex and season (N = number of fish examined; Log a = Log W (or Log SL) axis-intercept; b = slope; and r = correlation coefficient).

| Season | Sex | Standard length range in mm | N | Log W = Log a + b (Log SL) | | | | Calculated weight for a 300 mm SL fish in g |
|----------------------------|--------|-----------------------------|------|----------------------------|--------|------------------------------|--------|---|
| | | | | Log a | b | 95% confidence interval of b | r | |
| Winter | Female | 75-460 | 246 | -4.9599 | 3.0526 | 3.0312-3.0740 | 0.9985 | 399.7 |
| Winter | Male | 92-418 | 159 | -4.8990 | 3.0286 | 2.9648-3.0924 | 0.9912 | 401.1 |
| Spring | Female | 92-544 | 424 | -5.0362 | 3.0922 | 3.0711-3.1134 | 0.9975 | 420.3 |
| Spring | Male | 100-419 | 266 | -5.1024 | 3.1214 | 3.0949-3.1480 | 0.9975 | 426.3 |
| Summer | Female | 39-453 | 374 | -4.5878 | 2.9071 | 2.8680-2.9461 | 0.9914 | 410.6 |
| Summer | Male | 40-412 | 280 | -4.6472 | 2.9219 | 2.8751-2.9688 | 0.9909 | 389.7 |
| Autumn | Female | 82-518 | 639 | -4.9466 | 3.0481 | 3.0318-3.0645 | 0.9976 | 401.7 |
| Autumn | Male | 76-465 | 382 | -4.9463 | 3.0508 | 3.0314-3.0703 | 0.9980 | 408.2 |
| Combined | Female | 39-544 | 1683 | -4.9472 | 3.0516 | 3.0402-3.0629 | 0.9970 | 409.2 |
| Combined | Male | 40-465 | 1087 | -4.9466 | 3.0510 | 3.0343-3.0676 | 0.9958 | 408.4 |
| Log SL = Log a + b (Log W) | | | | | | | | |
| Winter | Female | 75-460 | 246 | 1.6271 | 0.3266 | 0.3243-0.3289 | 0.9985 | 400.5 |
| Winter | Male | 92-418 | 159 | 1.6306 | 0.3244 | 0.3176-0.3312 | 0.9912 | 406.9 |
| Spring | Female | 92-544 | 424 | 1.6327 | 0.3217 | 0.3195-0.3239 | 0.9975 | 421.6 |
| Spring | Male | 100-419 | 266 | 1.6384 | 0.3188 | 0.3161-0.3215 | 0.9975 | 427.4 |
| Summer | Female | 39-453 | 374 | 1.5927 | 0.3381 | 0.3336-0.3427 | 0.9914 | 412.9 |
| Summer | Male | 40-412 | 280 | 1.6050 | 0.3360 | 0.3306-0.3414 | 0.9909 | 394.1 |
| Autumn | Female | 82-518 | 639 | 1.6266 | 0.3265 | 0.3248-0.3283 | 0.9976 | 402.7 |
| Autumn | Male | 76-465 | 382 | 1.6241 | 0.3265 | 0.3244-0.3286 | 0.9980 | 409.8 |
| Combined | Female | 39-544 | 1683 | 1.6260 | 0.3257 | 0.3245-0.3269 | 0.9970 | 410.4 |
| Combined | Male | 40-465 | 1087 | 1.6275 | 0.3250 | 0.3233-0.3268 | 0.9958 | 411.4 |

TABLE 4.

Standard length-weight relationships for *Cynoscion nebulosus* collected from different localities and calculated using different forms of the regression equation (ln = natural logarithm).

| Sex | Season | Length range in mm | N | Equation | r | Calculated weight for a 300 mm SL fish in g | Geographical locality | Reference |
|-----|----------|--------------------|------|---------------------------------|--------|---|-----------------------|---------------|
| F | Winter | 75-460 SL | 238 | ln W = -11.4000+3.0484 (ln SL) | 0.9985 | 398.4 | Mississippi Sound | Present study |
| M | Winter | 92-418 SL | 144 | ln W = -11.2720+3.0269 (ln SL) | 0.9903 | 400.5 | Mississippi Sound | Present study |
| F | Spring | 92-544 SL | 425 | ln W = -11.6020+3.0935 (ln SL) | 0.9974 | 421.0 | Mississippi Sound | Present study |
| M | Spring | 100-419 SL | 264 | ln W = -11.7522+3.1221 (ln SL) | 0.9976 | 426.5 | Mississippi Sound | Present study |
| F | Summer | 39-453 SL | 368 | ln W = -10.6100+2.9151 (ln SL) | 0.9919 | 410.4 | Mississippi Sound | Present study |
| M | Summer | 40-412 SL | 281 | ln W = -10.6970+2.9213 (ln SL) | 0.9909 | 389.8 | Mississippi Sound | Present study |
| F | Autumn | 82-518 SL | 628 | ln W = -11.3860+3.0473 (ln SL) | 0.9976 | 401.5 | Mississippi Sound | Present study |
| M | Autumn | 76-465 SL | 372 | ln W = -11.4132+3.0556 (ln SL) | 0.9981 | 409.7 | Mississippi Sound | Present study |
| F | Combined | 39-544 SL | 1649 | Log W = -5.4471+3.1681 (Log TL) | 0.9967 | 408.6 ¹ | Mississippi Sound | Present study |
| M | Combined | 40-465 SL | 1060 | Log W = -5.4608+3.1742 (Log TL) | 0.9970 | 408.8 ¹ | Mississippi Sound | Present study |
| F | Combined | 39-544 SL | 1659 | W = -483.1290+3.2522 (SL) | 0.9277 | 492.5 | Mississippi Sound | Present study |
| M | Combined | 40-465 SL | 1061 | W = -355.5150+2.6350 (SL) | 0.9348 | 435.0 | Mississippi Sound | Present study |
| F | Combined | 203-546 SL | 97 | Log W = -4.4160+2.8442 (Log SL) | 0.9207 | 426.0 | Chandeleur Is., LA | Present study |
| M | Combined | 193-394 SL | 78 | Log W = -4.2650+2.7710 (Log SL) | 0.9361 | 397.3 | Chandeleur Is., LA | Present study |

TABLE 4. (Continued)

Standard length-weight relationships for *Cynoscion nebulosus* collected from different localities and calculated using different forms of the regression equation (ln = natural logarithm).

| Sex | Season | Length range in mm | N | Equation | r | Calculated weight for a 300 mm SL fish in g | Geographical locality | Reference |
|-----|----------|--------------------|------|-----------------------------------|--------|---|-----------------------------|---------------------------|
| | | 49–902 TL | 9498 | Log W = -5.192+3.062 (Log TL) | 0.988 | 407.4 ¹ | Texas bays | Harrington et al. (1979) |
| | | 21–138 SL | 35 | Log W = -4.62811+2.91740 (Log SL) | 0.996 | 396.9 | Upper Galveston Bay, TX | Matlock and Strawn (1976) |
| | | 21–629 TL | 1208 | Log W = -5.4215+3.1542 (Log TL) | 0.9941 | 405.2 ¹ | South-central Louisiana | Hein et al. (1980) |
| | | | 49 | Log W = -4.39+2.7995 (Log SL) | | 350.5 | | Vetter (1977) |
| | Combined | | 307 | Log W = -5.3333+3.1131 (Log TL) | | 391.2 ¹ | Ft. Myers and Cedar Key, FL | Moffett (1961) |

¹Using value adjusted to SL from conversion factor of work cited.

however, could be attributed to the specific equations for males in winter and summer.

The common logarithmic regression equations could be analyzed with ANOC between males and females on a seasonal basis because data for all four seasons, separate and grouped, were linear and variances were homogeneous. Means between sexes differed only for summer and autumn samples ($F = 48.74, 6.84 > F_{.05}[1,651 - 1,018 \text{ df}] = 3.86$), and one regression line could not represent both sexes ($F = 24.45, 3.44 > F_{.05}[2,651 - 1,017 \text{ df}] = 3.02$). In both cases, however, slopes for both regression lines were the same ($F = 0.23, 0.04 < F_{.05}[1,650 - 1,017 \text{ df}] = 3.86$); the regression for the means in both cases was linear ($F = -0.03, 0.03 < F_{.05} = 3.86$), but with a difference in intercepts ($F = 48.77, 6.81 > F_{.05} = 3.86$).

Comparing regression equations based on data from individual seasons and also on data from combined seasons for each sex revealed differences for all combinations except those for males in winter versus those in summer, autumn, and all seasons combined and those for differences in means in females from winter versus summer. Means for the other cited comparisons, most of which involved spring regressions, differed ($F = 5.33 - 48.29 > F_{.05} = 3.85$), and one regression line could not be used to represent the pairs ($F = 14.44 - 50.29 > F_{.05} = 3.02$). The linear slopes of those regression lines differed ($F = 6.44 - 71.37 > F_{.05} = 3.85$). Variances for SL and weight measurements, however, were not homogeneous for the following comparisons: female spring versus autumn and winter; male summer versus spring, autumn and combined; male autumn versus spring and combined. Nevertheless, the means for length and weight of all of those comparisons, except males in summer versus spring, differed when compared using Snedecor and Cochran's (1967) test for means when variances are unequal.

The usefulness of fitted regression equations can and has often been questioned (e.g., Ricker 1973). Values depend on whether and how data are collected and pooled. Data from Mississippi illustrate that one should not calculate weight of fish caught during specific periods, such as spring, using an equation derived from data that had been pooled from one or more entire years. Equations derived from three year-groups, 1980, 1979, and 1972–1978, usually differed little (much less than those from seasonal groups) when like-groups of similar sample-size were compared. Consequently, they were pooled. However, a small sample-size and a skewed frequency of fish in various length-groups often influenced values considerably, neither producing a fit approaching that for grouped data nor having a significant correlation coefficient.

The equations without logarithmic transformation, and consequently neither linear nor meeting the necessary assumptions, had low r values as well as produced unrealistic calculated weights. Transformed linear data based on relatively small samples from Chandeleur Islands also contributed to relatively low r values (0.92 to 0.94). Using females from this group as examples to illustrate the wide range of values producing the fits, I calculated that a 300 mm SL female in spring would weigh 491.3 g (N = 32) compared to 386.6 g (N = 14) in summer and 400.7 g (N = 51) in autumn. The 95% confidence interval about a b (slope) value of 2.9881 in spring ranged from 2.0311 to 3.9451 and the others had similarly large ranges. Adkins et al. (1979) provided length-weight frequency graphs for males and females with calculated curves using a different transformation and obtained r values of 0.926 and 0.927 for 429 females and 147 males from an area in Louisiana adjacent to Mississippi. Large sample sizes of fish from Texas and Louisiana (Harrington et al. 1979, Hein et al. 1980) produced pooled values

similar to those in Mississippi. However, as seen by seasonal data from Mississippi, even when data for fish are pooled and a fit has a high correlation coefficient, the equation still may be inadequate for comparative purposes. For that reason, K values for groups of fish broken down by year, season, length of fish, stage of maturation, and sex are presented below.

Condition Coefficient, Liver Weight, and Gonad Weight

The condition coefficient,

$$K = \frac{W \times 10^5}{SL^3},$$

often represents a more practical means to compare length-weight relationships of fish-groups restricted by length, stage of maturity, and certain other parameters than does the regression equation. Table 5 shows that fish-groups from 22 to 40 cm long had relatively high K values in spring and low ones in winter. Fish over 30 cm in summer, a period when most have released large quantities of gametes, also had a low K. Females generally had a higher K than their male counterparts. Differences in K among corresponding groups in different years as well as those of individuals within certain specific groups as indicated by high standard errors (SE) illustrate variability. Table 6 combines the data for all years, and Table 7 lists bimonthly values based on total length (K_{TL}) for use as comparisons with those by other authors.

Tables 8 and 9 use the same data as in Table 5, but group individual values according to stage of maturity rather than by length of fish. Seasonally, the K values for grouped 1972–1980 data (Tables 6 and 9) portray a more gradual increase by stage of development than by length. On the other hand, this trend is not apparent from 1979 or 1980 data (Tables 5 and 8).

The hepatosomatic index,

$$HSI = \frac{\text{Liver weight} \times 100}{\text{Total fish weight}},$$

is listed on the same tables as K values. It tends to increase with fish-length, with relatively high values in winter and relatively low ones in summer (Tables 5 and 6). In several cases, the HSI for females tended to be larger than that for their male counterparts in the same group, especially in large fish (Table 6). From Mississippi Sound, the high HSI values of 4.15 and 3.95 for females and 3.46 and 3.44 for males occurred during winter. An immature fish had an even higher value. A male and female from Chandeleur Islands had HSI values of 4.46 and 4.03 during autumn. Furthermore, HSI values among grouped samples often varied more than corresponding K values for the same group.

In addition to being relatively small, livers of numerous fish during summer months, specifically apparent in May, June, and August 1973, and in August 1979, exhibited extensive lipid vacuolization. These cream-colored livers often contained separate yellowish focal areas, and they contrasted

conspicuously with the brownish-red colored livers that were noted during most of the year. Of 85 of these fish with fatty livers, only 19 were males, and all those with gross yellowish areas were females. The 85 comprised males and females from 128 to 441 mm long, mostly in stages III to V, but a few in stages I and II. Fatty deposits of adipose tissue in the body cavity appeared pronounced in most fish during autumn and winter.

Seasonal variation in the gonosomatic index,

$$GSI = \frac{\text{Weight of gonads} \times 100}{\text{Total weight of fish}},$$

showed an increase by fish-length and by stage of maturity, as well as reflected pronounced seasonality (Tables 10 and 11). The ovary increased in relative weight more than the testes during spring and summer when maturation and spawning took place. Few fish had conspicuously high GSI values. One stage VI 326 mm female caught 21 May 1980 and releasing ova when handled had a GSI = 10.01, and that for a stage V 200 mm female caught 14 July 1976 was 12.37. Values of GSI were often higher in 1979 than in corresponding seasons during 1980. Grimes and Huntsman (1980) discussed some of the problems inherent in using a gonad-index.

Variation among relative weights of both liver and gonads in the larger, more mature fish is expressed by the high SE's (Tables 5, 9, 10, and 11). That variation plus seasonal differences also appear evident in fitted seasonal regression equations relating either liver or gonad weights with fish weight (Tables 12 and 13). In spite of most r values being less than 0.95, fitted equations are presented. Calculated values from the equation, especially as exemplified by those from early and late stage gonads of summer females (Table 13), do not always take maturation into account, but they do allow comparisons by seasons and sex of fish. When regression equations for both gonad and liver weights on fish weight were fit for summer males and summer females separated into groups of 40 to 249 mm and 250 to 453 mm, the r values were much lower than those for the same fish grouped by developmental stages as listed in Tables 12 and 13. Because samples of fish collected in different seasons and different years comprised different numbers of fish in specific length- and developmental stage-groups and because members of these groups ranged widely in length, data from representative fish in two restricted length-groups provide a more meaningful comparison (Table 14). Regardless of similarity in stage and size, considerable variation still existed. Nevertheless, Table 14 shows that variation occurred seasonally as indicated earlier; that little relative difference existed between liver weight in males and females, especially large individuals; and that the liver during much of the year weighed much more than the gonads. A 368 mm male in spring had an 18.25 g liver and a 2.05 g testes. Difference in weight between ovaries and testes became especially disparate in gravid fish because of the heavy ovaries.

TABLE 5.

Seasonal condition coefficient (K[standard length]) and hepatosomatic index (HSI) of *Cynoscion nebulosus* from Mississippi Sound relative to year, sex, and length of fish.

| | Standard length in millimeters | | | | | | | | | | | | | | |
|----------------|--------------------------------|-----------|-----------|-------------|-----------|-----------|-------------|-----------|-----------|-------------|-----------|-----------|-------------|-----------|-----------|
| | < 140 | | | 140-219 | | | 220-299 | | | 300-399 | | | ≥ 400 | | |
| | Sample size | K±SE | HSI±SE | Sample size | K±SE | HSI±SE | Sample size | K±SE | HSI±SE | Sample size | K±SE | HSI±SE | Sample size | K±SE | HSI±SE |
| Autumn '72-'77 | | | | | | | | | | | | | | | |
| Female | 112 | 1.42±0.01 | 1.30±0.04 | 57 | 1.42±0.02 | 1.52±0.23 | 53 | 1.53±0.03 | 1.21±0.09 | 174 | 1.50±0.02 | 1.13±0.03 | 41 | 1.47±0.03 | 1.20±0.09 |
| Male | 103 | 1.43±0.01 | 1.29±0.05 | 37 | 1.43±0.02 | 1.40±0.05 | 52 | 1.61±0.06 | 1.17±0.09 | 91 | 1.57±0.03 | 1.22±0.05 | 6 | 1.40±0.05 | 1.28±0.23 |
| Winter '72-'78 | | | | | | | | | | | | | | | |
| Female | 48 | 1.39±0.01 | 1.70±0.09 | 17 | 1.51±0.04 | 1.42±0.17 | 10 | 1.54±0.05 | 1.83±0.08 | 31 | 1.61±0.02 | 1.80±0.09 | 3 | 1.39±0.12 | 2.17±0.45 |
| Male | 25 | 1.43±0.03 | 1.81±0.15 | 10 | 1.89±0.49 | 1.50±0.14 | 12 | 1.46±0.03 | 1.68±0.16 | 30 | 1.52±0.02 | 1.72±0.09 | 1 | 1.37 | 0.89 |
| Spring '72-'78 | | | | | | | | | | | | | | | |
| Female | 55 | 1.43±0.02 | 1.34±0.06 | 31 | 1.44±0.03 | 1.15±0.09 | 21 | 2.00±0.15 | 1.35±0.08 | 92 | 1.60±0.02 | 1.58±0.04 | 19 | 1.57±0.03 | 1.67±0.14 |
| Male | 44 | 1.39±0.02 | 1.31±0.06 | 22 | 1.50±0.04 | 1.10±0.08 | 49 | 1.60±0.01 | 1.20±0.05 | 41 | 1.56±0.02 | 1.16±0.06 | 0 | | |
| Summer '72-'78 | | | | | | | | | | | | | | | |
| Female | 8 | 1.60±0.09 | 0.95±0.12 | 4 | 1.80±0.13 | 2.30±0.89 | 75 | 1.50±0.02 | 1.23±0.07 | 40 | 1.45±0.02 | 1.30±0.12 | 8 | 1.37±0.04 | 1.40±0.30 |
| Male | 6 | 1.58±0.05 | 0.77±0.09 | 34 | 1.48±0.02 | 0.70±0.04 | 134 | 1.49±0.01 | 0.86±0.06 | 52 | 1.42±0.03 | 0.96±0.09 | 8 | 1.32±0.07 | 1.54±0.27 |
| Autumn '78 | | | | | | | | | | | | | | | |
| Female | 0 | | | 0 | | | 7 | 2.03±0.49 | 1.65±0.17 | 105 | 1.54±0.01 | 1.64±0.06 | 7 | 1.53±0.04 | 2.02±0.14 |
| Male | 0 | | | 0 | | | 17 | 1.59±0.02 | 1.65±0.11 | 15 | 1.57±0.04 | 1.66±0.17 | 0 | | |
| Winter '79 | | | | | | | | | | | | | | | |
| Female | 3 | 1.43±0.04 | 0.45±0.26 | 16 | 1.42±0.03 | 1.90±0.24 | 4 | 1.55±0.09 | 1.98±0.21 | 62 | 1.49±0.02 | 2.24±0.14 | 0 | | |
| Male | 5 | 1.44±0.02 | 0.97±0.31 | 19 | 1.44±0.01 | 1.89±0.11 | 20 | 1.54±0.02 | 1.85±0.11 | 16 | 1.43±0.08 | 2.01±0.14 | 1 | 1.41 | 1.82 |
| Spring '79 | | | | | | | | | | | | | | | |
| Female | 0 | | | 13 | 1.47±0.03 | 0.94±0.07 | 30 | 1.53±0.02 | 1.30±0.07 | 96 | 1.60±0.01 | 1.77±0.05 | 8 | 1.61±0.07 | 2.01±0.09 |
| Male | 0 | | | 4 | 1.48±0.05 | 0.83±0.13 | 30 | 1.57±0.03 | 1.22±0.08 | 36 | 1.60±0.01 | 1.32±0.05 | 1 | 1.56 | 1.42 |
| Summer '79 | | | | | | | | | | | | | | | |
| Female | 0 | | | 22 | 1.57±0.02 | 1.04±0.08 | 163 | 1.58±0.01 | 1.25±0.03 | 32 | 1.56±0.05 | 1.54±0.09 | 5 | 1.31±0.11 | 2.13±0.25 |
| Male | 0 | | | 27 | 1.50±0.04 | 0.82±0.06 | 49 | 1.51±0.02 | 0.73±0.03 | 7 | 1.27±0.13 | 0.56±0.09 | 1 | 1.46 | 0.56 |
| Autumn '79 | | | | | | | | | | | | | | | |
| Female | 0 | | | 0 | | | 86 | 1.50±0.01 | 1.11±0.04 | 48 | 1.49±0.01 | 1.41±0.06 | 9 | 1.51±0.05 | 1.91±0.09 |
| Male | 0 | | | 2 | 1.48±0.01 | 0.88±0.20 | 44 | 1.54±0.02 | 1.05±0.05 | 13 | 1.49±0.04 | 1.10±0.08 | 0 | | |
| Winter '80 | | | | | | | | | | | | | | | |
| Female | 0 | | | 0 | | | 37 | 1.47±0.01 | 0.91±0.04 | 11 | 1.37±0.05 | 1.26±0.12 | 3 | 1.43±0.02 | 2.44±0.16 |
| Male | 0 | | | 0 | | | 13 | 1.50±0.02 | 1.00±0.07 | 6 | 1.41±0.02 | 1.32±0.11 | 1 | 1.48 | 1.67 |
| Spring '80 | | | | | | | | | | | | | | | |
| Female | 0 | | | 8 | 1.57±0.03 | 1.02±0.17 | 47 | 1.58±0.02 | 1.35±0.06 | 31 | 1.60±0.03 | 1.78±0.11 | 12 | 2.52±1.83 | 1.87±0.27 |
| Male | 0 | | | 6 | 1.60±0.03 | 0.93±0.08 | 8 | 1.71±0.03 | 1.35±0.11 | 31 | 1.60±0.02 | 1.47±0.11 | 2 | 1.47±0.12 | 1.21±0.19 |

TABLE 5. (Continued)

Seasonal condition coefficient (K[standard length]) and hepatosomatic index (HSI) of *Cynoscion nebulosus* from Mississippi Sound relative to year, sex, and length of fish.

| | Standard length in millimeters | | | | | | | | | | | | | | |
|------------|--------------------------------|------|--------|-------------|-----------|-----------|-------------|-----------|-----------|-------------|-----------|-----------|-------------|-----------|-----------|
| | < 140 | | | 140-219 | | | 220-299 | | | 300-399 | | | ≥ 400 | | |
| | Sample size | K±SE | HSI±SE | Sample size | K±SE | HSI±SE | Sample size | K±SE | HSI±SE | Sample size | K±SE | HSI±SE | Sample size | K±SE | HSI±SE |
| Summer '80 | | | | | | | | | | | | | | | |
| Female | 0 | | | 1 | 1.56 | 0.58 | 50 | 1.53±0.03 | 1.23±0.07 | 7 | 1.44±0.08 | 1.54±0.08 | 1 | 1.43 | 1.12 |
| Male | 0 | | | 10 | 0.94±0.02 | 0.58±0.08 | 21 | 1.57±0.02 | 0.83±0.07 | 3 | 1.54±0.04 | 0.94±0.07 | 0 | | |
| Autumn '80 | | | | | | | | | | | | | | | |
| Female | 0 | | | 3 | 2.12±0.44 | 1.08±0.14 | 15 | 1.57±0.02 | 1.21±0.10 | 40 | 1.50±0.02 | 1.62±0.06 | 8 | 1.52±0.02 | 1.50±0.24 |
| Male | 0 | | | 4 | 1.66±0.02 | 1.15±0.22 | 62 | 1.58±0.01 | 1.21±0.05 | 17 | 1.54±0.03 | 1.54±0.09 | 1 | 1.45 | 1.43 |

TABLE 6.

Seasonal condition coefficient (K[standard length]) and hepatosomatic index (HSI) of *Cynoscion nebulosus* from Mississippi Sound from 1972-1980 relative to sex and length of fish.

| | Standard length in millimeters | | | | | | | | | | | | | | | | | | | |
|--------|--------------------------------|-----------|-------------|-----------|-------------|-----------|-------------|-----------|-------------|-----------|-------------|-----------|-------------|-----------|-------------|-----------|-------------|-----------|-------------|-----------|
| | < 140 | | | | 140-219 | | | | 220-299 | | | | 300-399 | | | | ≥ 400 | | | |
| | Sample size | K±SE | Sample size | HSI±SE | Sample size | K±SE | Sample size | HSI±SE | Sample size | K±SE | Sample size | HSI±SE | Sample size | K±SE | Sample size | HSI±SE | Sample size | K±SE | Sample size | HSI±SE |
| Autumn | | | | | | | | | | | | | | | | | | | | |
| Female | 119 | 1.42±0.01 | 119 | 1.29±0.04 | 53 | 1.45±0.03 | 53 | 1.30±0.05 | 134 | 1.51±0.01 | 133 | 1.13±0.04 | 285 | 1.50±0.01 | 281 | 1.36±0.03 | 48 | 1.51±0.02 | 44 | 1.51±0.02 |
| Male | 112 | 1.43±0.01 | 112 | 1.32±0.05 | 36 | 1.46±0.02 | 36 | 1.29±0.06 | 150 | 1.54±0.01 | 150 | 1.19±0.04 | 78 | 1.50±0.02 | 75 | 1.29±0.06 | 6 | 1.41±0.05 | 6 | 1.29±0.23 |
| Winter | | | | | | | | | | | | | | | | | | | | |
| Female | 51 | 1.40±0.01 | 51 | 1.63±0.10 | 33 | 1.46±0.03 | 33 | 1.65±0.15 | 51 | 1.49±0.01 | 51 | 1.17±0.07 | 105 | 1.50±0.01 | 105 | 1.93±0.06 | 6 | 1.41±0.05 | 6 | 2.30±0.21 |
| Male | 30 | 1.43±0.02 | 30 | 1.67±0.15 | 29 | 1.59±0.16 | 29 | 1.76±0.14 | 45 | 1.51±0.02 | 45 | 1.56±0.09 | 52 | 1.48±0.03 | 52 | 1.77±0.08 | 3 | 1.42±0.04 | 3 | 1.46±0.35 |
| Spring | | | | | | | | | | | | | | | | | | | | |
| Female | 55 | 1.42±0.01 | 55 | 1.35±0.06 | 50 | 1.47±0.02 | 50 | 1.09±0.06 | 81 | 1.56±0.01 | 81 | 1.34±0.04 | 207 | 1.60±0.01 | 206 | 1.70±0.03 | 31 | 1.54±0.03 | 31 | 1.88±0.11 |
| Male | 45 | 1.40±0.02 | 45 | 1.29±0.06 | 26 | 1.50±0.03 | 26 | 1.04±0.07 | 86 | 1.60±0.01 | 86 | 1.22±0.04 | 106 | 1.58±0.01 | 106 | 1.31±0.04 | 3 | 1.50±0.09 | 3 | 1.28±0.16 |
| Summer | | | | | | | | | | | | | | | | | | | | |
| Female | 8 | 1.60±0.09 | 6 | 0.95±0.12 | 27 | 1.60±0.03 | 27 | 1.20±0.15 | 255 | 1.56±0.01 | 249 | 1.27±0.03 | 74 | 1.49±0.02 | 73 | 1.36±0.07 | 10 | 1.40±0.04 | 10 | 1.75±0.24 |
| Male | 8 | 1.52±0.06 | 8 | 0.75±0.07 | 66 | 1.48±0.01 | 65 | 0.74±0.04 | 149 | 1.50±0.01 | 148 | 0.77±0.02 | 53 | 1.42±0.02 | 50 | 0.76±0.04 | 4 | 1.26±0.13 | 4 | 0.80±0.21 |

TABLE 7.
Bimonthly condition coefficients calculated using total length of *Cynoscion nebulosus*
from Mississippi Sound and Barataria Bay, Louisiana.

| Month | Sex | N | Mississippi Sound | | | Barataria Bay ¹ | |
|-------|-----|-----|----------------------------------|-----|-------------------------------------|----------------------------|-------------------------|
| | | | All fish K _{TL} ± SE | N | > 275 mm SL K _{TL} ± SE | 1976 K _{TL} | 1978 K _{TL} |
| Feb | M | 39 | 0.92±0.01 | 22 | 0.94±0.02 | 0.83 | |
| | F | 58 | 0.91±0.01 | 40 | 0.96±0.01 | 0.85 | |
| Apr | M | 131 | 0.96±0.01 | 73 | 1.00±0.01 | 1.05 | 0.99 |
| | F | 178 | 0.95±0.01 | 117 | 1.01±0.01 | 1.06 | 1.02 |
| Jun | M | 76 | 0.92±0.01 | 30 | 0.99±0.01 | 1.00 | 0.92 |
| | F | 166 | 0.97±0.01 | 39 | 1.03±0.02 | 1.04 | 0.97 |
| Aug | M | 122 | 0.92±0.01 | 78 | 0.92±0.01 | 1.01 | 0.89 |
| | F | 148 | 0.96±0.01 | 88 | 0.96±0.02 | 0.98 | 0.93 |
| Oct | M | 120 | 0.97±0.01 | 49 | 0.96±0.01 | 1.01 | 0.91 |
| | F | 207 | 0.94±0.01 | 183 | 0.93±0.01 | 1.00 | 0.87 |
| Dec | M | 184 | 0.84±0.01 | 33 | 0.96±0.01 | 0.95 | |
| | F | 272 | 0.87±0.01 | 112 | 0.97±0.01 | 0.94 | |

¹Based on graphs published by Hein and Shepard (1980).

Condition coefficient, gonad weight, and liver weight all varied seasonally and were at least partially related. The contribution of gonad weight to K showed significance only for stage V females limited to spring and summer (Table 15). Patterns in variation among the three factors intensified in fish > 400 mm long. From data presented, the exact relationship is speculative. Relative weight of gonads, especially ovaries, was high in spring and summer, whereas relative liver weight steadily decreased from a high in winter. Hein and Shepard (1979b) reported seasonal variations in K and GSI for samples of spotted seatrout greater than 230 mm TL in Louisiana. Their average values produced a pattern similar to that from Mississippi with differences occurring between male and female counterparts. However, when compared with Mississippi averages, most values for 1976 Louisiana samples were higher and many for 1978 Louisiana samples were lower. Those authors (1979a) also calculated K and GSI values for Louisiana fish over 310 mm TL caught October, November, and December from marsh environments and compared them with corresponding values for fish from sandy coastal areas and islands. The K values for those two groups were similar, but GSI was higher for females in marshes during October and November than in coastal areas during those months. Average total weight for those females, however, was considerably less during those two months suggesting continual recruitment of fish from the marsh into the coastal stock. The commercial Ritchie Fish Computer (Professional Model) established K_{TL} for the spotted seatrout as 1.0 which is misleading as shown by this study. For some cases, mostly involving freshwater fishes, K values have been known to increase with age, differ according to sex, and change during spawning (e.g., Lagler 1952). Lagler

suggested that for best comparisons, K values should characterize fish of the same length, age, and sex. Comparisons can have merit when using data from similar sites at different times or from different localities at the same time.

All three indices used above provide useful tools for fisheries management; however, they may be misused and the reasons for their relationships are complex. Nutritional and environmental parameters apparently play important roles in addition to those involving maturation and spawning. Data for females and males are usually separated because females grow faster and in latter years are more abundant than males (e.g., Tabb 1961).

Two examples illustrate some of the confusion involving the HSI. Bulow et al. (1978) found that the bluegill, *Lepomis macrochirus* Rafinesque, in two lakes in Tennessee had a high HSI in May when the GSI was highest and attributed that HSI to high food intake. The bluegill feeds throughout the year, but growth is most efficient at about 30°C (Lemke 1977). The authors recognized other contributing factors influencing HSI and did not sample from December to March. In the dab, *Limanda limanda* (Linnaeus), from the North Sea, the HSI was high from October to March, reaching a peak at or just preceding early spawning, and the index corresponded directly with K (Htun-Han 1978). Unlike the bluegill, the dab does not feed during winter. Htun-Han (1978) assumed the changes in K related to depletion of body reserves during gonad maturation. He could not relate decrease in liver weight with vitellogenesis as others have done because the HSI remained relatively high and constant throughout the spawning period. He suggested that HSI and K declined because the dab stopped feeding during winter. Contrarily, the plaice, *Pleuronectes platessa* Linnaeus, from

TABLE 10.
Gonosomatic index (GSI) of *Cynoscion nebulosus* relative to length of fish.

| | Standard length in millimeters | | | | | | | | | |
|----------------|--------------------------------|-----------|-------------|-----------|-------------|-----------|-------------|-----------|-------------|-----------|
| | <140 | | 140-219 | | 220-299 | | 300-399 | | ≥400 | |
| | Sample size | GSI±SE | Sample size | GSI±SE | Sample size | GSI±SE | Sample size | GSI±SE | Sample size | GSI±SE |
| Autumn '72-'77 | | | | | | | | | | |
| Female | 112 | 0.15±0.02 | 57 | 0.31±0.04 | 53 | 0.69±0.07 | 174 | 0.56±0.02 | 41 | 0.70±0.04 |
| Male | 103 | 0.02±0.01 | 37 | 0.11±0.05 | 52 | 0.21±0.02 | 91 | 0.25±0.02 | 6 | 0.14±0.03 |
| Winter '72-'78 | | | | | | | | | | |
| Female | 48 | 0.05±0.01 | 17 | 0.20±0.03 | 10 | 0.52±0.11 | 31 | 0.74±0.04 | 3 | 0.96±0.14 |
| Male | 25 | 0.02±0.01 | 10 | 0.12±0.02 | 12 | 0.14±0.03 | 30 | 0.32±0.03 | 1 | 0.16 |
| Spring '72-'78 | | | | | | | | | | |
| Female | 55 | 0.12±0.03 | 31 | 0.24±0.03 | 21 | 1.34±0.24 | 92 | 3.06±0.20 | 19 | 5.10±0.84 |
| Male | 44 | 0.06±0.01 | 22 | 0.29±0.05 | 49 | 1.25±0.06 | 41 | 1.19±0.07 | 0 | |
| Summer '72-'78 | | | | | | | | | | |
| Female | 8 | 0.51±0.05 | 4 | 5.45±3.78 | 75 | 2.77±0.20 | 40 | 3.66±0.24 | 8 | 4.01±0.71 |
| Male | 6 | 0.00±0.00 | 34 | 0.43±0.07 | 134 | 0.82±0.05 | 52 | 1.25±0.07 | 8 | 1.48±0.35 |
| Autumn '78 | | | | | | | | | | |
| Female | 0 | | 0 | | 7 | 0.68±0.03 | 105 | 0.70±0.02 | 7 | 0.97±0.08 |
| Male | 0 | | 0 | | 17 | 0.18±0.07 | 15 | 0.15±0.01 | 0 | |
| Winter '79 | | | | | | | | | | |
| Female | 3 | 0.04±0.04 | 16 | 0.35±0.06 | 4 | 0.72±0.08 | 62 | 0.95±0.05 | 0 | |
| Male | 5 | 0.05±0.02 | 19 | 0.06±0.01 | 20 | 0.10±0.01 | 16 | 0.20±0.03 | 1 | 0.16 |
| Spring '79 | | | | | | | | | | |
| Female | 0 | | 13 | 0.40±0.04 | 30 | 2.19±0.37 | 96 | 3.20±0.23 | 8 | 1.77±0.62 |
| Male | 0 | | 4 | 0.90±0.30 | 30 | 1.05±0.07 | 36 | 1.14±0.06 | 1 | 1.24 |
| Summer '79 | | | | | | | | | | |
| Female | 0 | | 22 | 1.20±0.21 | 163 | 3.50±0.15 | 32 | 4.98±0.24 | 5 | 4.29±0.45 |
| Male | 0 | | 27 | 0.82±0.06 | 49 | 1.02±0.05 | 7 | 1.20±0.08 | 1 | 0.90 |
| Autumn '79 | | | | | | | | | | |
| Female | 0 | | 0 | | 86 | 0.62±0.02 | 48 | 0.63±0.02 | 9 | 1.22±0.17 |
| Male | 0 | | 2 | 0.46±0.14 | 44 | 0.18±0.02 | 13 | 0.25±0.05 | 0 | |
| Winter '80 | | | | | | | | | | |
| Female | 0 | | 0 | | 37 | 0.82±0.02 | 11 | 0.80±0.03 | 3 | 0.93±0.07 |
| Male | 0 | | 0 | | 13 | 0.10±0.01 | 6 | 0.15±0.02 | 1 | 0.19 |
| Spring '80 | | | | | | | | | | |
| Female | 0 | | 8 | 0.37±0.04 | 47 | 1.53±0.20 | 31 | 2.57±0.44 | 12 | 1.73±0.28 |
| Male | 0 | | 6 | 1.01±0.05 | 8 | 1.20±0.11 | 31 | 0.93±0.11 | 2 | 1.03±0.52 |
| Summer '80 | | | | | | | | | | |
| Female | 0 | | 1 | 0.42 | 50 | 2.65±0.26 | 7 | 4.59±0.49 | 1 | 5.01 |
| Male | 0 | | 10 | 0.37±0.04 | 21 | 0.56±0.09 | 3 | 0.41±0.15 | 0 | |
| Autumn '80 | | | | | | | | | | |
| Female | 0 | | 3 | 0.27±0.10 | 15 | 0.55±0.03 | 40 | 0.65±0.02 | 8 | 0.79±0.04 |
| Male | 0 | | 4 | 0.09±0.03 | 62 | 0.18±0.03 | 17 | 0.14±0.02 | 1 | 0.15 |
| Autumn '72-'80 | | | | | | | | | | |
| Female | 119 | 0.16±0.02 | 53 | 0.27±0.02 | 133 | 0.61±0.03 | 283 | 0.64±0.01 | 46 | 0.89±0.05 |
| Male | 111 | 0.02±0.01 | 36 | 0.14±0.06 | 150 | 0.18±0.02 | 75 | 0.21±0.02 | 6 | 0.13±0.02 |
| Winter '72-'80 | | | | | | | | | | |
| Female | 51 | 0.05±0.01 | 33 | 0.28±0.04 | 51 | 0.75±0.03 | 105 | 0.84±0.02 | 6 | 0.94±0.07 |
| Male | 30 | 0.03±0.01 | 29 | 0.08±0.01 | 45 | 0.11±0.01 | 52 | 0.27±0.02 | 3 | 0.17±0.01 |
| Spring '72-'80 | | | | | | | | | | |
| Female | 55 | 0.12±0.03 | 50 | 0.30±0.02 | 81 | 1.79±0.18 | 207 | 3.00±0.15 | 31 | 4.39±0.49 |
| Male | 45 | 0.07±0.01 | 26 | 0.42±0.08 | 86 | 1.17±0.05 | 106 | 1.12±0.05 | 3 | 1.10±0.38 |
| Summer '72-'80 | | | | | | | | | | |
| Female | 8 | 0.05±0.05 | 27 | 1.72±0.55 | 252 | 3.28±0.12 | 73 | 4.43±0.17 | 10 | 4.50±0.55 |
| Male | 8 | 0.00±0.00 | 66 | 0.56±0.04 | 148 | 0.72±0.04 | 50 | 1.09±0.06 | 4 | 0.96±0.14 |

TABLE 11.
Gonosomatic index (GSI) of *Cynoscion nebulosus* relative to the fish's stage of maturity.

| | Stage of maturity | | | | | | | | | | | | | |
|----------------|-------------------|-----------|-------------|-----------|-------------|-----------|-------------|-----------|-------------|-----------|-------------|-----------|-------------|-----------|
| | I | | II | | III | | IV | | V | | VI | | VII | |
| | Sample size | GSI±SE | Sample size | GSI±SE | Sample size | GSI±SE | Sample size | GSI±SE | Sample size | GSI±SE | Sample size | GSI±SE | Sample size | GSI±SE |
| Autumn '72-'77 | | | | | | | | | | | | | | |
| Female | 134 | 0.15±0.02 | 56 | 0.40±0.04 | 185 | 0.58±0.02 | 53 | 0.70±0.03 | 9 | 1.49±0.46 | 0 | | 0 | |
| Male | 138 | 0.02±0.01 | 81 | 0.20±0.03 | 60 | 0.27±0.02 | 8 | 0.55±0.10 | 0 | | 0 | | 0 | |
| Winter '72-'78 | | | | | | | | | | | | | | |
| Female | 47 | 0.07±0.02 | 18 | 0.14±0.03 | 34 | 0.64±0.04 | 10 | 0.94±0.05 | 0 | | 0 | | 0 | |
| Male | 28 | 0.03±0.01 | 17 | 0.10±0.02 | 33 | 0.32±0.02 | 0 | | 0 | | 0 | | 0 | |
| Spring '72-'78 | | | | | | | | | | | | | | |
| Female | 68 | 0.13±0.02 | 22 | 0.33±0.03 | 11 | 0.92±0.09 | 32 | 1.67±0.16 | 80 | 3.98±0.25 | 0 | | 0 | |
| Male | 53 | 0.06±0.01 | 6 | 0.38±0.05 | 40 | 0.92±0.07 | 45 | 1.36±0.07 | 12 | 1.30±0.13 | 0 | | 0 | |
| Summer '72-'78 | | | | | | | | | | | | | | |
| Female | 10 | 0.34±0.30 | 7 | 0.51±0.11 | 9 | 0.83±0.20 | 24 | 2.73±0.29 | 84 | 3.83±0.21 | 0 | | 0 | |
| Male | 15 | 0.04±0.02 | 66 | 0.37±0.03 | 67 | 0.86±0.04 | 31 | 1.32±0.13 | 56 | 1.49±0.07 | 0 | | 0 | |
| Autumn '78 | | | | | | | | | | | | | | |
| Female | 0 | | 2 | 0.40±0.08 | 107 | 0.70±0.01 | 8 | 0.84±0.06 | 2 | 1.36±0.00 | 0 | | 0 | |
| Male | 2 | 0.04±0.03 | 24 | 0.17±0.05 | 6 | 0.17±0.02 | 0 | | 0 | | 0 | | 0 | |
| Winter '79 | | | | | | | | | | | | | | |
| Female | 7 | 0.29±0.14 | 13 | 0.34±0.05 | 60 | 0.93±0.05 | 4 | 1.11±0.07 | 1 | 1.11 | 0 | | 0 | |
| Male | 20 | 0.05±0.01 | 21 | 0.09±0.01 | 19 | 0.19±0.03 | 1 | 0.13 | 0 | | 0 | | 0 | |
| Spring '79 | | | | | | | | | | | | | | |
| Female | 0 | | 26 | 0.49±0.03 | 22 | 0.91±0.03 | 0 | | 97 | 3.95±0.21 | 1 | 1.03 | 1 | 0.72 |
| Male | 0 | | 1 | 0.21±0.00 | 37 | 0.94±0.06 | 0 | | 32 | 1.27±0.05 | 0 | | 0 | |
| Summer '79 | | | | | | | | | | | | | | |
| Female | 0 | | 38 | 0.76±0.16 | 6 | 1.03±0.35 | 5 | 4.07±0.39 | 168 | 4.27±0.12 | 5 | 1.22±0.32 | 0 | |
| Male | 0 | | 9 | 0.61±0.12 | 5 | 0.76±0.11 | 6 | 1.00±0.10 | 63 | 1.04±0.04 | 0 | | 0 | |
| Autumn '79 | | | | | | | | | | | | | | |
| Female | 0 | | 21 | 0.52±0.02 | 109 | 0.64±0.01 | 0 | | 8 | 1.22±0.19 | 0 | | 5 | 0.84±0.10 |
| Male | 2 | 0.04±0.02 | 23 | 0.10±0.01 | 32 | 0.26±0.02 | 0 | | 2 | 0.59±0.01 | 0 | | 0 | |
| Winter '80 | | | | | | | | | | | | | | |
| Female | 0 | | 0 | | 48 | 0.81±0.02 | 3 | 0.93±0.07 | 0 | | 0 | | 0 | |
| Male | 0 | | 6 | 0.10±0.01 | 13 | 0.12±0.01 | 1 | 0.19 | 0 | | 0 | | 0 | |
| Spring '80 | | | | | | | | | | | | | | |
| Female | 1 | 0.34 | 30 | 0.48±0.04 | 16 | 1.01±0.06 | 3 | 1.40±0.10 | 44 | 2.67±0.22 | 4 | 6.20±1.94 | 0 | |
| Male | 0 | | 1 | 0.13 | 27 | 0.80±0.08 | 6 | 0.84±0.13 | 13 | 1.58±0.13 | 0 | | 0 | |
| Summer '80 | | | | | | | | | | | | | | |
| Female | 0 | | 8 | 0.54±0.04 | 4 | 0.77±0.08 | 0 | | 36 | 3.96±0.24 | 2 | 4.11±0.58 | 9 | 1.33±0.27 |
| Male | 0 | | 5 | 0.28±0.07 | 23 | 0.38±0.04 | 0 | | 6 | 1.07±0.14 | 0 | | 0 | |
| Autumn '80 | | | | | | | | | | | | | | |
| Female | 1 | 0.15 | 12 | 0.46±0.04 | 53 | 0.68±0.01 | 0 | | 0 | | 0 | | 0 | |
| Male | 2 | 0.02±0.00 | 69 | 0.14±0.02 | 12 | 0.30±0.07 | 0 | | 1 | 0.75 | 0 | | 0 | |

TABLE 11. (Continued)
Gonosomatic index (GSI) of *Cynoscion nebulosus* relative to the fish's stage of maturity.

| | Stage of maturity | | | | | | | | | | | | | |
|----------------|-------------------|-----------|-------------|-----------|-------------|-----------|-------------|-----------|-------------|-----------|-------------|-----------|-------------|-----------|
| | I | | II | | III | | IV | | V | | VI | | VII | |
| | Sample size | GSI±SE | Sample size | GSI±SE | Sample size | GSI±SE | Sample size | GSI±SE | Sample size | GSI±SE | Sample size | GSI±SE | Sample size | GSI±SE |
| Autumn '72-'80 | | | | | | | | | | | | | | |
| Female | 134 | 0.15±0.02 | 80 | 0.42±0.02 | 368 | 0.63±0.01 | 33 | 0.77±0.03 | 14 | 1.46±0.23 | 0 | | 5 | 0.84±0.12 |
| Male | 141 | 0.02±0.01 | 155 | 0.17±0.02 | 78 | 0.26±0.02 | 1 | 0.08 | 3 | 0.64±0.06 | 0 | | 0 | |
| Winter '72-'80 | | | | | | | | | | | | | | |
| Female | 55 | 0.09±0.02 | 31 | 0.22±0.03 | 142 | 0.81±0.02 | 17 | 0.98±0.04 | 1 | 1.11±0.00 | 0 | | 0 | |
| Male | 48 | 0.04±0.01 | 44 | 0.09±0.01 | 65 | 0.25±0.02 | 2 | 0.16±0.04 | 0 | | 0 | | 0 | |
| Spring '72-'80 | | | | | | | | | | | | | | |
| Female | 69 | 0.13±0.02 | 70 | 0.45±0.02 | 43 | 0.94±0.03 | 25 | 1.79±0.18 | 211 | 3.66±0.14 | 5 | 5.17±2.04 | 1 | 0.72 |
| Male | 53 | 0.06±0.01 | 8 | 0.33±0.05 | 95 | 0.90±0.04 | 53 | 1.30±0.06 | 56 | 1.34±0.05 | 0 | | 0 | |
| Summer '72-'80 | | | | | | | | | | | | | | |
| Female | 10 | 0.34±0.30 | 52 | 0.69±0.12 | 14 | 0.86±0.15 | 15 | 3.78±0.36 | 262 | 4.20±0.10 | 2 | 4.11±0.82 | 14 | 1.29±0.21 |
| Male | 15 | 0.04±0.02 | 79 | 0.39±0.03 | 85 | 0.76±0.04 | 19 | 1.15±0.09 | 77 | 1.08±0.04 | 0 | | 0 | |

TABLE 12.
Liver weight - fish weight relationships of *Cynoscion nebulosus* from Mississippi Sound (using common logarithmic transformation) by sex of fish and season.

| Season | Sex | SL range in mm | N | Log FW = Log a+b (Log LW) | | | | |
|--------|---------------------|----------------|-----|---------------------------|--------|------------------------------|---|--------|
| | | | | Log a | b | 95% confidence interval of b | Calculated liver weight for a 410g fish | r |
| Winter | Male | 92-418 | 144 | 1.8703 | 0.8539 | 0.8000-0.9079 | 7.40 | 0.9345 |
| Winter | Female | 75-460 | 238 | 1.8871 | 0.8527 | 0.8162-0.8891 | 7.10 | 0.9487 |
| Spring | Male | 100-419 | 264 | 1.9742 | 0.8967 | 0.8642-0.9292 | 5.15 | 0.9583 |
| Spring | Female | 92-544 | 423 | 1.9367 | 0.8465 | 0.8273-0.8656 | 6.29 | 0.9732 |
| Summer | Male | 40-412 | 273 | 2.2239 | 0.6430 | 0.5889-0.6970 | 4.03 | 0.8180 |
| Summer | Female | 39-453 | 358 | 2.1154 | 0.6576 | 0.6171-0.6981 | 5.71 | 0.8611 |
| Autumn | Male | 76-465 | 372 | 1.9454 | 0.9218 | 0.8935-0.9501 | 5.30 | 0.9578 |
| Autumn | Female | 82-518 | 624 | 1.9703 | 0.8911 | 0.8688-0.9134 | 5.26 | 0.9530 |
| Summer | Male ¹ | 40-377 | 176 | 2.2118 | 0.6191 | 0.5541-0.6841 | 4.44 | 0.8186 |
| Summer | Male ² | 201-412 | 96 | 2.2443 | 0.6730 | 0.5608-0.7852 | 3.53 | 0.7756 |
| Summer | Female ¹ | 39-310 | 73 | 2.1042 | 0.7362 | 0.6315-0.8409 | 4.91 | 0.8572 |
| Summer | Female ² | 209-453 | 270 | 2.1356 | 0.6234 | 0.5651-0.6816 | 5.83 | 0.7896 |

¹ Stages I-III. ² Stages IV-VI.

TABLE 13.
Gonad weight - fish weight relationships of *Cynoscion nebulosus* from Mississippi Sound
(using common logarithmic transformation) by sex of fish and season.

| Season | Sex | SL range in mm | N | Log FW = Log a+b (Log GW) | | | | |
|--------|---------------------|-------------------|-----|---------------------------|--------|---------------------------------|--|--------|
| | | | | Log a | b | 95% confidence interval of b | Calculated gonad weight for a 410g fish | r |
| Winter | Male | 92-418 | 121 | 2.7111 | 0.5801 | 0.5223-0.6379 | 0.68 | 0.8767 |
| Winter | Female | 75-460 | 204 | 2.3390 | 0.5878 | 0.5651-0.6104 | 2.92 | 0.9636 |
| Spring | Male | 100-419 | 239 | 2.2905 | 0.5199 | 0.4952-0.5446 | 4.17 | 0.9375 |
| Spring | Female | 92-544 | 405 | 2.2320 | 0.4636 | 0.4487-0.4785 | 6.63 | 0.9501 |
| Summer | Male | 40-412 | 263 | 2.3161 | 0.3748 | 0.3380-0.4116 | 6.19 | 0.7787 |
| Summer | Female | 39-453 | 356 | 2.1850 | 0.3386 | 0.3116-0.3657 | 18.34 | 0.7947 |
| Autumn | Male | 76-465 | 258 | 2.6544 | 0.5334 | 0.4761-0.5906 | 0.84 | 0.7536 |
| Autumn | Female | 82-518 | 576 | 2.3533 | 0.6878 | 0.6729-0.7027 | 2.38 | 0.9669 |
| Summer | Male ¹ | 40-377 | 166 | 2.3423 | 0.3620 | 0.3140-0.4099 | 5.59 | 0.7585 |
| Summer | Male ² | 201-412 | 96 | 2.1689 | 0.6016 | 0.5368-0.6665 | 5.47 | 0.8849 |
| Summer | Female ¹ | 39-310 | 70 | 2.2595 | 0.4084 | 0.3373-0.4794 | 7.33 | 0.8120 |
| Summer | Female ² | 209-453 | 271 | 1.8887 | 0.5784 | 0.5326-0.6242 | 17.86 | 0.8348 |

¹ Stages I-III. ² Stages IV-VI.

TABLE 14.
Seasonal differences in mean weight (in grams) of liver and gonad for *Cynoscion nebulosus* in Mississippi Sound
comprising two restricted length-groups in developing III and gravid reproductive stages.

| Season | Sex | Stage | 250-265 mm SL | | | 350-365 mm SL | | |
|--------|-----|-------|---------------|---------------|---------------|----------------|---------------|---------------|
| | | | N | Liver wt ± SE | Gonad wt ± SE | N | Liver wt ± SE | Gonad wt ± SE |
| Winter | M | III | 3 | 3.81±0.78 | 0.24±0.04 | 5 | 14.51±1.60 | 1.81±0.39 |
| | F | | 4 | 2.13±0.18 | 1.85±0.19 | 18 | 14.98±1.38 | 5.93±0.28 |
| Spring | M | III | 9 | 4.39±0.36 | 3.32±0.46 | 7 | 9.94±1.87 | 5.46±1.17 |
| | F | | 1 | 6.27 | 1.88 | 1 | 9.95 | 5.10 |
| Summer | M | III | 4 | 1.84±0.13 | 1.81±0.31 | 2 | 3.81±1.75 | 4.29±0.44 |
| | F | | 5 | 2.44±0.68 | 2.48±0.64 | 0 | | |
| Autumn | M | III | 11 | 2.54±0.11 | 0.64±0.21 | 6 | 6.92±1.65 | 1.44±0.22 |
| | F | | 7 | 2.61±0.27 | 1.58±0.15 | 30 | 8.87±0.71 | 4.32±0.25 |
| Winter | M | V | 0 | | | 3 ¹ | 10.08±1.81 | 1.07±0.25 |
| | F | | 0 | | | 8 ¹ | 13.63±1.40 | 6.18±0.13 |
| Spring | M | V | 2 | 1.63±0.23 | 3.41±1.03 | 7 | 12.01±1.10 | 7.05±1.65 |
| | F | | 10 | 4.05±0.28 | 8.08±1.26 | 22 | 14.43±0.85 | 25.41±3.39 |
| Summer | M | V | 23 | 1.87±0.12 | 3.33±0.19 | 2 | 4.20±0.83 | 4.91±1.09 |
| | F | | 39 | 3.38±0.17 | 10.13±0.76 | 14 | 8.55±1.22 | 30.06±3.22 |
| Autumn | M | V | 1 | 2.20 | 2.01 | 0 | | |
| | F | | 3 | 3.33±0.30 | 4.34±2.10 | 1 | 7.92 | 5.85 |

¹ Because no fish 350-365 mm long were collected, these data refer to fish 345-349 mm long.

the Irish Sea did not feed from December until March, but its liver weight was high, especially in lipids, from June to November with a dip in August. Dawson and Grimm (1980) measured the seasonal lipid, glycogen, protein, and ash content in liver and carcass and related the changes in energy

content to ovarian maturation and growth. Although seasonal fluctuations in liver weight and composition were dramatic in the plaice, the amount of energy gained from catabolism during starvation was only about 8% of that from the carcass.

TABLE 15.

Seasonal condition coefficients calculated using standard length and both total weight and that weight minus gonad weight of *Cynoscion nebulosus* from Mississippi Sound.

| | Autumn | | Winter | | Spring | | Summer | |
|---------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| | Female | Male | Female | Male | Female | Male | Female | Male |
| $K_{(SL)} \pm SE$ | | | | | | | | |
| Total sample size | 410 | 79 | 152 | 52 | 279 | 204 | 287 | 184 |
| Sample size | 364 | 75 | 138 | 50 | 43 | 95 | 14 | 84 |
| Stage III | 1.50±0.01 | 1.49±0.01 | 1.48±0.01 | 1.53±0.01 | 1.53±0.02 | 1.57±0.01 | 1.48±0.03 | 1.50±0.01 |
| Sample size | 32 | 1 | 13 | 2 | 25 | 53 | 15 | 23 |
| Stage IV | 1.52±0.05 | 1.43±0.00 | 1.46±0.03 | 1.51±0.05 | 1.56±0.02 | 1.60±0.01 | 1.44±0.05 | 1.42±0.03 |
| Sample size | 14 | 3 | 1 | 0 | 211 | 56 | 258 | 77 |
| Stage V | 1.48±0.04 | 1.46±0.05 | 1.49±0.00 | | 1.60±0.01 | 1.62±0.02 | 1.56±0.01 | 1.49±0.02 |
| $K_{(SL-G)} \pm SE$ | | | | | | | | |
| Total sample size | 410 | 79 | 152 | 52 | 279 | 204 | 283 | 180 |
| Sample size | 364 | 75 | 138 | 50 | 43 | 95 | 14 | 84 |
| Stage III | 1.49±0.01 | 1.48±0.01 | 1.47±0.01 | 1.52±0.01 | 1.51±0.02 | 1.56±0.01 | 1.47±0.03 | 1.49±0.01 |
| Sample size | 32 | 1 | 13 | 2 | 25 | 53 | 15 | 19 |
| Stage IV | 1.51±0.05 | 1.42±0.00 | 1.44±0.03 | 1.51±0.05 | 1.54±0.02 | 1.58±0.01 | 1.39±0.04 | 1.41±0.04 |
| Sample size | 14 | 3 | 1 | 0 | 211 | 56 | 254 | 77 |
| Stage V | 1.46±0.04 | 1.45±0.05 | 1.48±0.00 | | 1.54±0.01 | 1.60±0.02 | 1.49±0.01 | 1.48±0.02 |

The seatrout in our study also has a high HSI in winter, but it feeds throughout the year and spawns in summer rather than February-April like the dab. The winter diet in Mississippi may be less in quantity, and, when examined, it did consist more of polychaetes and less of shrimps and fishes than during the rest of the year (Overstreet and Heard 1982), but the quality of the diet probably had little bearing on glycogen intensification in the liver during winter. Heidinger and Crawford (1977) showed experimentally that the HSI of the largemouth bass, *Micropterus salmoides* (Lacépède), in addition to being positively correlated to quantity of daily food intake, increased with a decrease in temperature. These same relationships also held true for percentage glycogen in the liver in that fish. Percentage of crude fat in the liver increased with both an increase in amount of food eaten and in temperature. At least in rainbow trout, HSI and glycogen level increased more when fed a diet high in cerelose (d-glucose) compared to one low in that component, with levels being accelerated at low temperature. When individuals were starved, the two measurements decreased faster than corresponding ones in fish fed a diet low in cerelose, but low temperature reduced this decrease during fasting, potentially jeopardizing the health of fish under those conditions (Hilton 1982). For some species of fish, abundance of glycogen in the liver varied differently at different temperatures depending on amount of exercise (Dean and Goodnight 1964).

In addition to maintaining glycogen in the liver as a storage product, some fish, such as herring, store large amounts of lipids in their flesh whereas others, such as the spotted seatrout, store large amounts in adipose tissue in the body

cavity. During ovarian maturation, visceral lipids are transported to the liver, transformed, and mobilized into development of ova (Sargent 1976). In females, the transfer to the ovary apparently responds to estrogens, whereas in males, mobilization of lipids from adipose depots to muscle and testes is probably controlled by adrenocorticosteroids or prolactin (Dindo and MacGregor 1981). Some difference between mechanisms in females and males is suggested by differences in indices and the abundance of fatty deposition in the liver of females. Lipid abundance was not measured; however, Thompson (1966) analyzed total oil, moisture, protein, and ash of *Cynoscion nothus* (Holbrook) from the northern Gulf of Mexico. The monthly samples composed fish that ranged from 148 to 312 mm TL and averaged 5 to 7% oil and 73 to 75% moisture from 12 August to December and 2 to 4% and 74 to 79%, respectively, from January to 1 August. These reasonably low percentages of oil contrasted with a high of 17% in the related *Leiostomus xanthurus* Lacépède during May (compared to 1% in January). Also, the length of seatrout was relatively small in Thompson's samples, and several fish were probably not mature. In any event, the types of lipid present have a significant relation to energy and condition, and they vary according to temperature and diet (Cowey and Sargent 1972). As an example of effect on K, when levels of high energy triglyceride fats are low, protein rather than lipids may contribute heavily to supplying metabolic energy during catabolism. Since protein is low in energy relative to fats, K values may be low, and using lipid-moisture values as an indication of condition may be prone to gross errors (Caulton and Bursell 1977).

In any event, the liver of the seatrout increases in wet weight during winter similarly to that in the largemouth bass and some other fishes, and it decreases during summer at or following its spawning period the same as in many other fishes. Because reproductive and other cycles differ among fishes, because environmental influences and behavioral patterns differ among most other similarly studied fishes, and because a variety of factors affect the size and composition of the liver, lipid metabolism and transport, and maturation, the seasonal dynamics of the seatrout's liver from Mississippi differ from those in many species, and fluctuations may differ yearly. Moreover, the sensitivity of the HSI is greater than that of K, as indicated by the higher corresponding SE's in seasonal values.

Size of Mature Fish, Sex Ratio, and Spawning Fish

Length of fish as well as season influence maturity, and Table 16 presents the differences in fish length relative to season, stage, and sex. Most spawning occurred in summer when 76% of the females and 28% of the males were recorded as gravid or spawning. Nevertheless, in spring these percentages were 51 and 20%, compared to 3 and 2% in autumn, and less than 1% in winter. During summer, about one-quarter of both males and females in the 140 to 219 mm group were gravid (Table 16). These included females 189 and 200 mm SL and seven males 201 to 206 mm. With progressive increase in length-groups of females during summer, the percentage of gravid or spawning individuals was 0, 26, 78, 91, and 100%, suggesting an especially great spawning potential for fish over 220 mm. Also involved in this potential is fecundity, which will be discussed later.

As length of fish increased, the percentage of females present increased (Table 17). Of those examined fish over 400 mm long, few were males. For those less than 300 mm, the number of males and females was about equal. On the other hand, in all length-groups a trend existed for the percentage of females to increase with an increased stage of maturity. Large males, however, occasionally appeared to be abundant. Data on sexed seatrout collected in summer and autumn of 1982 from the same area, but after tabularization of the preceding data and therefore not discussed elsewhere, contained 9, 4, 8, and 0 males in groupings 300 to 349, 350 to 399, 400 to 499, and ≥ 500 mm SL, respectively, compared to 13, 3, 5, and 4 females in the same groups. During that 1982 period, the two largest males, a 474 mm SL gravid one and a 463 mm SL postspawned one, weighed 1,752 and 1,370 g and had $K = 1.65$ and 1.38 compared to the largest female which measured 543 mm and weighed 2,540 g with $K = 1.59$ in December.

The numerous collections of spotted seatrout included 106 lots with nine or more fish. When percentage of females in those samples was considered by length of fish and season of capture and then compared with values for the combined data in Table 16, some trends became apparent. During winter, some groups had more males or females than ex-

pected based on average values in Table 16, but no collections were dominated by a single sex of fish. In spring, a group of 15 fish from Chandeleur Islands consisted of all females. Three nearshore groups (with 10 to 46 fish) from Mississippi Sound were composed of 20, 22, and 90% females, values conspicuously different from the average. These groups, however, were the only conspicuous single-sex-dominated groups from the 25 spring collections having several fish. All these groups contained gravid females. During summer, 15 of 26 collections were sexually disproportionate, and in all those that had at least one female present, at least one female was gravid. Four groups collected from off the barrier islands had 0 to 27% females ($N = 10$ to 49), each with at least one gravid female, if females were present. Four inshore groups had 7 to 22% females ($N = 9$ to 76), and seven had 90 to 100% ($N = 10$ to 49), mostly gravid individuals between 200 to 300 mm long. In other words, a tendency for schooling by sex existed during spawning season. By autumn when 37 groups were examined, three groups from Gautier had 12, 14, and 19% females ($N = 14$ to 37), and one group of 30 fish from Back Bay of Biloxi contained all females. Other groups had a male:female ratio which was consistent with averages shown in Table 16.

Spawning fish were collected from nearshore habitats at Deer Island (13 May 1980), Pass Christian (24 August 1980), and Davis Bayou (12 August 1980) and from near barrier islands at the south side of Horn Island (8 May 1980) and southwestern Cat Island (21 May 1980). Water temperature ranged between 25 and 30°C and salinity was usually relatively high, but was as low as 10.0 ppt at Deer Island on 13 May. Spent and gravid females also occurred together at the barrier islands (Ship and Cat islands) and at inshore sites (Deer Island and mouth of West Pascagoula River) from June through October. Those schools also contained gravid males and females with developing ovaries. Of those seatrout examined from Galveston Bay, Texas, a group from 28 April 1977 contained spawning females and a group on 8 September 1976 had spent and gravid females.

Spawning is a prolonged process that usually takes place from April to September with some noted cases of spawning individuals occurring as early as March and as late as November. Hein and Shepard (1979b) provided a table that lists spawning data from numerous cited studies conducted from Georgia to Texas. Some of those cited authors suggest two peaks of spawning activity. All the habitats where spawning occurred and where spent and gravid individuals occurred together in Mississippi were shallow. Those off the barrier islands were in or near grass-beds, but those inshore were not. Tabb (1966) and others suggested that the fish prefer deeper areas in estuaries. What happened to embryos and larvae in 10 ppt is uncertain. Arnold et al. (1976) found no adverse effects at 25 to 30 ppt, and Colura (1974) induced spawning in captive fish and followed development of resulting larvae in 14 to 18 ppt. Rapid metamorphosis and growth occurred experimentally at 28°C, but not at all at 23.5°C in Texas

TABLE 16.
Relationship between length and stage of maturity for 2,736 individuals of *Cynoscion nebulosus*
from Mississippi Sound separated into males and females on a seasonal basis.

| Stage of Development | Standard length in millimeters | | | | | | | | | | | | Total | Grand Total | |
|----------------------|--------------------------------|-----|-----|---------|-----|---------|-----|---------|-----|------|-----|-------|-------|-------------|---|
| | <140 | | | 140-219 | | 220-299 | | 300-399 | | >400 | | Total | | | |
| | U | M | F | M | F | M | F | M | F | M | F | M | | | F |
| Winter | | | | | | | | | | | | | | | |
| I | 15 | 23 | 39 | 20 | 9 | --- | --- | --- | --- | --- | --- | 43 | 48 | 91 | |
| II | | 2 | 9 | 9 | 19 | 28 | 1 | 6 | --- | 1 | --- | 46 | 29 | 75 | |
| III | | --- | --- | --- | 1 | 16 | 49 | 47 | 91 | 1 | --- | 64 | 141 | 205 | |
| IV | | --- | --- | --- | --- | --- | --- | 1 | 11 | 1 | 6 | 2 | 17 | 19 | |
| V | | --- | --- | --- | --- | --- | --- | --- | 1 | --- | --- | 0 | 1 | 1 | |
| VI | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 0 | 0 | 0 | |
| VII | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 0 | 0 | 0 | |
| Total | 15 | 25 | 48 | 29 | 29 | 44 | 50 | 54 | 103 | 3 | 6 | 155 | 236 | 391 | |
| Spring | | | | | | | | | | | | | | | |
| I | 9 | 44 | 54 | 9 | 15 | --- | --- | --- | --- | --- | --- | 53 | 69 | 122 | |
| II | | 1 | 5 | 7 | 31 | --- | 34 | 1 | 1 | --- | --- | 9 | 71 | 80 | |
| III | | --- | --- | 9 | --- | 40 | 6 | 48 | 36 | 1 | 2 | 98 | 44 | 142 | |
| IV | | --- | --- | --- | --- | 32 | 11 | 22 | 19 | --- | 2 | 54 | 32 | 86 | |
| V | | --- | --- | 2 | --- | 12 | 38 | 37 | 153 | 2 | 27 | 53 | 218 | 271 | |
| VI | | --- | --- | --- | --- | --- | 1 | --- | 4 | --- | --- | 0 | 5 | 5 | |
| VII | | --- | --- | --- | --- | --- | 1 | --- | --- | --- | --- | 0 | 1 | 1 | |
| Total | 9 | 45 | 59 | 27 | 46 | 84 | 91 | 108 | 213 | 3 | 31 | 267 | 440 | 707 | |
| Summer | | | | | | | | | | | | | | | |
| I | 34 | 9 | 8 | 4 | 1 | 2 | 1 | --- | --- | --- | --- | 15 | 10 | 25 | |
| II | | --- | --- | 29 | 18 | 49 | 30 | 1 | --- | --- | --- | 79 | 48 | 127 | |
| III | | --- | --- | 16 | 1 | 42 | 8 | 28 | 2 | --- | --- | 86 | 11 | 97 | |
| IV | | --- | --- | 2 | --- | 8 | 18 | 10 | 5 | 3 | --- | 23 | 23 | 46 | |
| V | | --- | --- | 16 | 7 | 48 | 188 | 15 | 68 | 1 | 11 | 80 | 274 | 354 | |
| VI | | --- | --- | --- | --- | --- | 1 | --- | 2 | --- | --- | 0 | 3 | 3 | |
| VII | | --- | --- | --- | --- | --- | 13 | --- | 1 | --- | --- | 0 | 14 | 14 | |
| Total | 34 | 9 | 8 | 67 | 27 | 149 | 259 | 54 | 78 | 4 | 11 | 283 | 383 | 666 | |
| Autumn | | | | | | | | | | | | | | | |
| I | 10 | 109 | 106 | 26 | 27 | 6 | --- | 1 | --- | --- | --- | 142 | 133 | 275 | |
| II | | 3 | 13 | 8 | 25 | 109 | 32 | 23 | 6 | 2 | 1 | 145 | 77 | 222 | |
| III | | --- | --- | 1 | --- | 34 | 94 | 39 | 228 | 4 | 16 | 78 | 338 | 416 | |
| IV | | --- | --- | --- | --- | 1 | 1 | --- | 9 | --- | 23 | 1 | 33 | 34 | |
| V | | --- | --- | 1 | --- | 1 | 2 | 4 | 4 | --- | 8 | 6 | 14 | 20 | |
| VI | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 0 | 0 | 0 | |
| VII | | --- | --- | --- | --- | --- | 4 | --- | 1 | --- | --- | 0 | 5 | 5 | |
| Total | 10 | 112 | 119 | 36 | 52 | 151 | 133 | 67 | 248 | 6 | 48 | 372 | 600 | 972 | |

U = Unsexed immature individuals.

(Colura 1974). In addition to the studies in the southeastern United States, Tucker and Brown (1981) reported peaks in natural spawning, 18 May - 14 June and 13-26 July, in the spotted seatrout from the Chesapeake Bay of Virginia where requirements may differ. In summary, the period for spawning varies somewhat geographically and yearly, often with two apparent peaks, one about May-June and one in July-August. In Mississippi during most years, some individuals spawn monthly from May through August and rarely into October.

The appearance of fish 10 mm SL or less throughout Mississippi Sound, adjacent bays, and Gulf of Mexico immediately adjacent to the barrier islands reflect recent

spawning. These fish have been collected by GCRL personnel in small numbers, but even fish 3.0 mm SL occur within all general areas (Loman 1978, Sally Richardson and Joanne Laroche, personal communication, James Warren, personal communication). Specimens 2.5 mm SL have been collected as early as 6 May and as late as 12 September (Richardson and Laroche, personal communication). Over 70% of fish shorter than 50 mm SL in Mississippi come from shallow areas with grassy bottoms (Loman 1978). Year-old fish 130 to 155 mm SL occur concurrently in May and growth can be approximated using monthly length-frequency diagrams (James Warren, personal communication).

Some seatrout spawn at a small size. Determining age by

TABLE 17.

Percentage of female *Cynoscion nebulosus* by length-group (sample-size in parentheses). Data for localities other than Mississippi are derived from small samples collected in spring, summer, and autumn, except for the lack of an autumn sample from Florida.

| | Standard length in millimeters | | | | | Total |
|---|--------------------------------|------------|------------|------------|------------|-------------|
| | <140 | 140-219 | 220-299 | 300-399 | >400 | |
| Mississippi Sound, Mississippi ¹ | 55.0 (425) | 49.2 (313) | 55.4 (961) | 69.4 (925) | 85.7 (112) | 60.6 (2736) |
| Chandeleur Islands, Louisiana | -- | 41.6 (12) | 53.2 (92) | 57.5 (66) | 100.0 (5) | 55.4 (175) |
| Galveston Bay, Texas | -- | -- | 6.2 (16) | 41.8 (43) | 73.3 (15) | 40.5 (74) |
| Apalachee and Tampa bays, Florida | -- | -- | 44.1 (34) | 85.7 (42) | 100.0 (3) | 60.6 (89) |

¹Note discussion in text on additional collections in 1982 containing a high percentage of large males.

scales and otoliths sometimes provides questionable results, although at least some individuals spawn in their second year and most do in the third year. Workers from Florida, Louisiana, and Texas have found gravid females nearly as short as some of those occurring in this study as well as gravid males shorter than in this study (Klima and Tabb 1959, Stewart 1961, Hein and Shepard 1979b, Miles 1951).

The fact that seatrout can spawn when less than 20 cm long does not have nearly the influence on the fishery as the facts that 1) percentage of gravid females increases with body length and 2) larger females produce more eggs than smaller ones. These factors will be discussed below. The jump from less than 30% of the females being gravid or spawning when less than 30 cm long to over 90% when greater than 30 cm becomes considerably important when one recognizes the increased percentage of females in the subpopulation related with increase in length of fish. Male: female ratios in Georgia, Louisiana, and Texas have been reported as 1:1.7, 1:2.4, and 1:2 (Mahood 1975, Hein and Shepard 1979b, Pearson 1929), but unless fish are divided into length-groups, such ratios can be misleading and even then relatively large sample sizes are necessary. Unlike samples from Mississippi, those grouped by age from east-central Florida and by length from northwestern Florida contained no male fish above 7 years old and 375 mm SL long, respectively (Tabb 1961, Klima and Tabb 1959).

Data from Texas, Florida, and Chandeleur Islands (Table 17) exemplify some problems created by small samples. In Chandeleur collections during summer, 30 stage V fish 220 to 299 mm long were males compared to 9 females. In autumn when fish were not gravid, there were 28 males and 4 females 220 to 399 mm long in stage II compared to 4 males and 46 females in stages III and IV. The same pattern held in Texas samples except the autumn break favoring females was at stage IV rather than III. Part of this difference is based on the assumption that females are larger than males of the same age (e.g., Tabb 1961). Based on numerous observations of specific samples in Mississippi, some indicated above, those observations on fish from the three non-Mississippi locations cited above do not represent the entire subpopulations at those locations. Even if they did, samples

taken at other times of the year would alter overall values. Based on the larger samples from Mississippi, one can assume that some large males exist in Florida. Nevertheless, many fishermen recognize the preponderance of large females and call all large trout "sows." Tabb (1966) stated that the schooling behavior of the spotted seatrout in Florida breaks down by age 5 or 6 (2.7 to 3.6 kg) when most males have died, and the "sow," or "gator," trout adopt a semi-solitary existence. Tabb (1961) found 81% of 210 year fish from Indian River, (east-central) Florida, were males. First-year fish (< 140 mm) from Mississippi agree more with those from the Everglades National Park, Florida (Stewart 1961) and during summer, females apparently outnumbered males nearly two to one. Perhaps most fish of undetermined sex were males which would make that ratio about even and contribute to an abundance of males during the summer.

The apparent disproportionate loss of male spotted seatrout with age has not been observed for all seatrouts. Wilk (1980) reported for *C. regalis* an equal sex ratio for all sizes of fish throughout its range along the Atlantic coast. He stated that no differences in sex ratio of fish occurred among years and that no apparent schooling by sex occurred during any time of their life. No literature reference reports schooling by a disproportionate percentage of male and female spotted seatrout as suggested by the several discussed collections from Mississippi.

Fecundity and Gonads

Based on calculated numbers of oocytes from ovaries in females for each stage throughout the year, a progressive increase in the number occurred from stage II to IV, but the number per gram of ovary remained approximately equal (Table 18). As can be seen from the corresponding SE's in Table 18, considerable fluctuation existed within each group. Since values for oocyte number in the comparative stages during 1979 and 1980 did not differ substantially, those data were combined. The highest number of oocytes larger than 30 μ m in diameter from an individual based on the displacement technique was calculated as 10,599,376 and came from a 518 mm gravid female. Using the gravimetric technique, the same fish would have 15,567,833 oocytes.

TABLE 18.
Average fecundity of *Cynoscion nebulosus* from Mississippi Sound in 1979–1980 determined by volumetric displacement method in relation to stage of development.

| Stage | N | Calculated mean no. eggs \pm SE | Mean wt of fish in g \pm SE | Mean no. eggs/g fish \pm SE | Mean ovarian wt in g \pm SE | Mean no. eggs/g ovary \pm SE |
|-----------------|----|-----------------------------------|-------------------------------|-------------------------------|-------------------------------|--------------------------------|
| Maturing virgin | 7 | 1,369,662 \pm 211,048 | 300.1 \pm 40.5 | 5,006 \pm 1,274 | 1.65 \pm 0.29 | 876,898 \pm 128,127 |
| Developing III | 35 | 2,882,176 \pm 310,051 | 536.0 \pm 35.8 | 5,186 \pm 275 | 4.24 \pm 0.36 | 663,986 \pm 24,527 |
| Developing IV | 6 | 6,750,669 \pm 538,584 | 966.6 \pm 85.1 | 7,340 \pm 976 | 11.40 \pm 1.63 | 641,649 \pm 95,055 |
| Gravid | 35 | 2,333,217 \pm 405,887 | 540.1 \pm 75.3 | 4,283 \pm 354 | 15.21 \pm 1.97 | 175,242 \pm 24,570 |
| Spawning | 3 | 4,051,107 \pm 185,560 | 634.3 \pm 51.7 | 6,493 \pm 687 | 49.14 \pm 14.80 | 110,558 \pm 46,699 |
| Spent | 7 | 1,806,220 \pm 417,205 | 371.1 \pm 72.2 | 5,139 \pm 966 | 5.07 \pm 1.46 | 464,756 \pm 89,177 |

This amount was probably not an atypically large one or was not totally dependent on fish-length because a 402 mm long stage III female had 10,231,237 oocytes (13,044,827 using gravimetric calculations). Moreover, only relatively large oocytes in the aliquots are counted. Figure 3 illustrates length versus percentage-frequency for the different stages and shows no oocytes smaller than 31 μ m in diameter. Some oocytes about 30 to 50 μ m and all smaller ones were missed in the aliquots as can be seen from later micrographs of ovarian tissue. The graphs represent gonads sampled throughout the year even though large oocytes were restricted to prespawning, spawning, and postspawning periods.

The number of oocytes per gram of ovary dropped off conspicuously by the time fish became gravid to spent (stages V, VI, and VII) because the eggs were larger. The size of ovaries, however, increased considerably when fish were spawning (Tables 18–19). The mean number of oocytes per gram of fish varied widely, but the number for stages other than V was typically between 5,000 and 7,000. To assess the effects of spawning, the values calculated for number of oocytes in gravid fish were divided into monthly groups (Table 19). The considerable variation in oocytes per gram of ovary during most months plus the relatively low means in May and July illustrate the long spawning period and possibility of two or more spawning peaks, at least for specific individuals. Fish identified as being spent, even though having relatively small numbers of countable oocytes, had an average or nearly average number per gram of fish or per gram of ovary. Many of these were small oocytes (Figure 3).

A few authors have reported the fecundity of a limited number of spotted seatrout (Pearson 1929, Moody 1950, Tabb 1961, Sundararaj and Suttikus 1962, Adkins et al. 1979). Tabb (1961) and Sundararaj and Suttikus (1962) both showed a progression in the number of eggs with length of fish, reaching maximum estimated numbers of about 1,100,000 oocytes both in 625 mm SL (5-to 8-year-old) females in Indian River, Florida, and in 504 mm TL (4-year-old) females in Louisiana. These and the other cited authors counted only large yolky eggs, presumably near or during spawning periods. Data provided here treat oocytes from 31

to 593 μ m in diameter rather than those only over 300 μ m or some other unstated value. On the other hand, a 326 mm

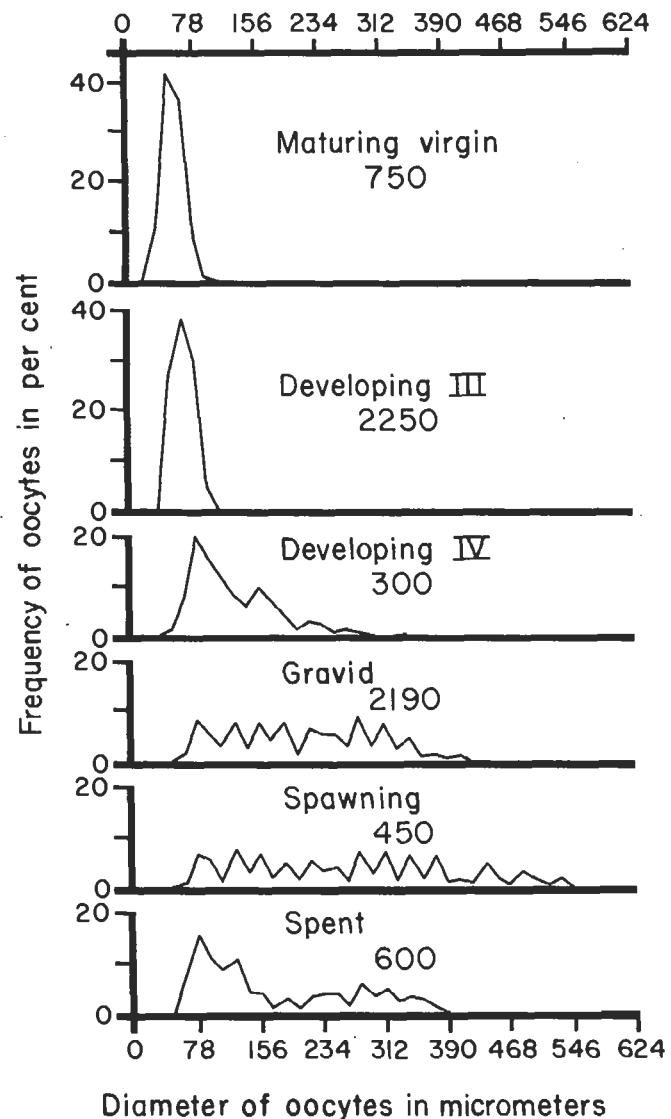


Figure 3. Length-frequency of oocytes over 30 μ m from *Cynoscion nebulosus* according to stage of maturity.

TABLE 19.
Average monthly fecundity in gravid *Cynoscion nebulosus* from Mississippi Sound in 1979–1980.

| Stage | N | Calculated mean no. eggs \pm SE | Mean wt of fish in g \pm SE | Mean no. eggs/g fish \pm SE | Mean ovarian wt in g \pm SE | Mean no. eggs/g ovary \pm SE |
|-----------|---|--------------------------------------|----------------------------------|----------------------------------|----------------------------------|-----------------------------------|
| March | 4 | 3,695,539 \pm 1,770,561 | 674.8 \pm 27.4 | 5,218 \pm 2,390 | 13.07 \pm 1.30 | 254,619 \pm 105,469 |
| April | 4 | 4,715,872 \pm 1,397,829 | 1,048.6 \pm 424.2 | 4,961 \pm 410 | 19.99 \pm 10.80 | 325,043 \pm 65,590 |
| May | 7 | 1,427,752 \pm 212,318 | 606.5 \pm 49.2 | 2,404 \pm 418 | 18.41 \pm 2.91 | 81,732 \pm 11,071 |
| June | 8 | 1,142,781 \pm 168,044 | 262.1 \pm 16.6 | 4,334 \pm 615 | 6.43 \pm 0.88 | 219,743 \pm 67,962 |
| July | 6 | 1,039,433 \pm 171,241 | 246.8 \pm 23.7 | 4,258 \pm 635 | 10.61 \pm 1.59 | 97,856 \pm 7,982 |
| August | 4 | 2,094,323 \pm 503,073 | 392.8 \pm 89.1 | 5,307 \pm 282 | 22.26 \pm 8.33 | 124,640 \pm 42,275 |
| September | 1 | 3,677,195 | 672.0 | 5,457 | 25.92 | 141,481 |

spawning fish in May contained 2,254,134 oocytes over 300 μ m in diameter (3,968,050 when using gravimetric technique), and several fish had over 1,500,000 large oocytes. Because spawning occurs over several months and because vitellogenesis can proceed rapidly in small oocytes, all oocytes over 30 μ m should be treated. In fact, one should determine whether oocytes less than 30 μ m in May also can ripen by August.

Even disregarding problems concerning oocyte-size, estimated fecundity values are not exact. Sundararaj and Suttikus (1962) found they estimated the number of large yolky eggs as 8.5 to 8.9% higher when dealing with 232,936 and 480,180 eggs. Most estimates, such as the one by those authors, have been based on a gravimetric ratio. The displacement ratio appears more accurate to me and is less influenced by the presence of tunica albuginea and "excess" fluid in ovarian tissues. When dividing the estimates of fecundity in Mississippi seatrout using weight by those derived using displacement of water, those using weight had a mean 1.70 \pm 0.03 times greater with a range of from 0.97 to 2.81. Relatively wide variation occurred among values within groups of all the different stages.

Variation in oocyte-count can be attributed to errors in measurements as well as to content of fluid and presence of somatic tissue. Considering the large size of some gravid ovaries, the error in measuring an aliquot (initially totalling about 0.060 \pm 0.002g and 0.10 \pm 0.01 ml) can be significant, especially since it is greatly magnified in the total estimation. Both size and position of aliquot have some influence on accuracy of the method. By doubling the size of the aliquot, the total estimate was occasionally off by a little more than 10%, and when the aliquot was taken from the center of the ovary where no capsular tunic material was present but some oocytes were larger, the estimate was 5 to 8% lower. To these factors, the size of oocytes and the amount of fluid blotted also influence accuracy. In the ovaries of two gravid fish during May, 150 oocytes from their central portions averaged 405 and 357 μ m in diameter compared to 360 and 332 μ m for 150 oocytes near the corresponding periphery.

Considering all the factors that result in errors when

determining fecundity, the numbers listed in Tables 18 and 19 may be somewhat low. In any event, they are not unrealistic and suggest that the spotted seatrout is capable of spawning many more eggs per season than previously assumed. Even small individuals less than 1 kg maintained under artificial light and temperature regimes spawn several million eggs per year (Colura, personal communication). The modes and medians of ripe egg diameters, between 440 and 500 μ m, showed the same differences. Colura (1974), when artificially inducing spawning in the seatrout using human chorionic gonadotropin (HCG), found that ovulation always occurred when ovarian eggs were initially at least 462 μ m in diameter and never when less than 410 μ m. Data in Figure 3 support those findings; only spawning fish had oocytes larger than 406 μ m. Fable et al. (1978) reported that spawned eggs measured 0.73 to 0.82 mm in diameter, averaging 0.77 mm and ranging from 0.70 to 0.85 mm when preserved.

Histology of gonads

In addition to being followed seasonally by gross observations, gonadal development was concurrently studied by histological observations of representative samples. Diagnoses from sections occasionally did not correspond with those gross ones determined from Table 1. Since examination of sectioned material aids in understanding the reproductive biology of the spotted seatrout, some observations occur below.

During late autumn and throughout winter, ovaries of females designated grossly as stages III and IV typically contained early stage oocytes before vitellogenesis ensued (Figures 4–8). These were seasons when the tunica albuginea surrounding most ovaries reached its maximal thickness. Some oogonia and primary oocytes (e.g., Figure 5) occurred in the ovaries throughout the year. As lipogenesis progressed in more developed oocytes, the presence of yolk vesicles resulted in less basophilic-appearing ooplasm. This less basophilic-appearing (Harris's hematoxylin and eosin Y) ooplasm ultimately took on a reddish color throughout when stained using Masson's trichrome method. The bluish

ooplasm of earlier phases using that method progressively changed from spotted to variegated with the red staining material as the basophilia decreased in intensity. In many ovaries during winter and early spring, the ooplasm developed a zonation with those zones located both peripherally and adjacent to the nucleus being stained darker than the zone in between (Figure 9). Following this yolk-vesicle stage, oocytes in the yolk-globule stage began showing up concurrently with others in the yolk-vesicle stage about April in many fish, and they typically lasted throughout the summer. The reddish-purple-staining (hematoxylin and eosin) vitelline material in the yolk globules occurred both as minute granules in vesicles and as large globules, with the size of the structures depending on the degree of coalescence (Figures 10–13). The globules stained purple with hematoxylin and pink with eosin. Oocytes as small as 70 to 80 μm underwent obvious vitellogenesis as determined by stained globules, but those exhibiting vitellogenesis generally measured 120 μm or larger. Nevertheless, some were smaller than their counterparts in the yolk-vesicle stage. Development of this yolk-globule stage within an individual fish, as well as that of the preceding yolk-vesicle stage, seldom appeared to proceed synchronously. Toward the end of summer, however, most oocytes not in an early oocyte stage had reached the late yolk-globule stage. As the oocytes approached maturation, most yolk globules coalesced into rather large spheres before fusing together, and the yolk vesicles gradually coalesced until a single lipid globule existed (Figures 14–17). Usually no longer spherical at this time, the large oocytes measured up to 560 μm long (Figure 17). As the globules and vesicles coalesced into homogeneous bodies, the nucleus appeared to migrate peripherally and lose its membrane. The oocytes took up fluid before ovulation.

If hydrated ova were not spawned, as commonly occurred in September and October, the overripe bodies, either those shed into the lumen (Figures 18–20) or those retained in the lamellae (Figures 21–22), remained hyaline in appearance. These oocytes degenerated and presumably most of their material was absorbed (Figures 22–24). Because some of the post-spawning females contained such large numbers of these hardened, residual oocytes, they were misdiagnosed as gravid using Table 1.

After fractional release of normal ripe ova, the retained secondary membranes of the oocytes could be recognized as spent and fluid-filled, collapsed or compressed follicles, or as degenerating follicles (Figures 17, 24–26). As seen in some previous figures, not all oocytes ripened or ovulated simultaneously. Some relatively well-developed oocytes among many early-stage oocytes that occurred in ovaries during late summer probably never would have spawned had the fish not been sampled (Figures 27–28). In similar cases during June and July, however, such oocytes probably would have continued to mature and be spawned (Figure 29).

Atresia, the regressive absorption of aborted oocytes, involved oocytes in all stages of development. In addition to that fate for the eosinophilic, hyaline, overripe, post-spawning oocytes (e.g., Figure 21), some oocytes in all stages underwent atresia throughout the year. Figure 30 shows one in a premature yolk-vesicle stage. The process can be followed easily, especially in well-developed oocytes because of their yolky components (Figures 31–37).

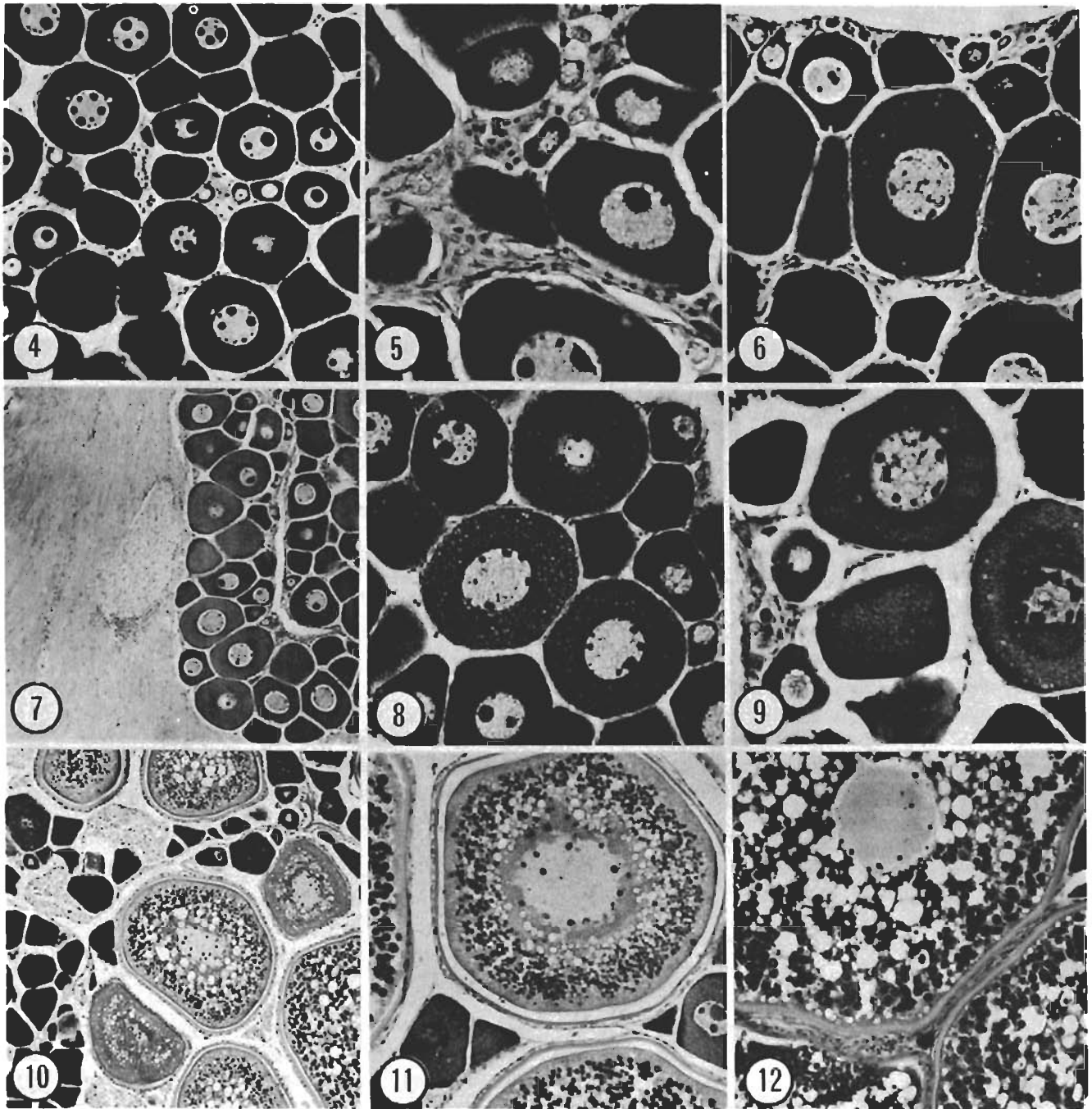
Examination of oocytes both microscopically and histologically showed that no oocytes in prespawning condition occurred in March and few occurred in April. Most ovaries of fish from May through August diagnosed using Table 1 as stages V–VII and many as stages III and IV contained an abundance of oocytes in advanced vitellogenic stages. All those 189 to 217 mm females diagnosed as stage V in summer (Table 16) had secondary or tertiary yolk-globule stage oocytes (see Nash and Shehadeh 1980 or other references for terminology of stages). During May through August, lamellae frequently contained oogonia, primary oocytes, yolk-vesicle oocytes, yolk-globule oocytes, and spent follicles at the same time. In September, stage V-diagnosed fish usually had oocytes in the primary or secondary, but not tertiary, yolk-globule stage. By October, if deposited yolk globules could be seen, they were restricted to oocytes in the primary stage. After that period, any oocytes containing yolk globules exhibited atresia.

The above observations suggest a fractional spawning with a prolonged, or serial, noncontinuous release of ova from May through August. Either a portion of the individuals did not initiate that spawning until June or July or they underwent a resting period at that time without active vitellogenesis transpiring (e.g., Figure 29).

Of all the ovaries examined, only one appeared grossly abnormal. When palpated, a portion felt brittle, much more so than ovaries containing residual hyaline-appearing oocytes. When sectioned, the ovary of this stage III fish in October exhibited a large region of degeneration (Figures 38–39).

In most cases, both developing or mature ovaries appeared similar in size and contained the same developmental stages. Comparative sections from anterior, midregion, and posterior of representative pairs showed little difference along the length or throughout the cross-section.

Numerical designations have been used to classify oocytes into different developmental stages, but because those stages designated by different authors (e.g., Combs 1969, Nash and Shehadeh 1980, Bruslé 1980) do not correspond, I chose to use descriptive names and avoid confusion. As shown from histological evidence from some females and to be supported further with data from males, neither numerical nor descriptive maturation stages for fish always compare with the actual reproductive stage of that individual. Because gonads of all fish were not sectioned and because numerical assignments are useful for comparisons with gross data in other works, they are utilized.



Figures 4–12. Sectioned ovarian tissue from *Cynoscion nebulosus*. 4. “Resting stage” oocytes, most having large spherical nucleoli dispersed throughout their nuclei. Although strongly basophilic, the cytoplasm of oocytes (ooplasm) in this developing III fish in January exhibits a few irregularly-dispersed yolk vesicles. Oogonia and primary oocytes are dispersed among the larger resting stages. 5. Close-up of ovary in developing III fish during November showing oogonia and primary oocytes among resting oocytes. The central small cells with dense nuclei are red blood cells. 6. Primary oocytes, including a small cluster of “chromatin nucleolus stage” oocytes lining the lamellar margin of an ovary in developing III fish during November. The more mature “resting oocytes” contain small basophilic thread-like nucleoli in addition to larger nucleoli (not shown in figure). 7. A developing IV fish in November with typical oocytes of stage III to IV fish from September through November. No large, vitellogenic oocytes occur in these ovaries as they do in post-spawning stage V fish during this same period, but the presumed pallial substance of Balbiani’s vitelline body surrounding the nucleus apparently prepares oocytes for vitellogenesis. Note portion of a moderately thick, muscular, intra-lamellar septum arising from the tunica albuginea located in the bottom of the figure. Nerves, such as the one shown, are common in the tunica albuginea. 8. “Post-peri-nucleolus stage” oocytes in developing IV fish during February with smaller nucleoli peripherally located. Lipogenesis actively resulting in small yolk and lipid vesicles in ooplasm of some oocytes and thereby producing a decrease in basophilic-appearing ooplasm. 9. Oocytes from a developing III fish in April stained using Masson’s trichrome method showing

Spermatogenesis, as well as oogenesis, progressed seasonally. Developmental components within an individual usually appeared similar throughout both testes, except in immature fish. In those, developmentally active cells occurred less abundantly in the anterior and central portions of a testis. In late autumn and early winter, the testes of fish diagnosed as stage I did not exhibit active spermatocytogenesis (Figure 40), but those in more advanced stages revealed various degrees of activity. Figure 40 illustrates the branching network of tubules in this unrestricted continuous spermatogonial testis-type as defined by Grier (1981). Figures 41 and 42 illustrate early development. Some testes had more advanced phases, and by spring active spermatogenesis had proceeded extensively in compact tubules. Relatively few spermatozoa, however, were being produced (Figure 43). By May, many males had gravid testes (Figure 44). Most testes remained with spermatozoa packed in tubule lumens until about September when the testes appeared to reach their spent condition, even though residual spermatozoa remained in the lumens for several months (Figures 45–46). As indicated earlier, a few testes actively produced some spermatozoa during autumn and winter months.

The processes of spermatocytogenesis (the first stage in which spermatogonia develop into spermatocytes which in turn produce spermatids) and spermiogenesis (the second stage in which spermatids transform into spermatozoa) together constitute spermatogenesis and take place within germinal cysts surrounded at this stage by compressed Sertoli cells and bound together by a basement membrane and boundary cells. Leydig cells can be seen along the basement membrane. Development occurs almost synchronously within each cyst. Figures 47 and 48 show several of these cysts in March and May, respectively, and Figures 49 through 57 magnify the various stages. Free spermatozoa occurred in most testes after April. They even occurred in lumens of tubules of fish diagnosed as virgin (Figure 58). By September, most residual spermatozoa in mature and developing fish were restricted to the lumens and not abundant in the sperm duct (Figures 59–60).

The tunica albuginea surrounding the testes never thickened seasonally to the degree it did about the ovary.

Even though all females diagnosed as gravid did not necessarily contain ripe eggs and environmental conditions during much of the study were probably not optimal or in some cases tolerable for seatrout, their spawning, and the successful hatching of embryos, enough evidence exists to assume that seatrout have the potential to spawn continually in Mississippi Sound from May through August during most

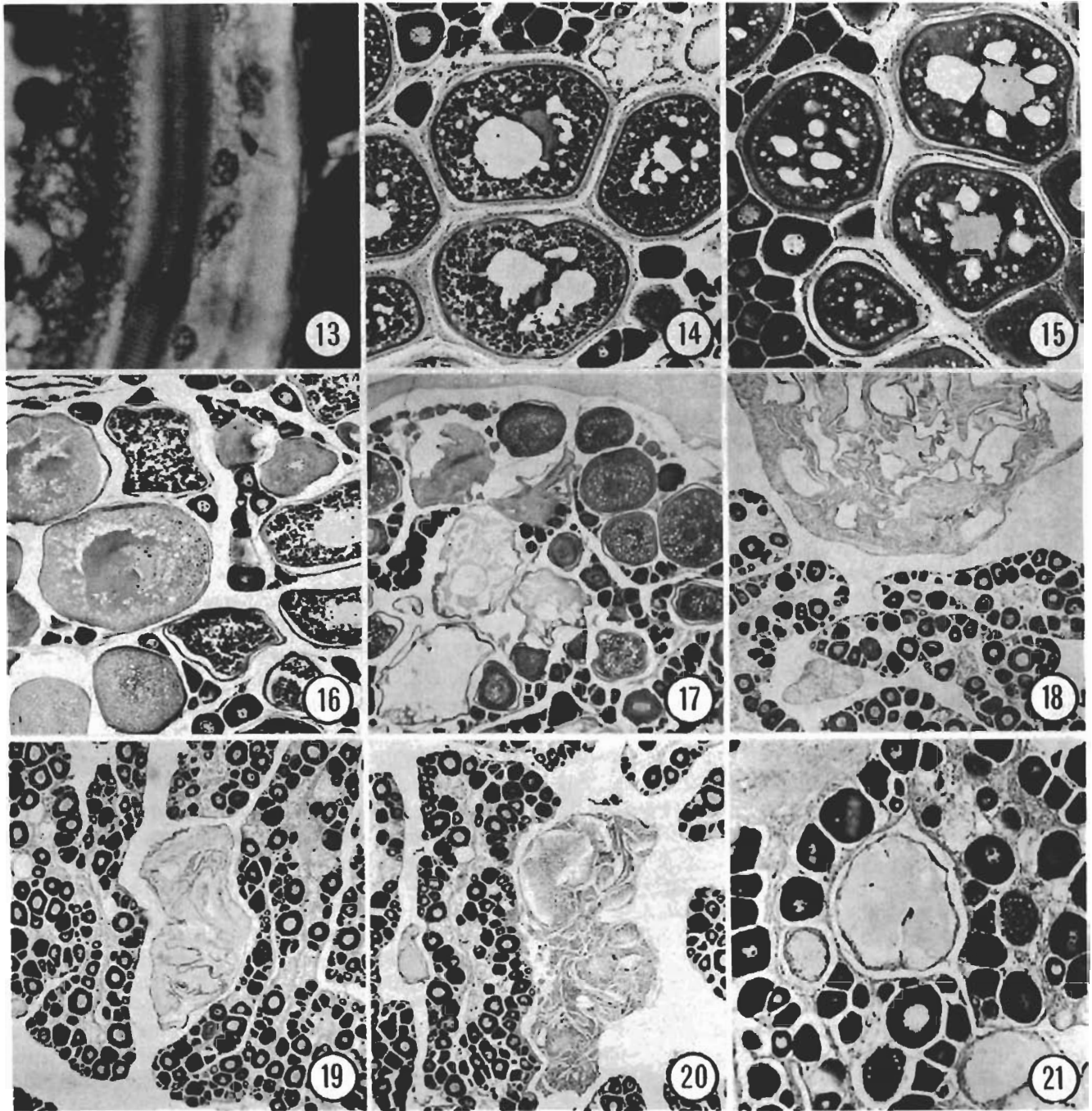
years and also during earlier and later months in exceptional years. Hein and Shepard (1979b) presented a table listing data from 21 sources on spawning seatrout, and, apparently in coastal regions south of Mississippi, ripe fish occasionally occur as early as February and as late as mid November. In the Everglades National Park, Florida, Jannke (1971) observed recently spawned larvae year-around, although their number was reduced during late fall and winter.

The important factors necessary for maturation and spawning seem to be restricted to photoperiod and temperature. Arnold et al. (1976) manipulated those two parameters and ultimately caused a group of spotted seatrout in an approximately 30,000 liter tank to spawn monthly for 13 consecutive months. They recorded 82 spawns during that period when the temperature remained at about 26°C with 15 hr of light and 9 hr of dark each day. Different dual or multiple peaks noted during different years in different regions by a variety of workers, either for individuals or stocks, probably reflect in part those two factors (e.g., Hein and Shepard 1979b).

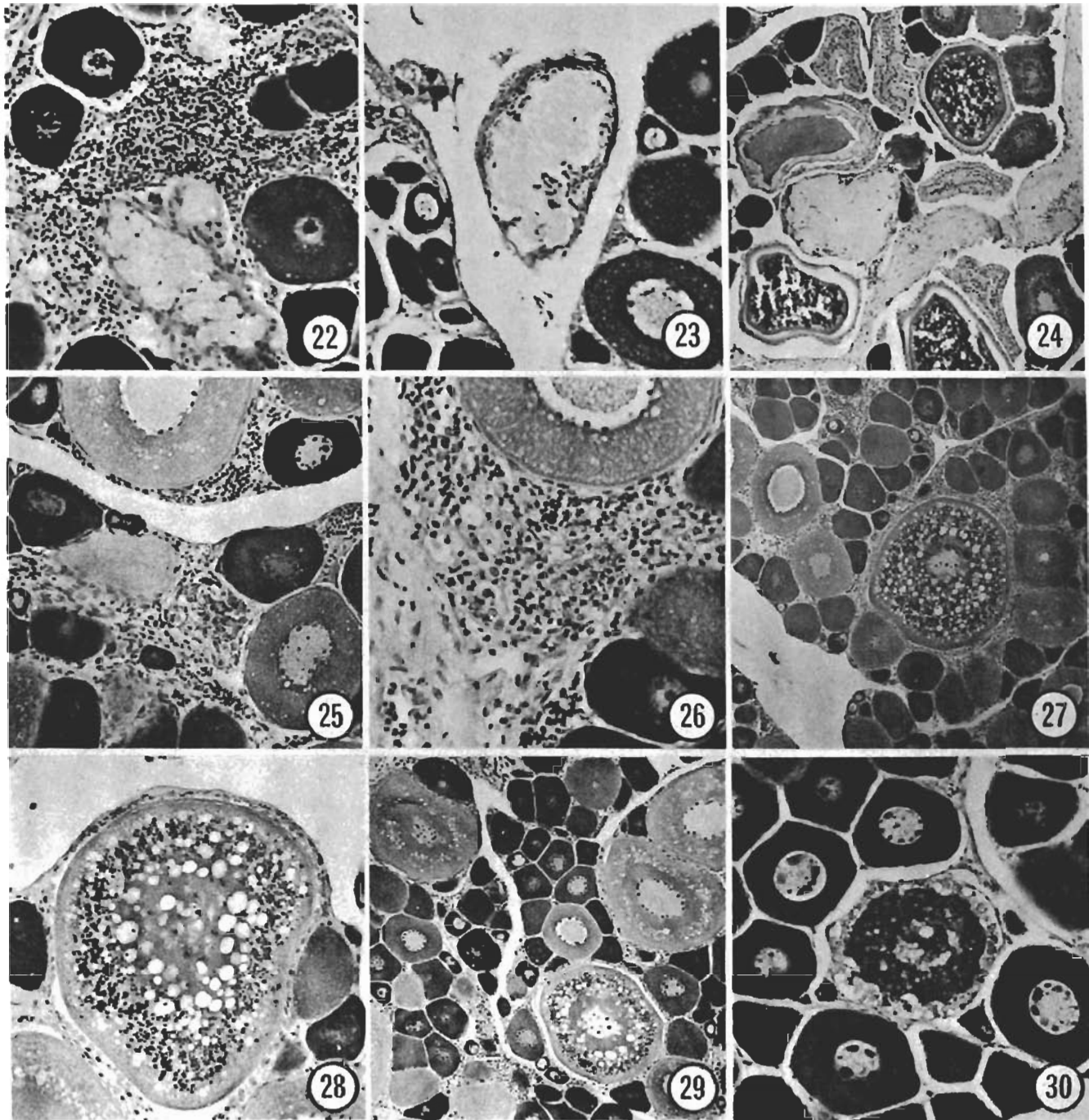
Given the proper temperature and photoperiod, enough oogonia presumably form and enough oocytes mature in an individual female so that the fish can continually spawn a total of several million eggs over its 4-month or longer spawning period. Colura (personal communication) estimated that a 0.7 kg fish in controlled conditions produced about 250,000 ova per spawn for nearly a year. Eggs are typically buoyant, and Colura (1974) found that those few sinking after experimentally inducing ovulation with injections of human chorionic gonadotropin (HCG) had a lower percentage hatch when compared to 90% of those that were clear, buoyant, and free of follicular tissue. Arnold et al. (1976) assumed that the naturally spawned eggs which sank in their seawater system either died or had not been fertilized. Eggs presumably also sink in low salinity water.

The number of juvenile seatrout does not necessarily correspond to the number of eggs spawned, fertilized, or hatched. Temperature, salinity, food, and other factors influence that production. When Colura (1974) reared seatrout at 23.5°C, assimilation of the yolk sac occurred by 96 hr and most fish died at that time without metamorphosing. The few that lived for 13 days apparently could not utilize the available food. On the other hand, those reared at 28°C hatched sooner (15 rather than 22 hr), developed faster, utilized the same food available to the others, and metamorphosed. Taniguchi (1980) predicted 100% survival of both eggs and newly hatched larvae between 23.1 and 32.9°C over a salinity range of 18.6 to 37.5 ppt. He determined that optimum

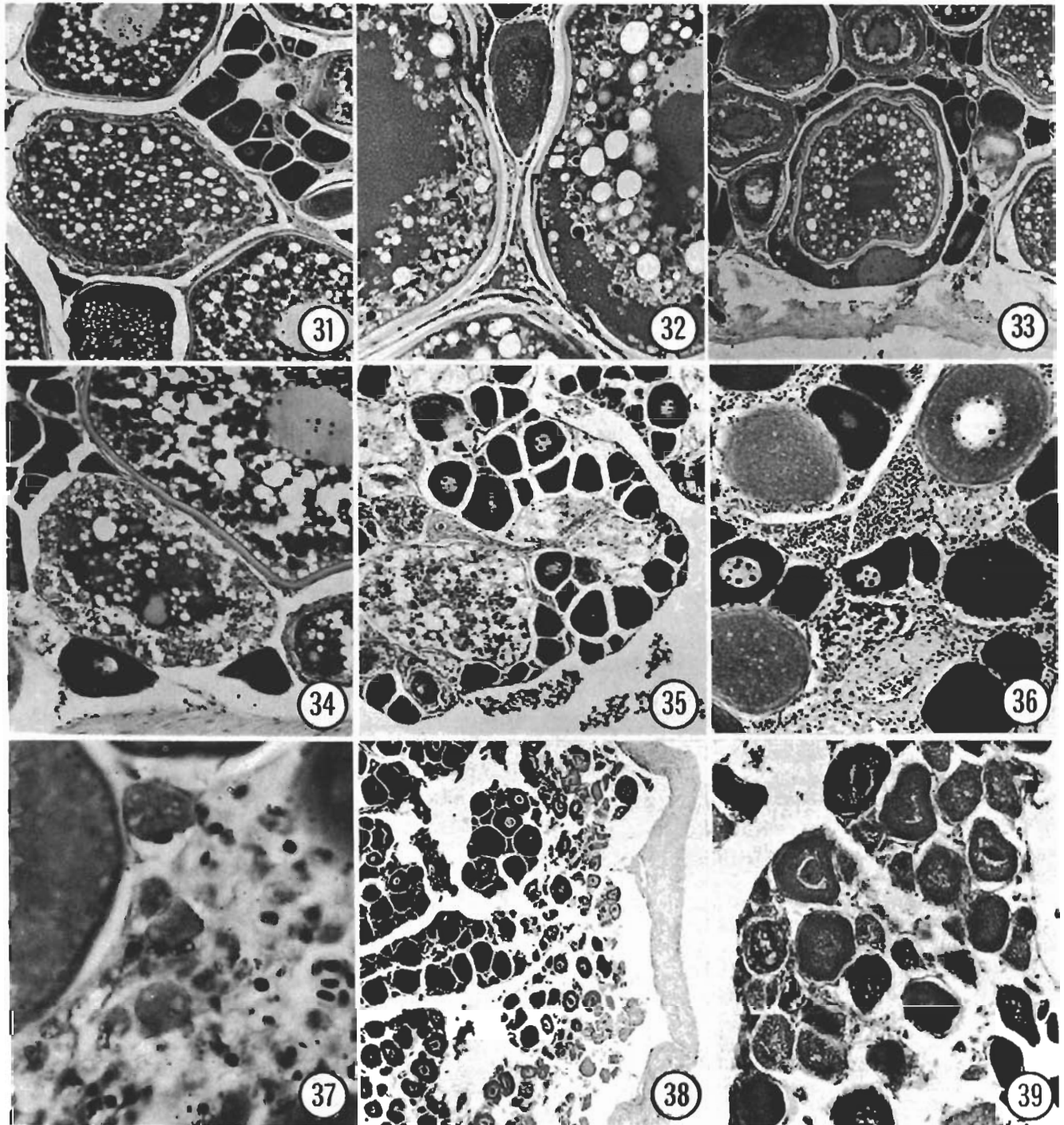
the intense reddish-violet staining property of the ooplasm at the periphery and surrounding the nucleus (probably pallial substance of Balbiani's vitelline body). 10. A developing III fish in August showing several oocytes simultaneously undergoing progressive stages of development as well as showing spent follicles. 11. Close-up of oocyte showing medium-sized yolk globules (vitelline granules; additional reddish-staining granules too small to see at this magnification occur abundantly, especially toward periphery), medium-sized yolk vesicles (including lipid material), and a nucleus with an irregular boundary, presumably allowing for increased RNA transportation from nucleoli to ooplasm. Note larger yolk globules in the adjacent, more-developed oocytes. 12. A more developed oocyte than in Figure 11 showing relatively even dispersal of yolk globules and yolk vesicles.



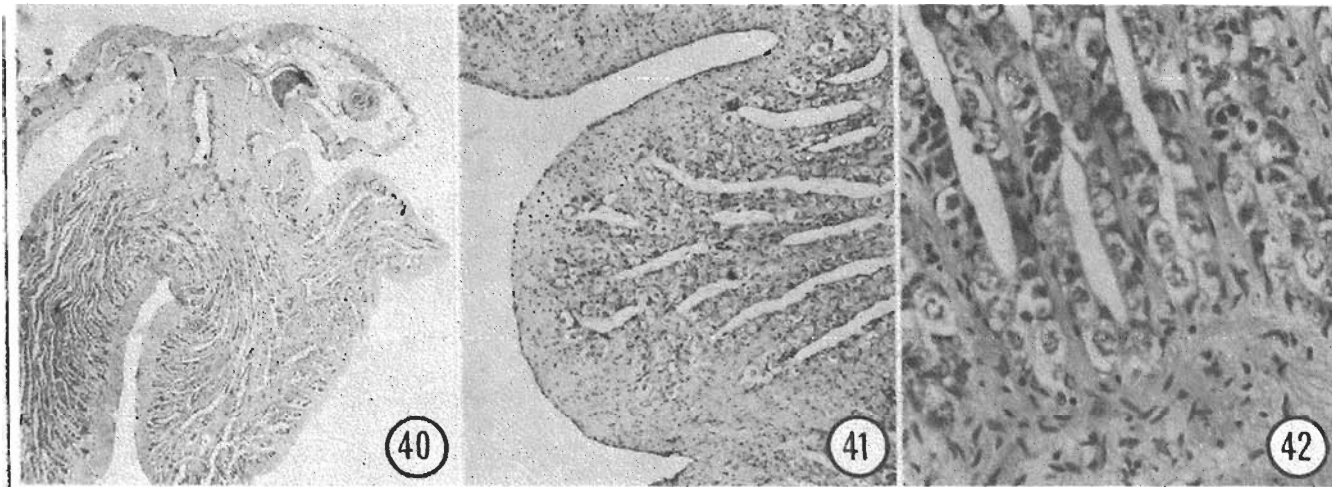
Figures 13–21. Sectioned ovarian tissue from *Cynoscion nebulosus*. 13. Close-up of zona pellucida (= zona radiata) showing periodicity of vertical striations. Note the ooplasm on the inside and the follicular epithelium bounded by theca abutting two oocytes externally. 14. Nearly ripe oocytes from gravid ovary in June with coalescing yolk vesicles forming large, central, yolk and lipid droplet and yolk globules coalescing throughout ooplasm. 15. Oocytes of different gravid fish in June, possibly with atypical or abnormal maturation, showing yolk vesicles coalescing, but vitellogenesis progressing differently than in oocytes in Figure 14 and in other ovaries. Fine yolk globules are abundant near periphery. 16. Nearly ripe oocytes in gravid ovary during August. 17. Ripe and nearly mature oocytes in September as well as spent follicles containing fluid or appearing nearly empty. 18. Portion of large residual mass of spent follicles and unspawned hydrated ova in lumen of spent ovary in September. A leukocytic reaction involves the peripheral area. Note numerous spent follicles occurring in lamellae. 19. A post-spawning residual mass of compacted, hydrated oocytes between lamellae. Note spent follicles in lamellae. 20. A degenerating residuum similar to that in Figure 19 with some vascularization internally. 21. Section from an ovary misdiagnosed as gravid in November because of numerous hydrated, unspent ova within lamellae.



Figures 22–30. Sectioned ovarian tissue from *Cynoscion nebulosus*. 22. Close-up of inflammatory cells invading atretic, unspent ova similar to those shown in Figure 21. 23. A degenerating hydrated ova similar to that in Figures 21–22, but occurring in lumen. 24. Collapsed, spent, follicular epithelial layers adjacent to degenerating ova as well as oocytes in various stages of development during September. 25. Spent fish in July showing inflammatory focus locating spent follicle. 26. Close-up of a different inflamed focus. The space separating ooplasm from nucleoplasm in large, upper oocyte contains vacuolar material rather than representing a fixation artifact. 27. A yolk globule stage oocyte that will probably undergo atresia. 28. A similar oocyte to that shown in Figure 27, but bordering lumen. Note poorly defined zona pellucida and central, fused, yolk globular material associated with relatively small, rather than large, yolk globules. 29. A rare yolk-globule stage oocyte among a variety of stages of oocytes in a spent fish in July. In contrast to the ovaries shown in Figures 27 and 28, this one would probably have produced more mature ova later in the summer. 30. Oocyte that had apparently undergone premature development exhibiting atresia in a developing III fish in April. Note abundant lipid vacuoles at periphery.



Figures 31–39. Sectioned ovarian tissue from *Cynoscion nebulosus*. 31. An oocyte (central large one) of a gravid fish in August undergoing early process of atresia. The zona pellucida is present, but fractured into small pieces. 32. Fragmented zona pellucida in two adjacent well-developed oocytes of small gravid fish in July. Note the small amount of yolk material leaking through fracture. 33. One of several oocytes in same ovary as Figure 32 with yolk material and nucleus that had leaked through fracture. Note invasion into leaked yolk by follicular cells. 34. An atretic oocyte in a more advanced state than that in Figure 31 from a fish nearly ready to spawn. Note the apparent lack of a zona pellucida and follicular investment. 35. A spent ovary in September with several oocytes in advanced stages of atresia. Note debris in lumen. 36. Ovary from a resting stage III fish in August exhibiting high degree of vascularity and absorption of oocytic materials. 37. Close-up of same ovary as in Figure 36 showing absorbed material, apparently proteinaceous and intracellular. Whereas clear-yellowish with numerous minute vacuolar areas suggesting lipid components, this material stains lavender using AFIP method for lipofuscin. Other products of a lipid nature occurred nearby as shown by washed-out vacuoles. 38. An abnormal ovary of a developing III fish in October in which a portion was degenerating. The upper left portion extends into normal-appearing “resting oocytes,” whereas those on the right are degenerate or necrotic, resulting in a hard, stiff ovary. 39. A close-up of degenerating oocytes and associated tissues from ovary shown in Figure 38.



Figures 40–42. Sectioned testicular tissue from *Cynoscion nebulosus*. 40. Low-power view of the branching unrestricted spermatogonial type of testis of maturing virgin, 282 mm SL fish in December showing a lack of active spermatogenesis. 41. Testis of developing III, 325 mm SL fish in January without spermatozoa in tubular lumens. 42. Close-up of testis used for Figure 41 showing stages of spermatocytogenesis in cysts surrounded by Sertoli cells.

temperature and salinity for yolk-sac larvae were 28.0°C and 28.1 ppt, respectively. Arnold et al. (1976) achieved satisfactory hatching of seatrout in 25 to 30 ppt, and Colura (personal communication) found a lower percentage hatched in 14 ppt than in 18 ppt. After hatching occurred, those larvae that hatched in 30 ppt could withstand salinities above 10 ppt. On the other hand, salinity of water where adults live and spawn in Mississippi and elsewhere often drops below 10 ppt, and that salinity presumably determines or influences survival of larvae as well as young juveniles. As with all animals, the quality of food influences growth and survival as does its quantity (Arnold et al. 1976, Taniguchi 1980). Mortalities in rearing facilities seemed to result largely from cannibalism (Arnold et al. 1976, Fable et al. 1978).

Migration

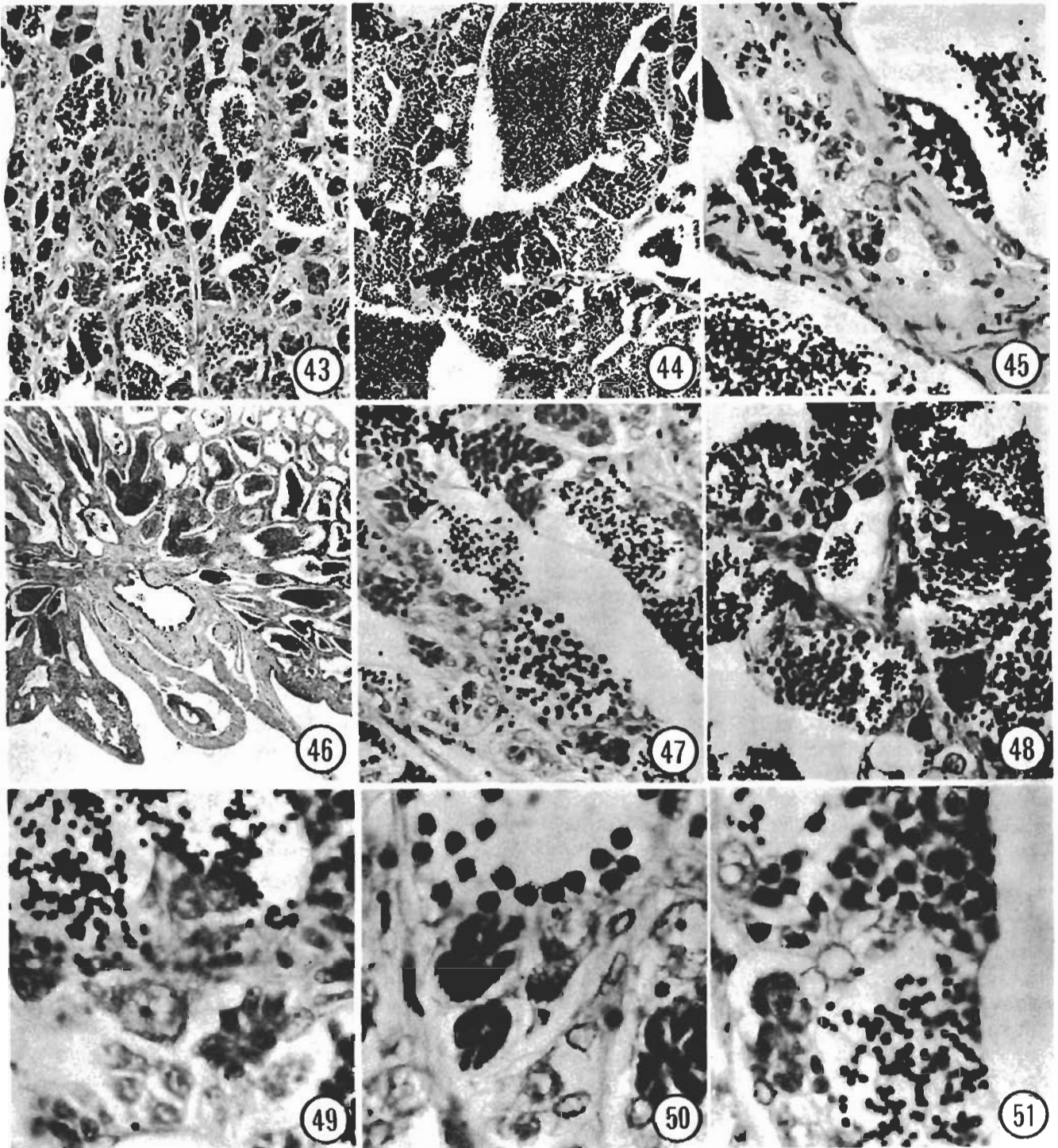
Tagged specimens of *Cynoscion nebulosus* as well as some of the sympatric *C. arenarius* suggest little movement by the two seatrouts within Mississippi Sound. Fourteen tag returns from 133 (10.5%) tagged spotted seatrout consisted of five fish 138 to 416 mm SL caught within a km of their release after 15 to 110 days, two fish 344 and 347 mm long caught there the same day, six fish 137 to 278 mm long that traveled a minimum of 4 to 15 km in 134 to 536 days with the two fish free over a year only 6 and 10 km away, and one fish 262 mm long that was recaptured 25.5 km away after 296 days. A 343 mm fish tagged 18 October 1982, after the 31 December 1981 date when data were no longer included in this report, moved at least 22 km in 23 days.

A relatively small number of specimens was tagged, primarily because abnormal environmental conditions resulted in a near absence of fish during many months; most fish caught were used to obtain data provided elsewhere in this study. I plan additional tagging in the future which, with

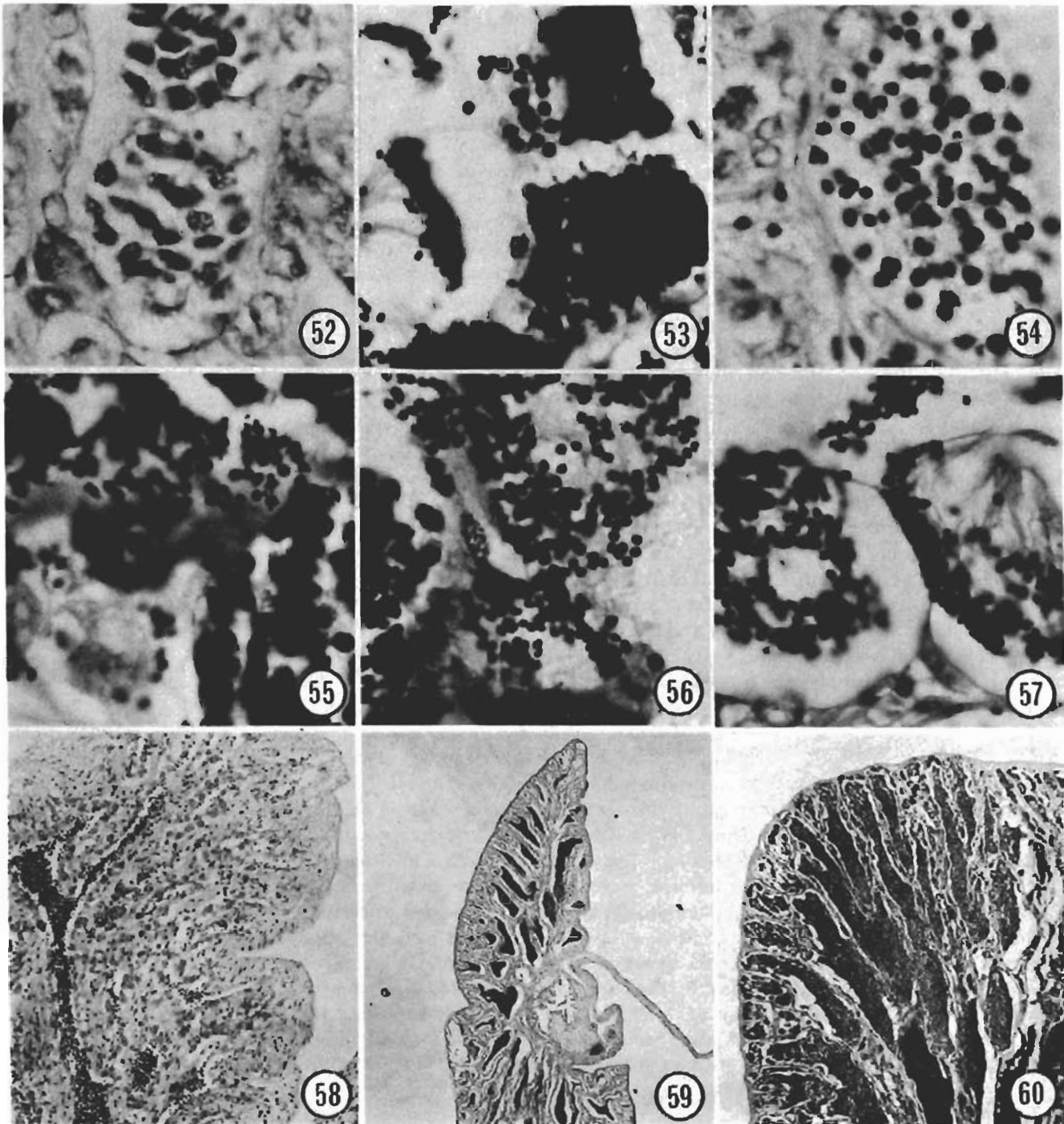
concurrent catch data, should help explain seasonal movements, and I also include below data on *C. arenarius* for comparative purposes. Local people returned tags or data on 12 of 320 (3.8%) tagged specimens of *C. arenarius*. Eight fish 148 to 270 mm SL were caught 1 km or less from where they were tagged and released 3 to 67 days earlier. Three others, 222, 143, and 142 mm SL, moved a minimum of 3, 7, and 12 km, respectively, within the same time frame. Another tag from a sand seatrout was found in the stomach of a spotted seatrout 17 km from where the former fish was tagged 97 days earlier.

Movement within the Mississippi Sound region appears restricted and related to temperature and salinity changes, foraging behavior, and perhaps spawning. The apparent tendency for some individuals to school by sex during their spawning season as described earlier may have been unusual, but the migration is not. Fishermen in Mississippi and adjacent Louisiana recognize seasonal migrations and associate them with seasonal changes in temperature and salinity. Evidence, however, is lacking to support any movement of the stock in the Sound to leave the general area or any immigration of fish from elsewhere. During cold periods, at least many individuals occupy relatively deep holes and channels in the Sound and bayous.

Numerous reports from Florida on tagging and growth suggest the existence of different stocks that seldom moved far (e.g., Iversen and Tabb 1962). Moffett (1961) reported on three stocks and found 95.3% of 470 returns were caught within 48 km of their release. Of the 16 fish that ended up farther than 145 km, four moved at least 388 km and one moved 507 km. Beaumariage (1969) reported on 537 returns and agreed that seatrout rarely moved as far as 32 to 48 km from their site of release. Of 95 returned fish (1.3%) in Louisiana, all but three were captured less than 3 km away



Figures 43–51. Sectioned testicular tissue from *Cynoscion nebulosus*. 43. A developing III fish in March showing active spermatogenesis in the still compact continuous unrestricted spermatogonial testes. Relatively few spermatozoa are being produced during this period. 44. Gravid testis in 419 mm SL fish in May showing lumens of tubules expanded with spermatozoa. 45. Close-up of 455 mm SL fish in September showing spermatogonia and spermatocytes as well as spermatozoa in tubule lumens. 46. A spent, 222 mm SL fish in September with residual spermatozoa abundant in tubule lumens, but nearly absent in spermatic duct. 47. Primarily early stages in developing III fish in March. Note lack of spermatozoa in tubule lumens. 48. Close-up showing all stages of spermatogenesis in cysts from fish that had recently become gravid in May. 49. Primary and secondary spermatogonia among Sertoli cells. 50. Spermatogonia through secondary spermatocytes. 51. Spermatogonia through spermatids.



Figures 52–60. Sectioned testicular tissue from *Cynoscion nebulosus*. 52. Vacuolated spermatocytes. 53. Relatively large primary spermatocytes adjacent to smaller secondary spermatocytes. 54. Secondary spermatocytes undergoing fission to form spermatids. 55. Residual bodies being cast off from spermatids. Some appear to be ingested by Sertoli cells. 56. Leydig cells along basement membrane, with their relatively large basophilic nucleus. Note apparent ingesta in centrally located Sertoli cell. 57. Germinal cysts with spermiogenesis in progress. Note adjacent late secondary spermatocytes in left of field. 58. Testis of a “virgin,” 214 mm SL fish in September showing spermatozoa in tubule lumens. 59. A developing III, 265 mm SL fish in September with spermatozoa primarily in tubule lumens, but some in spermatic duct. 60. A small peripheral portion of testis of 325 mm SL fish still gravid in September.

from where they were tagged; one was caught 40 km away and another occurred in a deep bayou following a cold front (Adkins et al. 1979). In Texas, tagging data collected by Simmons and Breuer, Bryan (1971), and McEachron and Matlock (1980) and summarized in the latter work also do not support long range migration of spotted seatrout. Nevertheless, like in Mississippi and Louisiana, fish appear to be absent from specific areas during specific periods. McEachron and Matlock (1980) speculated that fish move out of Bastrop Bayou in the Galveston Bay system in late autumn, return in early spring, move out again in late spring and return in early autumn. Based on tags from 57 recaptured fish that had been tagged at least 14 days, the average distance the fish were caught from the point of tagging in Bastrop Bayou was 24 km and the maximum was 122 km. Of those returns, 75% came from the Galveston Bay system, and 19% came from shallow Gulf of Mexico sites during summer. Whereas Bryan (1971) noted that 11 of 17 spotted seatrout tagged in Arroyo Colorado (lower Laguna Madre) and free for over 150 days were recaptured within 7 km of their tagging site, if he would have recognized those fish free for over 30 days, he would have noted about 22% of them to be more than 22 km from the site and only about 27% less than 7 km. Simmons and Breuer found that only 5 to 6% of the spotted seatrout tagged during 1950 to 1970 in Galveston, Matagorda, and Aransas bays were recaptured farther than 32.2 km, but that 11 to 16% had moved at least that far in San Antonio Bay, Corpus Christi Bay, and lower Laguna Madre and that 50% reflected the movement in upper Laguna Madre. Moreover, they used Monel jaw tags which usually do not remain in fish as long as abdominal anchor tags used in later efforts.

Parasites, Diseases, Mortalities, and Abnormal Conditions

Only representative fish underwent a critical examination for parasites. In some cases, fish during specific periods were examined for specific parasites (e.g., Overstreet 1977, Dardorff and Overstreet 1981), and in others conspicuous parasites were noted. Nevertheless, records of those occasional parasites encountered in or on *C. nebulosus* plus those infecting the related *C. arenarius* occur in Table 20 along with numerous other records obtained from the literature. For some, but not all, records where misidentifications are suspected or where "group names" are used, the name has been placed between quotation marks. A group name applies to similar-appearing larvae that when mature can be separated into more than one species, the identifications of which are not presently known.

Not on the list are a variety of microbial symbionts, some of which are pathogenic or potentially pathogenic if given the proper set of conditions. I have seen the viral disease lymphocystis on both *C. nebulosus* and *C. arenarius* in Mississippi Sound. Infecting connective tissue cells in the fins and body proper, the virions of lymphocystis disease cause hypertrophy, resulting in readily visible masses of hyaline-

encapsulated cells (Howse and Christmas 1970). Cell lines cultured from both *C. nebulosus* and *C. arenarius* support replication of the lymphocystis organisms (Middlebrooks et al. 1979, 1981). Presence of the disease in nature may indicate or help identify a polluted environment (Edwards and Overstreet 1976, Overstreet and Howse 1977, Sindermann 1979).

Several species of bacteria probably always occur on or in seatrout in their natural habitats. Whereas most species have no detrimental effect on the host, some cause disease or secondary infections, and others can cause disease in man if he eats the product inadequately prepared. Keel and Cook (1975) detected *Vibrio parahaemolyticus*, an agent of food poisoning, in oyster, shrimp, and fish samples in Mississippi, and it probably occurs in seatrout. The spotted seatrout has a predisposition for "fin rot syndrome," a term for certain nonspecific lesions (Overstreet and Howse 1977, Sindermann 1979). In those fishes examined in Mississippi, which included more than the spotted seatrout, pseudomonads, vibrios, and occasionally aeromonads occurred in affected individuals (Overstreet and Howse 1977). Adkins et al. (1979) reported that seatrout from a kill associated with low temperatures in February 1978 had lesions and abrasions contaminated with fungi and bacteria. Bacterial diseases probably have a great impact on egg and larval stages. As evidence, Shelbourne (1964) noted improved hatching and survival of larvae of another species concurrent with use of antibiotics or a combination of antibiotics and irrigation with ultraviolet-treated seawater.

Algae occasionally cause infections or disease in animals. Reports of their presence in fishes are uncommon (Edwards 1978) and in marine fishes are rare (Blasiola and Turnier 1979). In one case on 5 March 1973, a unicellular alga occurred in the flesh of a 428 mm SL female specimen of *C. nebulosus* caught off Front Beach, Ocean Springs. The agent fluoresced red; not restricted to a specific site, it occurred next to the integument, throughout the flesh, and adjacent to the vertebral column (Figures 61-62).

In addition to certain microbial infections, some protozoan and metazoan infections can also harm and even kill the seatrout hosts as well as allow secondary infections. Some affect larvae or juveniles, whereas others affect adults. Some only harm their hosts seasonally or when maintained in crowded conditions such as occur in aquaculture. Adkins et al. (1979) reported that a protozoan on the gills caused disease during a period of prolonged low temperature which allowed the seatrout to become more susceptible to fungal and bacterial infections. Many of those fish died and washed ashore.

Most parasites that kill or severely harm their hosts in nature have been observed or recognized only rarely because when a fish dies or becomes weakened, a predator or scavenger rapidly eats it. Rosenthal (1967) showed that larval hering reared with wild plankton became infected with the

TABLE 20.
Partial list of parasites from *Cynoscion nebulosus* and *C. arenarius*.

| Parasite | Cn | Ca | Site | Geographical locality | Reference |
|---|----|----|---------------------------------|--|--|
| Sarcostomata | | | | | |
| Dinoflagellida | | | | | |
| <i>Amyloodinium ocellatum</i> (Brown 1931) | X | | Gills | Mississippi | Lawler (1980) |
| | | X | | Mississippi | Present study |
| | X | X | | Experimental infection | Lawler (1980) |
| Apicomplexa | | | | | |
| Coccidia | | | | | |
| <i>Haemogregarina</i> sp. | X | | Leucocytes | Lemon Bay, FL | Saunders (1954) |
| Microsporida | | | | | |
| <i>Pleistophora</i> sp. | X | X | Liver | Mississippi | Present study |
| Myxozoa | | | | | |
| Myxosporea | | | | | |
| <i>Kudoa</i> sp. | | X | Muscle tissue | Mississippi | Present study |
| <i>Henneguya</i> sp. | X | X | Dorsal and caudal fins | Mississippi | Overstreet (1978), Present study |
| Ciliophora | | | | | |
| Peritrichia | | | | | |
| ? <i>Trichodina</i> sp. | X | X | Gills | Mississippi | Present study |
| Cestoda | | | | | |
| Tetraphyllidea | | | | | |
| " <i>Scolex polymorphus</i> " | X | | Cystic duct, intestine | Beaufort, NC | Linton (1905) |
| | X | X | Cystic duct, intestine | Mississippi, Louisiana | Present study |
| " <i>Scolex</i> sp., type small" | X | X | Intestine, rectum | Mississippi, Louisiana | Present study |
| " <i>Scolex</i> spp., type large" | X | X | Pyloric ceca, intestine, rectum | Mississippi, Louisiana | Present study |
| <i>Rhinebothrium</i> sp. | | X | Intestine | Mississippi | Present study |
| Tetrahynchea | | | | | |
| <i>Poecilancistrum caryophyllum</i> (Diesing 1950) metacestode (some ref. as <i>P. robustum</i>) | X | | Muscle | Texas | Chandler (1935), Schlicht and McFarland (1967) |
| | | | | Florida | Hutton and Sogandares-Bernal (1960), Goldstein (1963), Hutton (1964) |
| | | | | Louisiana | Boertje (1976), Adkins et al. (1979) |
| | X | X | | Texas, Louisiana, Mississippi, Florida | Overstreet (1977, 1978) |
| <i>Nybelinia bisulcata</i> (Linton 1889) (as <i>Tetrahynchus b.</i>) metacestode | X | | Stomach wall | Beaufort, NC | Linton (1905) |
| <i>Nybelinia</i> sp. metacestode | | X | Stomach wall | Mississippi | Present study |
| <i>Otobothrium crenacolle</i> Linton 1890 | X | | Submucosa of stomach | Beaufort, NC | Linton (1905) |
| | X | X | Mesentery | Mississippi | Present study |
| " <i>Rhynchobothrium</i> sp." | X | | On viscera | Beaufort, NC | Linton (1905) |
| Tetrahynchea sp. metacestode | X | | Muscle | Mississippi, Louisiana | Overstreet (1977) |
| Monogenea | | | | | |
| Diclidophoridae | | | | | |
| <i>Neoheterobothrium cynoscioni</i> (MacCallum 1917) (as <i>Choriocotyle reynoldsi</i>) (as <i>Choriocotyle c.</i>) | X | | Gills | Norfolk, VA | Frayne (1943) |
| | X | O | Gills | Alligator Harbor, FL; Grand Isle, LA | Hargis (1955b), Thatcher (1959) |
| | X | X | Mouth, gills, skin | Mississippi | Present study |
| Diplectanidae | | | | | |
| <i>Diplectanum bilobatum</i> Hargis 1955 | X | | Gills | Alligator Harbor, FL; Grand Isle, LA | Hargis (1955a) |
| | X | | | Grand Isle, LA | Thatcher (1959) |
| | X | | Gills | Mississippi | Present study |

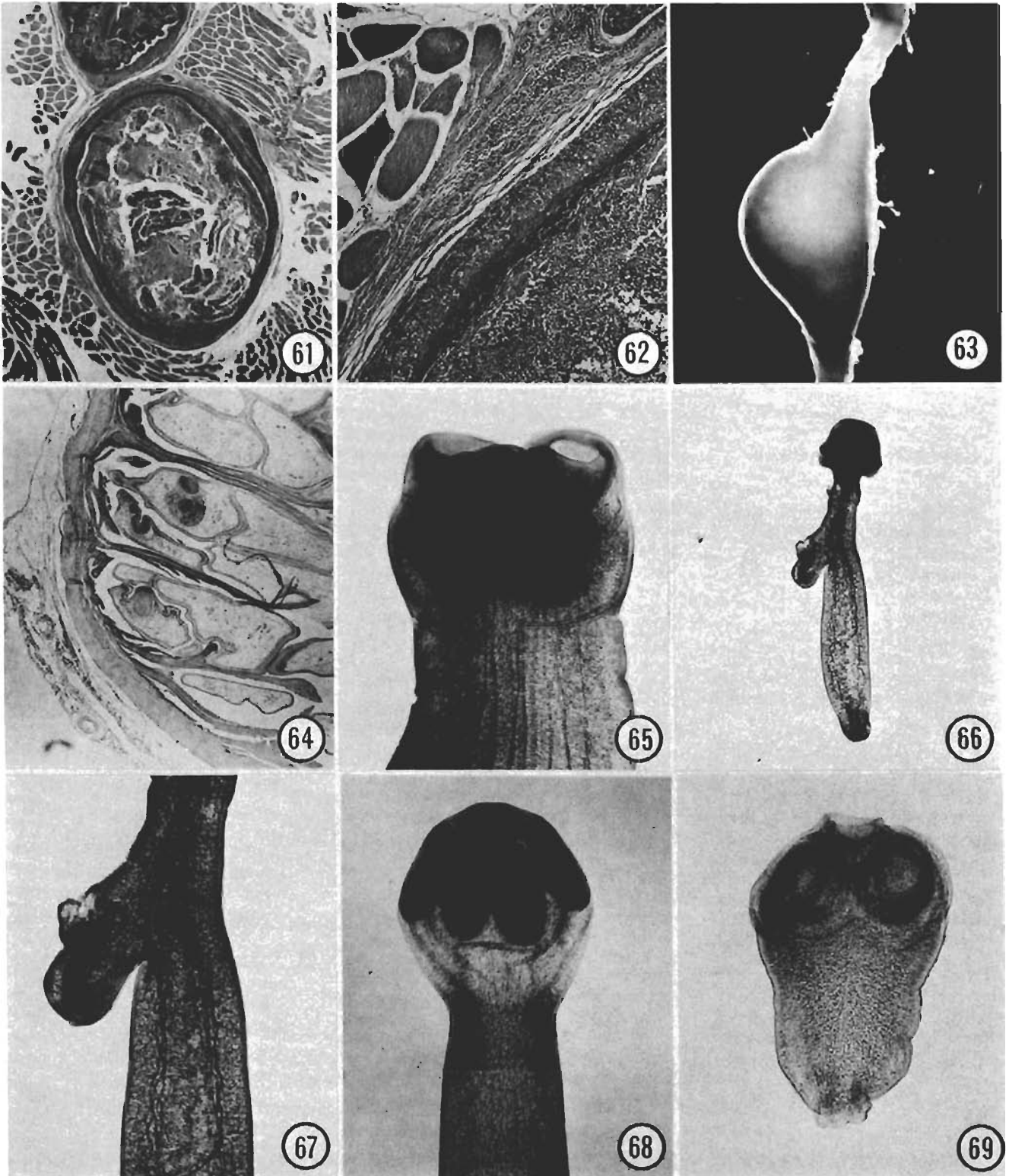
TABLE 20 (Continued)
 Partial list of parasites from *Cynoscion nebulosus* and *C. arenarius*.

| Parasite | Cn | Ca | Site | Geographical locality | Reference |
|--|----|----|--|---|---|
| Microcotylidae | | | | | |
| <i>Cynoscionicola heteracantha</i> (Manter 1938) | X | | Gills | Beaufort, NC | Linton (1905), Manter (1938) |
| (some ref. as <i>Microcotyle h.</i>) | X | | Gills | Alligator Harbor, FL | Hargis (1956) |
| | X | | Gills | Grand Isle, LA | Thatcher (1959) |
| | X | | Gills | Mississippi | Present study |
| Udonellidae | | | | | |
| <i>Udonella caligorum</i> Johnston 1835 | X | | Mouth and skin, typically on <i>Caligus praetextus</i> | Mississippi Sound | Overstreet (in press), Present study |
| spoiled monogeneans | X | X | | Port Aransas, TX | Koratha (1955) |
| Digenea | | | | | |
| Acanthocolpidae | | | | | |
| <i>Stephanostomum interruptum</i> Sparks and Thatcher 1958 | X | | Intestine | Grand Isle, LA and Port Aransas, TX | Sparks (1958), Sparks and Thatcher (1958) |
| | X | X | Intestine | Alligator Harbor, FL | Nahhas and Short (1965) |
| | X | X | Intestine, rectum | Mississippi | Present study |
| <i>Stephanostomum imparispine</i> (Linton 1905) | X | | | South Carolina? | Lawler (1978) |
| " <i>Stephanostomum tenue</i> " | X | | | North Carolina | Linton (1905) |
| <i>Stephanostomum</i> sp. metacercaria (as <i>S. valde - inflatum</i>) | X | | Cysts on viscera | Beaufort, NC | Linton (1905) |
| Aporocotylidae | | | | | |
| <i>Cardicola laruei</i> Short 1953 | X | X | Heart | Alligator Harbor; St. George Island, FL | Short (1953), Nahhas and Short (1965) |
| Bucephalidae | | | | | |
| <i>Bucephalus cynoscion</i> Hopkins 1956 | X | | | Grand Isle, LA | Hopkins (1956) |
| | X | X | | | Sparks (1958) |
| | X | X | Pyloric ceca, intestine, rectum | Barataria Bay, LA; Mississippi | Corkum (1967), Present study |
| <i>Bucephaloides caecorum</i> Hopkins 1956 | X | | Pyloric ceca | Grand Isle, LA | Hopkins (1956), Sparks (1958) |
| | X | | Pyloric ceca, upper intestine | Barataria Bay, LA; Mississippi | Corkum (1968) |
| | | X | | Galveston Bay, TX | Sparks (1960) |
| | X | X | Pyloric ceca, intestine | Mississippi | Present study |
| Cryptogonimidae | | | | | |
| <i>Metadena spectanda</i> Travassos, Freitas, and Bührnheim, 1967 metacercaria | | X | Fins, flesh | Mississippi | Present study |
| Didymozoidae | | | | | |
| Metacercaria | X | X | Stomach | Mississippi | Present study |
| Diplostomidae | | | | | |
| <i>Posthodiplostomum minimum</i> (MacCallum 1921) metacercaria | | X | | Louisiana | Arnold et al. (1967) |
| Gorgoderidae | | | | | |
| <i>Phyllodistomum</i> sp. | | X | Urinary bladder | Mississippi Sound | Present study |
| Hemiuridae | | | | | |
| " <i>Lecithochirium monticelli</i> " | X | | Intestine | North Carolina | Linton (1905) |
| <i>Lecithochirium</i> sp. | X | X | Stomach | Mississippi | Present study |
| <i>Parahemiurus merus</i> (Linton 1910) | X | | Stomach | Alligator Harbor, FL | Nahhas and Short (1965) |
| <i>Stomachicola rubea</i> (Linton 1910) | X | | | Sapelo Island, GA | Sinclair, Smith, and Sullivan (1972) |
| <i>Stomachicola magna</i> (Manter 1931) (as <i>Tubulovesicula</i> sp.) | X | | Stomach, air bladder | North Carolina | Manter (1931) |
| | X | X | Beneath ovarian membrane, in body muscles | Alligator Harbor, FL | Loftin (1960), Nahhas and Short (1965) |
| | X | X | Body cavity, muscles, stomach wall | Mississippi | Present study |
| Immature hemiurids | X | | | Grand Isle, LA | Sparks (1958) |

TABLE 20 (Continued)
 Partial list of parasites from *Cynoscion nebulosus* and *C. arenarius*.

| Parasite | Cn | Ca | Site | Geographical locality | Reference |
|---|----|----|-------------------------|--|---|
| Hirudinellidae | | | | | |
| <i>Hirudinella ventricosa</i> (Pallas 1774) metacercaria | | X | Body cavity | Round Island, Mississippi Sound | Present study |
| Pleorchiidae | | | | | |
| <i>Pleorchis americanus</i> Lühe 1906 | X | X | Intestine | West coast of Florida | Sogandares-Bernal and Hutton (1959), Hutton and Sogandares- Bernal (1960), Loftin (1960), Hutton (1964), Nahhas and Short (1965), Nahhas and Powell (1971) |
| | | X | | Grand Isle, LA | Sparks (1958) |
| | X | X | Intestine, pyloric ceca | Mississippi, Louisiana | Present study |
| Nematoda | | | | | |
| Anisakidae | | | | | |
| ? <i>Hysterothylacium reliquens</i> (Norris and Overstreet 1975) larva | X | X | Mesentery | Mississippi | Deardorff and Overstreet (1981) |
| <i>Hysterothylacium</i> type MB larva | X | X | Mesentery | Mississippi Sound, Gulf of Mexico | Deardorff and Overstreet (1981) |
| <i>Hysterothylacium</i> type MD larva | X | | Mesentery | Mississippi | Deardorff and Overstreet (1981) |
| " <i>Ascaris</i> sp." larva | X | | On viscera, mesentery | North Carolina | Linton (1905) |
| Camallanidae | | | | | |
| <i>Spirocamallanus ericotus</i> Fusco and Overstreet 1978 | X | X | Intestine | Mississippi | Present study |
| Philometridae | | | | | |
| Undescribed Philometrinae | X | | Encapsulated in mouth | Mississippi | Present study |
| Incertae sedis | | | | | |
| " <i>Agamonema</i> sp." | | X | | Louisiana | Arnold et al. (1967) |
| Annelida | | | | | |
| Hirudinea | | | | | |
| <i>Malmiana philotherma</i> Sawyer, Lawler, and Overstreet 1975 | | O | Gills | Mississippi | Present study |
| Copepoda | | | | | |
| Anthosomidae | | | | | |
| <i>Lernanthropus gisleri</i> van Beneden 1852 | X | | Gills | Grand Isle, LA; Port Aransas, TX; Tuxpan, Mexico | Causey (1953a, 1953b) |
| | | | | West Florida | Bere (1936) |
| | | | | Texas | Pearse (1952) |
| <i>Lernanthropus pomatomi</i> Rathbun 1887 | X | | Gills | Texas | Causey (1953b) |
| <i>Lernanthropus pupa</i> Burmeister 1833 | X | | Gills | Texas | Causey (1953b) |
| Caligidae | | | | | |
| <i>Caligus bonito</i> Wilson 1905 | | X | | Laguna Madre, TX | Simmons (1957) |
| <i>Caligus praetextus</i> Bere 1936 | | X | Gills | Texas | Causey (1953b), Present study |
| <i>Caligus rapax</i> Edwards 1840 (as <i>C. repax</i>) | | X | X | Laguna Madre, TX | Simmons (1957) |
| <i>Caligus sciaenops</i> Pearse 1952 | | X | Roof of mouth | Texas | Pearse (1952) |
| <i>Caligus</i> sp. larva | | X | Usually dorsum | East Florida (laboratory) | Houde (1972) |
| Pseudocynidae | | | | | |
| <i>Cybicola elongata</i> Pearse 1951 | | X | | Texas | Pearse (1952) |
| Branchiura | | | | | |
| <i>Argulus alosae</i> Gould 1841 | | X | Mouth, gills | Mississippi | Cressey (1978), Present study |
| Isopoda | | | | | |
| Cymothoidae | | | | | |
| <i>Cymothoa excisa</i> Perty 1834 | | | O | Gill arches | Grand Isle, LA |
| <i>Nerocila acuminata</i> Schioedte and Meinert 1910 | | | | | Comeaux (1942) |
| <i>Lironeca ovalis</i> (Say 1818) | | X | Gills | Texas | Pearson (1929) |
| | | X | Gills | Mississippi | Present study |
| <i>Cymothoa exigua</i> Schioedte and Meinert 1884 | | X | Gill arches | Grand Isle, LA | Comeaux (1942) |

Cn = *Cynoscion nebulosus*; Ca = *Cynoscion arenarius*; O = *Cynoscion nothus*.



Figures 61–62. Alga in muscle tissue of *Cynoscion nebulosus*. 61. Low-power view showing relative lack of a widespread associated inflammatory reaction. 62. Close-up of alga showing relationship with muscle tissue.

Figures 63–69. Cestodes in seatrouts. 63. Cystic duct of *Cynoscion nebulosus* expanded with apparently harmless infection of “*Scolex polymorphus*.” 64. Cross-section through cystic duct showing a few of the numerous metacystodes of “*Scolex polymorphus*.” 65. Scolex of “normal,” 1.35 mm long specimen of “*Scolex polymorphus*” to show its “polymorphic” character. 66. Specimen of 1.32 mm long “*Scolex*

larval stage of an ascaridoid nematode, tetraphyllidean cestode, lernaecoid copepod, and *Caligus rapax*. He estimated that those larval parasites, primarily the nematode and lernaecoid, killed about 10% of the actively feeding fish; related parasitic species infect the seatrout (Table 20). When Houde (1972, personal communication) fed wild plankton to larval *C. nebulosus*, the fish became infested with the chalimus stage of *Caligus* sp. which usually attached to the dorsum near the developing dorsal fin, but occasionally elsewhere. Houde noted that a single copepod could kill a Spanish sardine or bay anchovy when the fish was less than about 12 mm long. Fisheries personnel at GCRL have noted numerous specimens of larval, postlarval, and juvenile sciaenid fishes from Mississippi Sound and the northern Gulf of Mexico that have caligid larvae attached.

The most conspicuous external metazoan parasite of seatrouts in Mississippi is the isopod *Lironeca ovalis*. It can destroy a large amount of gill filament (e.g., Overstreet 1983). In fact, it may be responsible for mortalities, especially of juveniles. Pearson (1929) suggested that many such fish among young age-group fish may be "runt" or "constitutionally slow-growing fish during the early years of life, but which are eliminated from the fish stock gradually. . ." He went on to suggest that *L. ovalis*, which commonly occurred on *C. nebulosus* during its first two years, but seldom on older individuals, caused the infested fish to be shorter than uninfested counterparts in their own year classes. In Mississippi, individuals of *C. nebulosus* between 10 and 17 cm long from November through May commonly hosted one or two specimens of the parasite. As noted in Texas by Pearson, larger fish in Mississippi rarely had an infestation.

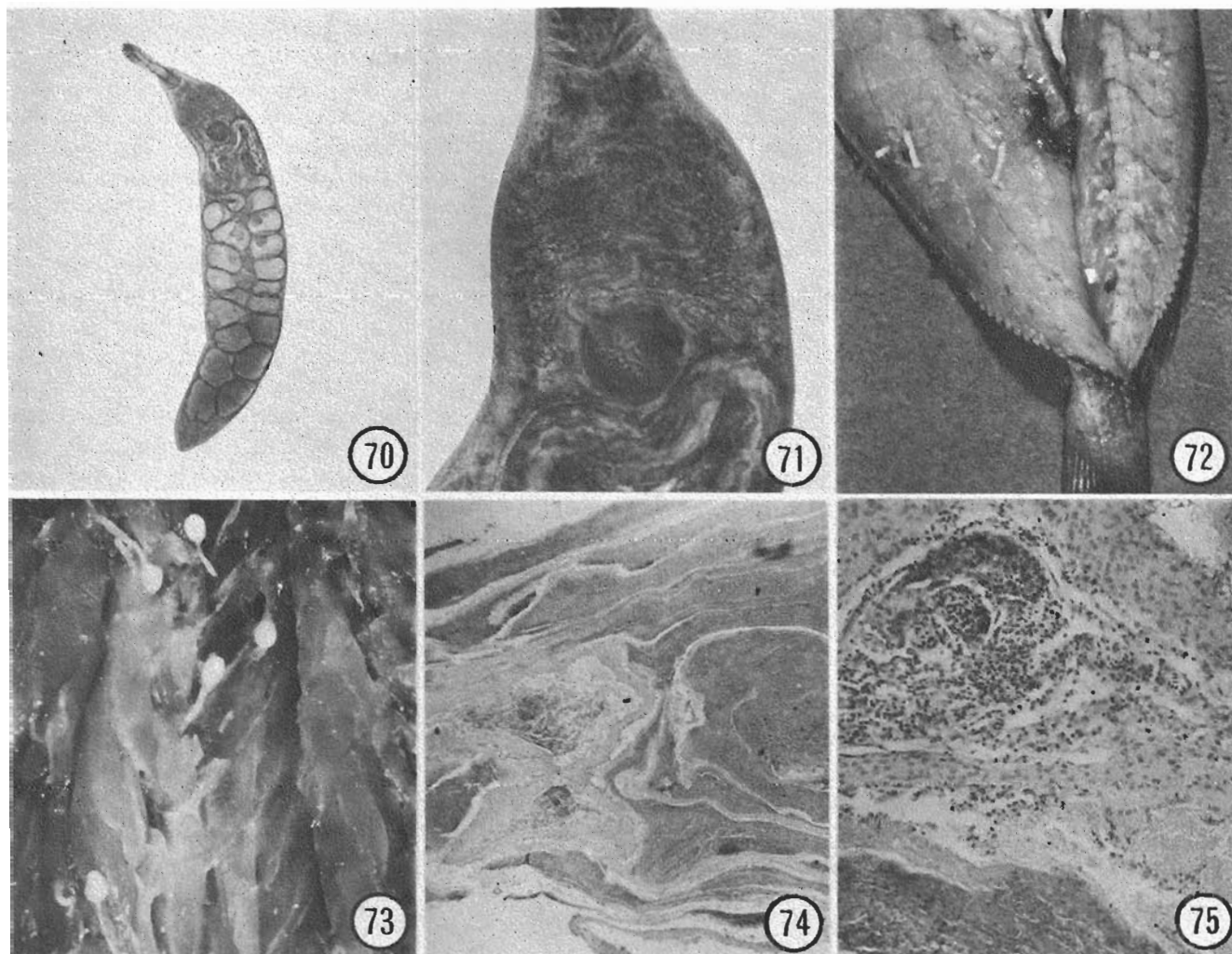
When crowded in aquacultural conditions, the seatrouts, as well as other fishes, become vulnerable to more diseases than in their natural environment. For those fish in ponds and closed systems where parasites are not continually introduced, parasites and disease-causing agents with direct life cycles cause the most harm. Bacterial diseases in reared seatrout were discussed previously. Over 90% of the spotted seatrout captured by gill net or trammel net and maintained in a pond died within 24 hr. Those that survived 30 days exhibited extensive bacterial infections (Elam 1971). When microbial diseases cause mortality of previously-unstressed fish, the deaths can usually be attributed indirectly to poor water quality. Parasites with direct cycles that cause disease in cultured seatrout include *Amyloodinium ocellatum*, peritrich ciliates, and monogeneans. Of these, the dinoflagellate *A. ocellatum* is the hardest to treat with chemicals. Lawler (1980) introduced a 160 mm TL uninfested fish into an in-

festated system, and it died in 42 hours with from 20 to 50 dinoflagellates per filament.

All parasites do not harm the seatrouts. In fact, most well-adapted parasites would reduce their potential for survival, if as individuals or populations they killed their hosts. A good example of what appears to be a harmless parasite is "*Scolex polymorphus*," a phyllobothriid tetraphyllidean metacestode that occurs in large numbers, sometimes hundreds, within the cystic duct and occasionally in the gall bladder and intestine of its host. Curtis (1911) showed inconclusively that the same or a similar species in *C. regalis*, identifiable as *Phoreiobothrium trilocolatum* Linton 1901, developed to maturity in the sand shark. The diameter of the cystic duct can be enlarged several times and packed with the parasite (Figures 63–67), but metabolism appears normal: food in the intestine of infected hosts appeared in a normal state of digestion, and condition coefficients of infected fish appeared "normal." The metacestode stage may be especially unusual in that it may undergo asexual budding, unknown for metacestodes other than the tetrathyridium stage of at least *Mesocestoides corti* Høepli 1925 in its second intermediate host (see Voge 1969). I have seen what appears to be more advanced cases of budding in the same or a related cestode from the cystic duct of other fishes. Several small larval helminths occurred in both seatrouts in small numbers that have no adverse effect on their hosts (Figures 68–71).

The metacestode stage of the tetrarhynchean *Poecilancistrum caryophyllum* in the musculature of the spotted seatrout (Figures 72–73) and several other sciaenids does not affect the condition coefficient of adult fish hosts (Overstreet 1977). A possibility exists that if a young fish less than 140 mm SL becomes infected, it dies. Whether this occurs or whether the apparent absence of infection in these small fish can be explained by these fish being spatially or temporally isolated from the preceding infective host remains to be determined. Overstreet (1977) provided data indicating that infected fish larger than 140 mm acquire an immunological response to challenge infections. Consequently, nearly all infected fish smaller than 400 mm in Mississippi had about two worms, whereas those longer had a wide range, but still averaged about 2.5 worms per infected fish. The prevalence gradually increased with increase in fish-length to 100% of fish 50 cm long. In regions of higher salinity such as Apalachee Bay, Florida, and during years with higher than normal salinity, the prevalence and intensity of infections of this parasite which matures exclusively in specific sharks were greater, presumably relating to the availability of infected intermediate hosts.

polymorphus" from cystic duct of *Cynoscion arenarius* showing initial stage of budding. 67. Close-up of specimen in Figure 66 to show that the excretory system of worm-proper is not involved with bulging portion. 68. Scolex of 4.24 mm long "Scolex sp., type large" from pyloric ceca of *Cynoscion arenarius* under slight pressure. Two septa occur in each bothridia. 69. "Scolex sp., type small," 370 μ m contracted specimen from intestine of *Cynoscion arenarius*.



Figures 70–75. Helminths and lesions in seatrouts. 70. Didymozoid digenean metacercaria, unencysted in lumen of stomach of *Cynoscion nebulosus* from Marsh Point, Ocean Springs. The adult probably occurs encysted in an offshore pelagic fish that feeds on the seatrout. 71. Close-up of digenean in Figure 70 showing characteristic muscular “stomach,” winding esophagus, and glandular forebody. 72. Flesh of *Cynoscion nebulosus* cut from vertebral column showing two metacystodes of *Poecilancistrum caryophyllum*. 73. Close-up of metacystodes of *Poecilancistrum caryophyllum* showing long tubes and bulbous portion enclosing scolex (from Overstreet 1977). 74. Lesion in caudal peduncle of *Cynoscion arenarius*, possibly resulting from injury or degenerated *Stomachicola magna*. Grossly, the lesion appeared as a 1.5 cm confined, chocolate-brownish, soft region. 75. Close-up of lesion in Figure 74. Lesions from predators, fishermen, parasites, and unknown causes occur occasionally in all species of *Cynoscion*.

These few specimens per fish of *P. caryophyllum*, a parasite that does not harm humans, even if eaten raw, result in large numbers of fish being uneaten or discarded. Guest and Gunter (1958), Overstreet (1978), and others discussed the economic loss attributed to infected fish. To better understand which category of people exhibit disgust, I developed a questionnaire for people attending Ocean Springs’ and Biloxi’s fishing rodeos; local, annual, weekend events sponsored by a young men’s organization. Registered fishermen try to catch the largest specimen of a variety of species, and they along with other interested people enjoy food, music, exhibits of fish, and contests of skill and luck.

Nonfishermen answering the questionnaire exhibited more disgust about infections than fishermen. When ques-

tioned directly or indirectly about “wormy trout,” most either were unaware or repulsed by them. Numerous seafood consumers have called GCRL to inquire about the edibility of such fish. Many of these informed people still will not eat infected fish regardless of the harmless nature of the worm. Of 121 questioned fishermen who caught from 30 to over 2,000 individual spotted seatrout per year, 43.8% saw the cestode and did not mind eating infected fish, but some culled the worms. More surprising to me, 24.8% of those fishermen regularly caught infected fish, knew that the fish were infected, and would not eat them. The remaining 31.4% showed no awareness that seatrout had worms, either because they did not fillet the fish or because they assumed the worms were fascia, nerves, or other tissues of the fish. Of the

fishermen who caught fewer than 30 specimens of seatrout per year, some said they did not fish specifically for seatrout because of their worms.

Another parasite that inspires consumer inquiries is *Stomachicola magna*. This hemiurid digenean occurs encapsulated or wandering in the peritoneum, flesh, or viscera. Often surrounded by dark-colored "melanin" pigment which attracts the consumer's eye, this up to 14 mm-long, pinkish-colored worm, with or without eggs, moves if removed from the capsule. A greater prevalence and intensity of infection occurred in *Cynoscion arenarius* than in *C. nebulosus*, but several fishes host this worm (Sinclair et al. 1972, Corkum 1966). No evidence suggests that it can infect or harm man. In fact, no parasite in properly cooked fish can harm people.

A few potential public health problems exist. Disease would probably develop only in those who ate inadequately prepared seatrout or who ate products from an especially polluted area. The seatrout contained at least one nematode, *Hysterothylacium* type MB larva, that can cause mucosal hemorrhaging and focal eosinophilia in the rhesus monkey, white mouse, and probably man (Overstreet and Meyer 1981). Also, the bacterium *Vibrio parahaemolyticus* and probably a few other microbial organisms can cause human disease if contaminated fish are eaten when inadequately prepared. High levels of toxic heavy metals and organic pollutants may cause human health problems, if both fish and consumer concentrate enough of the contaminant.

The parasites of seatrouts deserve considerably more attention than they have received. Many more species than listed in Table 20 probably occur. For example, the myxosporans *Sinuolinea dimorpha* (Davis 1916) in the urinary bladder and ureters and *Myxidium glutinosum* Davis 1917 in the gall bladder commonly occur in *C. regalis* in North Carolina (Davis 1917), and these or related species probably infect seatrouts in Mississippi. No critical examination of seatrouts for those or other protozoans was made, and, of those listed (Table 20), most are undescribed species. The microsporidian *Pleistophora* sp. in small cysts within the liver may be conspecific with the organism occurring also in Mississippi in *Bairdiella chrysoura* (Lacépède), *Micropogonias undulatus* (Linnaeus), *Pogonias cromis* (Linnaeus), *Sciaenops ocellatus* (Linnaeus), *Menticirrhus americanus* (Linnaeus), and *Leiostomus xanthurus* Lacépède. There may be more than one species in those sciaenids, and one or more of those species may appear morphologically different in different hosts.

Some helminths are definitely undescribed, such as the philometrid. The female of this species occurs encapsulated in the mouth. A few species, such as *Phyllodistomum* sp., were rare. That gorgoderid occurred in two fish, and the specimens did not have eggs fully enough developed to confirm whether the species was conspecific with *P. trinectes* Corkum 1961 which infects the sympatric *Trinectes macu-*

latus (Bloch and Schneider). Adults that correspond with the several listed immature forms need to be determined. Also, some species may be synonyms of others. Sinclair et al. (1972) and Stunkard (1980) considered *Stomachicola magna* as a junior synonym of *S. rubea*, a decision which needs confirmation. Also, whether *Cynoscionicola pseudoheteracantha* (Hargis 1955) from *C. nothus* (possibly *C. arenarius*, see Hargis 1956) is a junior synonym of *C. heteracantha* needs to be established. Since monogeneans usually exhibit a great deal of host-specificity, this question would aid in better understanding the seatrout relationships.

A few abnormalities have been reported in the spotted seatrout. Most affected fish probably become prey before their schoolmates, not surviving long. Examples of anomalous fish include at least two fish with a pug-headed condition (Rose and Harris 1968, Hein and Shepard 1980) and one with lordosis (Burgess and Schwartz 1975). Fish occasionally also have unexplainable internal lesions (Figures 74–75). Perhaps such conditions and lesions develop from surviving an attack from a predator, from obtaining inadequate diets, from degenerating parasites, as well as from surviving congenital developments; most individuals of the cestode *P. caryophyllum* probably live in the seatrout at least 3 years before degenerating (Overstreet 1977). Some lesions are known to result from parasites (RTLA-1726, Smithsonian Institution). Neoplasms are not reported from *C. nebulosus*, but probably occur on occasion; a possible lipoma has been described from *C. regalis* (see Tubiash and Hendricks 1973), and a similar noninvasive one has been collected by John Couch (Environmental Protection Agency, personal communication) in the body cavity of *C. nebulosus* from Pensacola Bay, Florida.

Mortalities and life-threatening situations involving seatrouts in addition to those resulting from biological agents often result from environmental conditions. The spotted seatrout takes less time to equilibrate to unfavorable environmental conditions than some other fishes and exhibits considerable tolerance to some chemicals. Compared to *C. arenarius*, *C. nebulosus* has a higher metabolic rate at 15°C, and that rate does not increase when the fish is transferred from 25 to 30°C (Vetter 1977, 1982). On the other hand, large numbers of the seatrout die periodically from low temperature. Adkins et al. (1979) reported dead and stunned seatrout in Louisiana in January 1977 and February 1978, and Gunter (1952) reviewed numerous cases in Texas. Gunter (1941) estimated a 77.6% decline in fisheries catch of seatrout 3 months after a freeze. Moore (1976), working near Redfish Bay and Port Aransas, Texas, noted that both large and small *C. nebulosus* became moribund at temperatures of 4°C and had restricted swimming at 7°C. The latter, but not those at 4.0 and 4.5°C, could recover if warmed to 10°C over an 8 hr period. In Florida, Tabb (1958) noted that seatrout recover from being immobilized by cold for short periods, but do not recover from exposure to 7°C for 24 hr.

The rate of temperature reduction and salinity concentration probably both influence the tolerance of seatrout to low temperature (Overstreet 1974). When metabolic rates were tested at 28°C, the optimal salinity was about 20 ppt in South Texas (Wohlschlag and Wakeman 1978). Maximum sustained swimming speeds also occurred at 20 or 25 ppt (Wakeman and Wohlschlag 1977). If possible, the species usually moves into deep water or channels as harsh conditions develop (Guest and Gunter 1958, personal observations). The ability of *C. nebulosus* to control its metabolic rate within a narrower range in response to seasonal temperature changes than does *C. arenarius* and presumably *C. nothus* is probably a major factor in determining distribution of the three species (Vetter 1982).

Larvae of seatrout, just like those of most fishes, cannot withstand rapid temperature or salinity changes. When the temperature in Texas ponds increased from 25 to 34°C in 3.5 hr, apparently nearly all fish died (Colura et al. 1976). Another problem of high temperatures involves supersaturation of gases, especially nitrogen. Seatrout exposed to such conditions developed exophthalmia and died (Parker et al. 1978). Consequently, eliminating such conditions should be considered when power plants are designed so that they could accommodate aquaculture facilities. Also, most larvae died when dissolved oxygen in all but the top 15 cm of water in Texas ponds dropped below 4.0 ppm (Colura et al. 1976). Larvae failed to survive to metamorphosis at 23.5°C, but developed well at 28°C (Colura 1974). Higman (1967) noted a similarity in curves describing the annual catch rate of seatrout in the Everglades National Park and the annual rainfall that occurred three years previously. Even though that implied that rainfall influenced survival of larval and juvenile seatrout, he considered other environmental parameters of greater importance.

Toxic chemicals also influence survival. When Johnson et al. (1977) tested the tolerance of eggs and larvae to chlorine using a static test, they concluded that larval loss should be considerable in areas of chlorinated effluent disposal where toxic products of sodium hypochlorite occur above 0.17 ppm. Butler (1969) examined DDT in six generations of seatrout and noted variations in resistance of offspring to the pesticide, with that resistance being dependent on the stage of oocytes present when the female was exposed. In the Laguna Madre, Texas, where DDT residues were consistently high, reaching as high as 8 ppm in the gonads, seatrout apparently did not breed for at least one or two years (Butler 1969, Butler et al. 1970). The seatrout apparently acquired the pesticide primarily from eating juvenile menhaden, and levels in the menhaden reached a peak in February 1968 (Breuer 1970).

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