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ASPECTS OF THE BIOLOGY OF THE RED DRUM, *SCIAENOPS OCELLATUS*, IN MISSISSIPPI

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ABSTRACT Several hundred specimens of the red drum from Mississippi were critically assessed. Regression equations for standard-length (SL) versus total-length differed between males and females and between small and large members of the same sex. A single regression line represented the weight-SL relationship for males with females. For condition coefficients to be helpful, fish had to be grouped at least by sex, season, and length or stage of maturity. By 12 months of age, most fish were about 30 to 32 cm SL and their distribution ranged throughout Mississippi Sound rather than being restricted to inshore bayou and marsh habitats like younger individuals. Juvenile fish tended to have a high hepatosomatic index (HSI) in winter, and adults had a low one following spawning. The gonosomatic index (GSI) was typically lower than the HSI except for gravid fish in spring and summer. The number of oocytes available for spawning appeared to be much higher than cited in previous reports. The highest calculated fecundity, occurring in a 758 mm SL fish, was 62 million using a volumetric displacement method and 95 million using a gravimetric one. Extrapolated estimates for larger fish were much higher. Resting and yolk-vesicle stage oocytes typically had an irregular shape, an eccentrically located nucleus, and an abundance of highly basophilic substance in the ooplasm. Throughout a seasonal histological examination, both gonads contained, often in an abundance, Periodic-acid-Schiff-positive granular leukocytes. Spawning took place in late September and October one year, but apparently has occurred over longer periods when conditions of temperature and photoperiod were appropriate. No tagged, 1-year-old fish were returned from farther than 33 km from the point of release. Adults, however, apparently migrated extensively, especially from October through April. Those adults tagged several km south of the barrier islands included individuals caught 778 km away in Texas after 746 days and 316 km away in Florida after 399 days. Another fish apparently migrated at least 120 km in inshore waters in 6 days or fewer. An estimated 25 million kg or more of red drum occurred at one time between the Mississippi River and Mobile Point, Alabama. The red drum served as a host for a variety of parasites, some capable of having an adverse effect on natural stocks, on cultured stocks, and on seafood consumers, and most species known to infect the drum are listed in a table. The red drum has succumbed to some microbial agents, low dissolved oxygen concentration, rapidly dropping temperatures, and other detrimental conditions, some unidentified or unexplained. Probably, considerable mortality can be attributed periodically to environmental or environmentally-influenced conditions and to parasitic infections.

INTRODUCTION

The red drum, *Sciaenops ocellatus* (Linnaeus), has been a historically important food fish, but the recent introduction of small purse seines in the northern Gulf of Mexico increased its importance in supporting a commercial fishery in that region. The fish ranges and is fished commercially and recreationally from New York to the Gulf of Mexico coast of northern Mexico. Because numerous aspects of the biology of the red drum have been misinterpreted or are not known and because the life history of the fish in Mississippi has been sparsely documented (e.g., Etzold and Christmas 1979), I undertook this study. Food contents have already been assessed (Overstreet and Heard 1978).

MATERIALS AND METHODS

The study was initiated in 1978 to run in conjunction with one involving the spotted seatrout, *Cynoscion nebulosus* (Cuvier), with the original intention to work aboard commercial purse seining vessels. In 1979, restrictions on commercial fishing halted that arrangement. Nevertheless, considerable data collected before and after 1979 have provided enough useful information to present. Methods including those for the diagnosis of gonad states are the same as reported for the seatrout study in this same issue (Overstreet 1983) except that collections extended into November 1982. Unless otherwise indicated, all sectioned material was stained with Harris's hematoxylin and eosin Y, all fish-lengths are standard length (SL), and all material is from Mississippi.

RESULTS AND DISCUSSION

Body Relationships and Growth

Equations to predict total length (TL) from standard length (SL) and vice versa occur in Table 1. The logarithmic transformation of $TL = aSL^b$, or $\text{Log TL} = \text{Log a} + b\ (\text{Log SL})$, produced the equation for all 861 fish as $\text{Log TL} = 0.1262 + 0.9809\ (\text{Log SL})$ with a correlation coefficient $(r) = 0.9978$. Since both equations produced similar values and equations based on nontransformed data are easier to work with and routinely reported in the literature, nontransformed data will be assessed in detail below.

Because lengths of the red drum covered a wide range and large fish (colloquially known as bull reds in Mississippi) and small fish (rat reds) generally occupied two different habitats (Gulf of Mexico and the estuary including and associated with Mississippi Sound, respectively), the data were

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TABLE 1.

Standard length-total length relationship for 861 individuals of *Sciaenops ocellatus* from Mississippi by sex and length group (N = number of fish examined; a = TL [or SL] axis-intercept; b = slope; and r = correlation coefficient).

Sex	Length group in mm	Standard length range in mm	N	TL = a + b (SL)				Calculated TL for a 350 mm SL fish	Calculated TL for a 550 mm SL fish
				a	b	95% confidence interval of b	r		
Unsexed		162–965	426	15.6378	1.1642	1.1540–1.1743	0.9959	423.1	656.0
Female	<550	164–540	92	27.4244	1.1091	1.0883–1.1300	0.9960	415.6	637.4
Male	<550	143–546	250	19.2152	1.1322	1.1179–1.1465	0.9949	415.5	642.0
Female	⩾550	552–855	39	–16.0844	1.1859	1.1099–1.2619	0.9820	399.0	636.2
Male	⩾550	550–857	54	–49.9480	1.2458	1.1712–1.3203	0.9776	386.1	635.2
Female	combined	164–855	131	16.0335	1.1385	1.1237–1.1534	0.9972	414.5	642.2
Male	combined	143–857	304	10.4411	1.1587	1.1492–1.1682	0.9974	416.0	647.7
Female and Male	combined	143–857	435	12.7971	1.1502	1.1424–1.1580	0.9974	415.4	645.4
All	combined	143–965	861	7.3032	1.1712	1.1657–1.1768	0.9975	417.2	651.5
				SL = a + b (TL)					
Unsexed		162–965	426	–7.6619	0.8519	0.8445–0.8593	0.9959	419.8	654.6
Female	<550	164–540	92	–21.3661	0.8944	0.8776–0.9112	0.9960	415.2	638.8
Male	<550	143–546	250	–13.4498	0.8743	0.8633–0.8853	0.9949	415.7	644.5
Female	⩾550	552–855	39	37.7042	0.8131	0.7610–0.8652	0.9820	384.1	630.1
Male	⩾550	550–857	54	69.0953	0.7672	0.7213–0.8131	0.9776	366.1	626.8
Female	combined	164–855	131	–11.3153	0.8734	0.8621–0.8848	0.9972	413.7	642.7
Male	combined	143–857	304	–6.8981	0.8585	0.8515–0.8655	0.9974	415.7	648.7
Female and Male	combined	143–857	435	–8.8855	0.8649	0.8590–0.8708	0.9974	414.9	646.2
All	combined	143–965	861	–3.4416	0.8495	0.8455–0.8536	0.9975	416.1	651.5

separated into those for fish larger and for fish smaller than 550 mm SL. Because of variation in seasonal data influenced by yearly differences and small sample sizes, those data for all seasons are combined and the various pairs compared using analysis of covariance (ANOC). Even though variances were homogeneous for comparisons between large and small fish of the same sex and both large and small individuals of different sexes, the means did not differ ($F = 0.04 - 2.45 < F_{.05(1,90-339\ df)} = \sim 3.95$), and one regression line could represent data for pairs between sexes ($F = 1.71 - 1.84 < F_{.05(2,89-338\ df)} = \sim 3.10$) except those of the same sex less than 550 mm versus those greater than 550 mm ($F = 12.78, 3.64 > F_{.05(2,300-127\ df)} = \sim 3.07$). The regression lines for those pairs, as well as those for when pairing all males versus all females which also could not be combined ($F = 5.73$) and had different means ($F = 6.16$), differed in their slopes ($F = 25.52, 6.97, 5.24 > F_{.05(1,300,\ 127,431\ df)} = 3.9$). The linear slopes ($F = 1.64 < F_{.05(1,1283\ df)} = 3.85$), but not intercepts ($F = 8.90 > F_{.05(1,1284\ df)} = 3.85$), were the same when comparing the regression line of unsexed fish with that for all fish combined. Other combinations did not have homogeneous variances.

Data are also compared by calculating from each equation the TL of both a 350 and a 550 mm SL fish. Note the slight difference that occurs in the corresponding values (Table 1) depending on whether TL or SL serves as the dependent variable. On the other hand, note that when calculated TL is based on an equation derived from large fish, it is shorter for a 350 mm SL fish than when it is based on small fish or on all fish combined. It exemplifies the inaccuracy in extrapolating from inappropriate data. The highest calculated TL values came from the equations based on the unsexed category, a group including a large number of adult fish that had been measured, tagged, and released, as well as including some small immature individuals.

Values have been determined for fish from other areas, and they do not always correspond with those presented here because of deviations possibly resulting from size of fish, sex of fish, and environmental factors in different geographic regions. Also, seasonal differences probably influenced values as shown by Overstreet (1983) for *Cynoscion nebulosus*, also from Mississippi. Hein et al. (1980) determined SL = –2.0520 + 0.8369 TL with r = 0.9996 based on 302 fish from Louisiana, 14 to 1135 mm TL; Jorgenson and Miller (1968) determined SL = –0.290 + 0.799 TL based on 5 fish from Georgia, 13 to 32 mm SL; Harrington et al.

(1979) determined TL = 12.870 + 1.177 SL with r = 0.995 based on 8982 fish, 67 to 785 mm SL; Luebke and Strawn (1973) determined TL = 24.069 + 1.141 SL for 40 fish averaging about 33 cm SL in Texas.

The relationship between SL and weight is indicated in Table 2 and Figure 1. The fitted equations for Log W = Log a + b (Log SL) and the reverse using SL as the dependent variable indicate the need in some cases to depend heavily on the length of fish used to derive the equation. Note especially the calculated weights for 350 mm fish based on equations derived from large fish.

Regression equations had a serious drawback in spite of their high correlation coefficients; that drawback was the lack of homogeneous variances when comparing by ANOC several of the different combinations listed in Table 2; specifically, calculated differences in slopes between large and small individuals of the same sex were not based on data meeting the required criteria. Comparisons of large females versus males and small females versus males had homogeneous variances, but for the large pair, the means did not differ ($F = 0.46 < F_{.05(1,74\ df)} = 3.97$), and one regression line could suffice for all the data ($F = 0.35 < F_{.05(2,73\ df)} = 3.12$). For the small pair, the means differed ($F = 12.30 > F_{.05(1,338\ df)} = 3.87$), one regression line could not be used for all the data ($F = 6.48 > F_{.05(2,337\ df)} = 3.03$), the linear ($F = 0.01$) slopes did not differ ($F = 0.68$), but their intercepts did differ ($F = 12.29 > F_{.05(1,338)} = 3.87$). There were no statistically significant differences when data for unsexed specimens were added to those for the combined males and females or when those for females (also for males, but the involved variances for those were not homogeneous) were compared with all data combined. Consequently, Figure 1 represents a general approximation of the weight-SL relationship for red drum in Mississippi that can be used, but with caution, especially regarding possible seasonal differences.

Weight-standard length regression equations have been determined for fish from areas other than Mississippi that should also be used with caution: Louisiana – 286 fish, 250 to 932 mm SL, Log W = –4.42161 + 2.83234 (Log SL_{mm}) (Boothby and Avault 1971); 568 fish, 8 to 183 mm SL, Log W = –7.2052 + 4.1913 (Log SL_{mm}) (Bass and Avault 1975); 302 fish, 14 to 1135 mm TL, Log W = –5.1197 + 3.0523 (Log TL_{mm}) (Hein et al. 1980); Texas – 8319 fish, 71 to 970 mm TL, Log W = –5.085 + 3.041 (Log TL_{mm}) (Harrington et al. 1979); a graph by Pearson (1929, Fig. 12),

TABLE 2.

Standard length-weight relationship for 480 individuals of *Sciaenops ocellatus* from Mississippi by sex and length group (N = number of fish examined; Log a = Log W [or Log SL] axis intercept; b = slope; and r = correlation coefficient).

Sex	Length group in mm	Standard length range in mm	N	Log W = Log a + b (Log SL)				Calculated weight for a 350 mm SL fish in g	Calculated weight for a 550 mm SL fish in g
				Log a	b	95% confidence interval of b	r		
Unsexed		162–965	62	–4.5318	2.9316	2.8394–3.0239	0.9927	844.1	3175.7
Female	<550	164–540	91	–4.5988	2.9559	2.8709–3.0408	0.9908	834.1	3172.8
Male	<550	143–546	250	–4.7125	2.9935	2.9475–3.0395	0.9925	800.3	3095.8
Female	⩾550	552–855	37	–6.3930	3.5896	3.1715–4.0078	0.9469	548.5	2778.5
Male	⩾550	550–857	40	–6.0026	3.4553	3.1065–3.8040	0.9559	613.6	2925.3
Female	combined	164–855	128	–4.6937	2.9920	2.9260–3.0579	0.9923	828.2	3202.3
Male	combined	143–857	290	–4.7956	3.0268	2.9932–3.0603	0.9955	803.1	3154.5
Female and Male	combined	143–857	418	–4.7902	3.0258	2.9965–3.0551	0.9950	808.4	3173.9
All	combined	143–965	480	–4.7358	3.0053	2.9766–3.0340	0.9944	812.6	3160.9
				Log SL = Log a + b (Log W)					
Unsexed		162–965	62	1.5618	0.3361	0.3255–0.3467	0.9927	836.7	3210.6
Female	<550	164–540	91	1.5746	0.3321	0.3226–0.3417	0.9908	830.2	3238.0
Male	<550	143–546	250	1.5882	0.3291	0.3240–0.3341	0.9925	802.6	3169.2
Female	⩾550	552–855	37	1.8901	0.2498	0.2207–0.2789	0.9469	414.9	2533.8
Male	⩾550	550–857	40	1.8309	0.2644	0.2377–0.2911	0.9559	498.1	2752.5
Female	combined	164–855	128	1.5856	0.3291	0.3218–0.3363	0.9923	817.3	3227.4
Male	combined	143–857	290	1.5932	0.3274	0.3238–0.3310	0.9955	802.2	3190.5
Female and Male	combined	143–857	418	1.5932	0.3272	0.3240–0.3304	0.9950	805.5	3206.3
All	combined	143–965	480	1.5872	0.3290	0.3259–0.3322	0.9944	809.9	3199.3

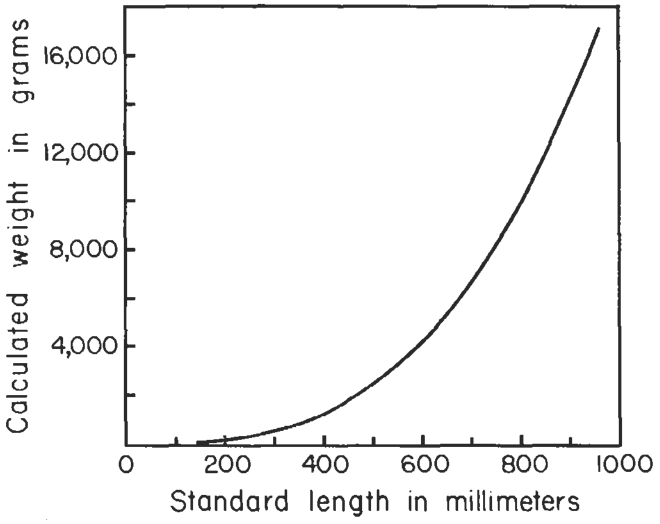


Figure 1. Standard length-weight relationship based on the equation Log W = –4.7358 + 3.0053 (Log SL).

47 fish, 283 to 411 mm in pond, Log W = –4.69 + 2.97 (Log SL_{mm}) (Luebke from Perret et al. 1980); and South Carolina – 88 fish in a marsh impoundment, Log W = –1.29596 + 2.74031 (Log SL_{cm}) (Theiling and Loyacano 1976).

Because of some of the problems involved with the above regression equations and with size of fish in different length-groups, the condition coefficient,

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

is presented for both males and females as well as seasonally for different length groups (Table 3). Comparative values also occur for fish in different stages of maturity (Table 4). Because of small sample sizes, data from different months and years were grouped by season. Both males and females larger than 700 and in stage IV and V during spring and summer tended to have relatively high K values. High ones for two females were 2.83 and 2.67 and for two males 2.73 and 2.67. The K does not necessarily increase with fish length or stage of maturity. On the other hand, "stage of maturity" is misdiagnosed in a few cases because the stages are based on appearance of maturing spotted seatrout (Overstreet 1983), and many more adult seatrout than adult red drum were examined. A few specific cases are pointed out in a later section on histology. With additional data, stages should be more precise and K tables should be more helpful. Nevertheless, a single or average K value representing a species of fish, regardless of sex, length, or season, can be misleading (e.g., by the commercial Richie Fish Computer [Professional Model], K_{TL} = 1.22).

By calculating K identically to that described here, Boothby and Avault (1971) calculated for adult fish in "good condition" as K = 1.3 (1.2–1.6) in winter, 1.4 (1.2–1.6) in spring, 1.4 (1.2–1.6) in summer, and 1.5 (1.2–1.7) in autumn. Luebke and Strawn (1973) calculated K for fish in two ponds receiving heated discharge water from a power plant and noted monthly values from 1.67 to 1.94 from June through November. Those latter values, higher than ones determined from adults in Louisiana, but lower than those for 568 juveniles in Louisiana (K = 1.773 to 2.077, $\bar{x}$ = 1.969 by Bass and Avault 1975), are somewhat less than some reported here, but variation existed, even among summer values for fish from Mississippi. To obtain the most value from condition coefficients, a continuum of comparative samples should be related (e.g., Ellis and Gowing 1957, Colle and Shireman 1980, Overstreet 1983).

The red drum grew rapidly, but inconsistently, in Mississippi. Over a 3-year period, Loman (1978) collected several 6 to 9 mm SL postlarvae in grassy or muddy shallow water habitats in Mississippi Sound. These fish were limited to September, October, or November and collected by a beam net only. As small juveniles, the fish occurred in marsh habitats, moving into bayous and canals from at least November through early summer. Consequently, these and other young specimens seldom occurred in trawls or beach seines unless captured from a channel during a cold period. Several fingerlings have been collected and many more seen, but their measurements are not included in the tables. They were seined from mouths of or short distances up bayous or from depressions in marshy areas where they stranded following especially high receding tides. A range of length from 4 to 8 cm SL for fish in January suggests variation in growth or differences in spawning dates.

Generalized growth of juveniles after about 7 months, assuming a spawn about September, can be followed by length-frequency data in Table 5. Because of the paucity of available fish, those individuals from all years using all methods of collection are pooled. Year-old fish averaged about 30 to 32 cm SL. The shorter fish were collected from bayous and Back Bay of Biloxi only. By mid-August, some relatively short fish came from off Deer Island and Round Island, islands occurring within Mississippi Sound, but not barrier islands delimiting the Gulf of Mexico. By September, some came from near the barrier islands as well as from the inshore marsh habitats.

Bass and Avault (1975) made nine collections at Grand Isle, Louisiana, from 30 October to 23 May. During that period the mean SL of the red drum increased from 15.7 to 145.0 mm for an average monthly growth of 18.8 mm for the first 7½ months of life (20.4 mm when considering largest individuals per sample). Simmons and Breuer (1962) reported a growth rate of from 19.2 to 34.2 mm per month for fish in their first year in the Upper Laguna Madre, Texas, where sporadic growth with a spring lag occurred. At Eighth Pass, Mexico, Miles (in Simmons and Breuer 1962) noted fish 200 mm TL in July, or 50 to 60 mm TL less than the fish observed in the Upper Laguna Madre by Simmons and Breuer. Based on tagging, Simmons and Breuer (1962)

TABLE 3.

Seasonal condition coefficient (K[standard length]) and hepatosomatic index (HSI) of *Sciaenops ocellatus* collected from 1972 to 1982 relative to sex and length of fish.

	Standard length in millimeters														
	<300			300–549			550–699			700–849			>850		
	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															
Female	10	1.90±0.11	1.28±0.18	22	1.92±0.05	1.36±0.12	6	1.74±0.16	1.00±0.09	3	1.82±0.13	1.03±0.09	0		
Male	23	1.91±0.05	1.60±0.18	61	1.90±0.02	1.50±0.06	11	1.88±0.05	0.93±0.08	4	1.56±0.04	1.03±0.11	0		
Winter															
Female	1	2.24	1.94	33	1.93±0.03	1.88±0.08	9	1.78±0.10	1.25±0.20	0			0		
Male	1	2.07	2.62	49	1.83±0.02	1.33±0.05	4	1.75±0.08	1.00±0.22	1	1.93	1.58	0		
Spring															
Female	1	1.78	0.61	15	1.94±0.06	1.11±0.05	2	1.69±0.17	0.96±0.11	13	2.21±0.10	1.71±0.14	1	1.96	1.39
Male	1	1.79	1.34	56	1.89±0.02	1.07±0.04	7	1.81±0.05	1.07±0.13	11	2.28±0.10	1.84±0.10	0		
Summer															
Female	5	1.90±0.05	1.09±0.15	8	2.00±0.13	1.03±0.12	2	1.78±0.00	1.24±0.72	1	1.91	2.44	0		
Male	56	1.84±0.02	0.91±0.03	10	1.82±0.03	1.02±0.06	1	1.95	0.91	1	1.88	1.92	0		

TABLE 4.

Seasonal condition coefficient (K[standard length]), hepatosomatic index (HSI) and gonosomatic index (GSI) of *Sciaenops ocellatus* in Mississippi relative to stage of maturity of fish.

	Stage of Maturity	Autumn		Winter		Spring		Summer	
		Female	Male	Female	Male	Female	Male	Female	Male
Sample size	I	12	38	24	0	5	16	6	51[1]
K±SE		1.87±0.09	1.94±0.03	1.95±0.04		1.83±0.04	1.83±0.04	1.92±0.04	1.83±0.02
HSI±SE		1.27±0.11	1.54±0.10	1.97±0.06		1.00±0.12	1.06±0.06	1.14±0.13	0.92±0.02
GSI±SE		0.03±0.01	0.02±0.00	0.03±0.00		0.04±0.02	0.03±0.01	0.02±0.01	0.02±0.00
Sample size	II	16	42[2]	8	49	11	38	5	13
K±SE		1.94±0.08	1.85±0.03	1.82±0.04	1.82±0.02	1.97±0.07	1.91±0.03	1.80±0.12	1.86±0.04
HSI±SE		1.52±0.14	1.51±0.09	1.60±0.27	1.32±0.06	1.12±0.07	1.13±0.04	1.00±0.11	0.94±0.08
GSI±SE		0.14±0.06	0.05±0.01	0.05±0.01	0.02±0.00	0.04±0.01	0.03±0.00	0.06±0.01	0.15±0.12
Sample size	III	11	7	9	4	3	11	0	3
K±SE		1.81±0.04	1.85±0.08	1.90±0.08	1.89±0.05	1.72±0.09	1.84±0.02		1.88±0.05
HSI±SE		0.99±0.16	1.30±0.21	1.52±0.20	1.73±0.19	1.17±0.26	0.94±0.13		0.98±0.10
GSI±SE		0.48±0.10	0.07±0.02	0.18±0.02	0.12±0.09	0.34±0.18	0.12±0.05		0.12±0.09
Sample size	IV	2	9	2	1	13	10	2	0
K±SE		1.93±0.15	1.96±0.07	1.78±0.61	1.94	2.22±0.09	2.32±0.10	2.42±0.30	
HSI±SE		0.88±0.11	0.94±0.09	0.81±0.18	0.74	1.69±0.15	1.87±0.11		
GSI±SE		0.57±0.31	0.30±0.07	0.21±0.00	0.06	0.67±0.04	0.32±0.01		
Sample size	V	0	3	1	0	0	0	3	1
K±SE	(and VII)		1.57±0.06	2.18				1.82±0.06	1.88
HSI±SE			1.03±0.17	0.45				1.64±0.61	1.92
GSI±SE			0.86±0.09	0.59				1.94±1.23	2.42

[1] Sample size for GSI was 49. [2] Sample size for HSI was 41 and that for GSI was 39.

TABLE 5.

Monthly length-frequencies of 484 juvenile *Sciaenops ocellatus* between 100 and 400 mm SL in Mississippi. The short individuals in May can be assumed to be about 7 months old.

Month	Length group in mm SL										No. of fish
	100–129	130–159	160–189	190–219	220–249	250–279	280–309	310–339	340–369	370–399	
May	2	1	1					7	4	2	17
June				2	2		1	2	2	2	11
July			4	5	5				1		15
August				3	76	24	11	2	1		117
September				1	1	9	15	3		1	30
October					2	10	47	26	4		89
November						3	7	14	2		26
December					1	7	7	14	17	6	52
January	2						13	31	3	2	51
February											
March						2	2	12	6	4	26
April						1		9	16	24	50
No. of fish	4	1	5	11	87	56	103	120	56	41	484

showed fish to average 325 mm TL at the end of the first year, 540 mm at the second, and 760 mm at the third, which are larger values than most authors report. Etzold and Christmas (1979) listed 34.0, 54.0, 64.0, 75.0, and 84.0 cm SL for fish through the fifth year, but these values probably are mean TL measurements presented by Pearson (1929). Arnold et al. (1977) reared 44 mm TL fingerlings to 250 mm (190 g) in 6 months and to 523 mm (1840 g) in 19 months.

Liver and Gonad Weights

Liver weight, expressed as the hepatosomatic index,

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

is summarized in Tables 3 and 4. In the first table, the index, calculated seasonally and by sex, occurs relative to fish-length. In the second, the index occurs relative to the fish's stage of maturity. In some groups, the average index had considerable variation, enough to question sexual differences. In general, no relationship existed between HSI and fish-length. A tendency, however, was apparent for a high index in fish during winter for individuals in stages I to III and during spring and summer for the more mature large fish. The index was relatively low following spawning season in adults.

The gonosomatic index,

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

except for the large stage V (gravid, but not ready to spawn) individuals in summer, was lower than the HSI (Tables 4 and 6). The highest values were 3.9 for a female and 2.4 for a male. Presumably, the value for a spawning female would be much higher. Females tend to have higher values than males in corresponding groups. The relationship between stage of maturity and fish-length is portrayed in Table 7.

Fecundity

The red drum is capable of producing a considerable number of oocytes. A linear relationship existed between SL and the logarithm of the number of oocytes over 16 to 30 μm for 22 fish 294 to 800 mm SL (Figure 2). The maximum calculated estimated number of oocytes from a 758 mm SL female in March was 61,998,776, or 94,513,172 when calculated using the gravimetric rather than the volumetric displacement method. The gravimetric method produced values 0.67 to 3.14 (avg. 1.69) times greater than the displacement method. The number of oocytes in the only gravid fish and the only calculation based on fixed material was nearly 16 million (Table 8) or 24,425,025 when based on weight. The number would have been higher had a piece of ovary not been removed and an adequate fresh aliquot fixed so that more small oocytes could be distinguished (Figure 3). If the relationship shown in Figure 2 continues to hold as fish-length increases, a large 953 mm SL fish (the largest tagged, but several longer ones were observed) could theoretically produce 290 million oocytes over 16 μm (or possibly 1.7 times that value using the gravimetric method). In any event, if spawned, the eggs from a single large red drum could supply more individuals than a reasonable total estimated number of living red drum over 300 mm. Of course, not all eggs hatch, and of those that do, relatively few resulting fish reach the juvenile stage and even fewer become adults. Overstreet (1983), in a paper on spotted seatrout, discussed the difference between the estimated numbers of seatrout oocytes using the volumetric and gravimetric methods as well as errors involved in those estimates using the same procedures. Table 8 shows an increase in

TABLE 6.

Gonosomatic index (GSI) of *Sciaenops ocellatus* relative to length of fish.

	Standard length in millimeters									
	<300		300–549		550–699		700–849		>850	
	Sample size	GSI±SE	Sample size	GSI±SE	Sample size	GSI±SE	Sample size	GSI±SE	Sample size	GSI±SE
Autumn										
Female	11	0.18±0.09	22	0.11±0.04	6	0.39±0.13	3	0.87±0.06	0	
Male	21	0.05±0.02	60	0.03±0.00	11	0.20±0.04	4	0.84±0.07	0	
Winter										
Female	1	0.01	33	0.05±0.01	9	0.17±0.03	0		0	
Male	1	0.03	49	0.02±0.00	4	0.05±0.01	1	0.36	0	
Spring										
Female	1	0.00	15	0.42±0.01	2	0.19±0.07	13	0.66±0.03	1	0.77
Male	1	0.00	56	0.04±0.01	7	0.06±0.02	11	0.31±0.01	0	
Summer										
Female	5	0.01±0.01	6	0.06±0.01	2	0.95±0.35	1	3.94	0	
Male	53	0.05±0.03	10	0.03±0.00	1	0.05	1	2.42	0	

TABLE 7.

Relationship between length of *Sciaenops ocellatus* and stage of maturity[1] for a total of 482 males (M) and females (F).

	Standard length in millimeters										
Stage of Development	<300		300–549		550–699		>700		Total		Grand Total
	M	F	M	F	M	F	M	F	M	F	
I	83	18	40	33	2	2	–	–	125	53	178
II	15	3	127	37	3	5	–	–	145	45	190
III	2	2	11	8	11	15	3	9	27	34	61
IV	–	–	2	2	8	3	12	14	22	19	41
V	–	–	–	–	–	5	4	3	4	8	12

[1] Diagnosed on basis of gross observations of spotted seatrout gonads (Overstreet 1983) and a few cases do not agree histologically.

mean number of oocytes by stage of maturity through developing IV fish using the conservative volumetric displacement method. This number also increased by stage of fish maturation when calculated as number per gram of fish. On the other hand, because of an increase in diameter of oocyte with stage of maturity, the number tended to decrease when assessed as number per gram of ovary.

Oocyte diameters increase with stage of maturity as mentioned above and shown in Figure 3. The graph includes only a single gravid individual with its much larger oocytes. Roberts, Harpster, and Henderson (1978) measured oocyte diameters during conditioning for spawning under different conditions, but not immediately preceding spawning. Holt, Johnson et al. (1981) reported spawned eggs as 0.93 mm (0.86 to 0.98 mm) in diameter. They estimated fecundity values as one half to two million eggs per season for a 3- to 5-year-old female. Higher values have been reported: 2.5 million for a 825 mm TL fish (Miles 1951) and about 3.5 million for a 90 cm TL fish (Pearson 1929). In any event, the number is actually much higher than those estimates as shown by spawned eggs. A single female (6.2 kg or less) produced 2,058,000 eggs in one of several controlled spawns; of those, 95% hatched (Roberts, Harpster, and Henderson 1978). Arnold et al. (1977) estimated a total of 60 million fertilized eggs produced by three relatively small individuals over a 76-day period.

Histology of gonads

Sections of many, but not all, stages in the development of the gametes provide a helpful view of maturation of this fish in the northern Gulf of Mexico.

In the ovary, numerous oocytes occurred within lamellar folds (Figures 4–5); most had a characteristically irregular shape and an eccentric nucleus. In those ovaries examined during winter and spring, the ooplasm appeared mottled in stained preparations. Usually the peripheral zone and an

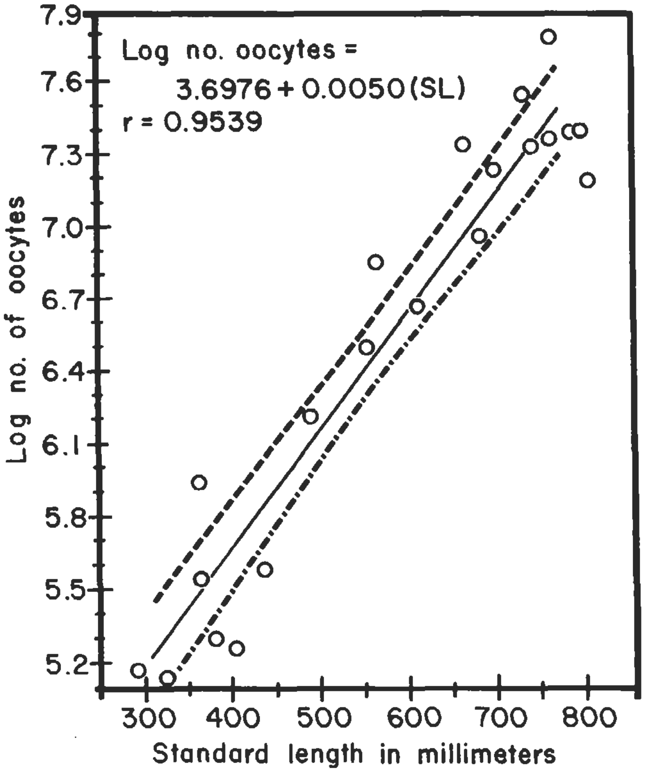


Figure 2. The logarithm of the number of oocytes estimated by volumetric displacement as a function of fish length. Only oocytes 16 to 30 μm and larger are included.

irregular zone adjacent to the nucleus stained more basophilic than that zone in between (Figures 6–8). Also during winter and early spring, the tunica albuginea surrounding the ovaries reached its thickest measurement.

Figure 9 shows oocytes in two stages of vitellogenesis, as well as primary oocytes which occurred throughout the year. Vitellogenesis, as determined by stained yolk globules, occurred in oocytes as small as 70 μm in diameter, but was typically more apparent in those well over 100 μm and in those larger than concurrent oocytes in the preceding yolk-vesicle stage. As oocytes in the yolk-globule stage ripen in late August and September, the osmophilic yolk vesicles (using osmium tetroxide method for fat-paraffin sections, in Luna 1968) coalesced to ultimately form a single lipid droplet; the purplish-stained yolk globules (in hematoxylin and eosin stain) gradually coalesced into moderately large spheres before fusing together and losing much of their color staining properties; and the nucleus appeared to migrate toward the cell's periphery and lose its irregular membrane (Figure 10). Nearly ripe, slightly misshapen, nonhydrated oocytes in late yolk-globule stage measured as long as 580 μm.

Spent ovaries occurred in fish during early and late October (Figure 11). In addition to containing spent follicles, the ovary during that time had numerous atretic oocytes (Figures 11–12). Granular leukocytes functioned partially in encapsulating atretic oocytes (Figures 13–14). These cells with Periodic acid-Schiff (PAS)-positive granules occurred abundantly among connective tissue of both ovary and testis, being most numerous in spent individuals (e.g., Figure 15).

An enlargement of the hyaline portion of the zona pellucida occurred in oocytes from the central portion of one gravid ovary and probably represents an atypical condition (Figures 16–18). Some oocytes with such an investment had entered a state of atresia, and a bacterium had invaded a few of the oocytes within a focal area (Figures 19–20).

When examined on a seasonal basis, the testes exhibited a dynamic pattern in development related to age and season. In young males, spermatogenesis occurred more abundantly near the periphery than centrally and more abundantly near the midtestis than near the ends. The degree of those processes could not be differentiated in most more-developed fish. Testes of two first-year fish diagnosed as virgin had spermatozoa present in peripheral tubule lumens (Figure 21). Gravid males in August revealed an active state of spermatogenesis (Figure 22), and many live males during this period released milt when handled. Compact tubules were composed of numerous individual germinal cysts separated by Sertoli cells and bound together by a basement membrane

TABLE 8.

Average fecundity of oocytes larger than about 16 μm in *Sciaenops ocellatus* from Mississippi determined by volumetric displacement method in relation to stage of development.

Stage	N	Calculated mean no. oocytes ± SE	Mean wt of fish in g ± SE	Mean no. oocytes/g fish ± SE	Mean ovarian wt in mg ± SE	Mean no. oocytes/g ovary ± SE
Virgin	3	226,183±81,938	939.3±308.8	244±36	0.27±0.12	908,202±174,767
Maturing Virgin	5	659,054±282,240	1,230.8±197.4	498±163	0.54±0.26	1,466,090±531,533
Developing III	6	10,291,489±3,118,787	4,435.4±509.9	2,153±469	18.46±7.42	800,584±233,437
Developing IV	7	29,002,812±6,230,008	9,108.0±687.6	3,198±667	54.79±6.50	505,853±54,111
Gravid[1]	1	15,775,570	9,776.7	1,614	364.55	43,274

[1] Based on fixed material with small portion missing.

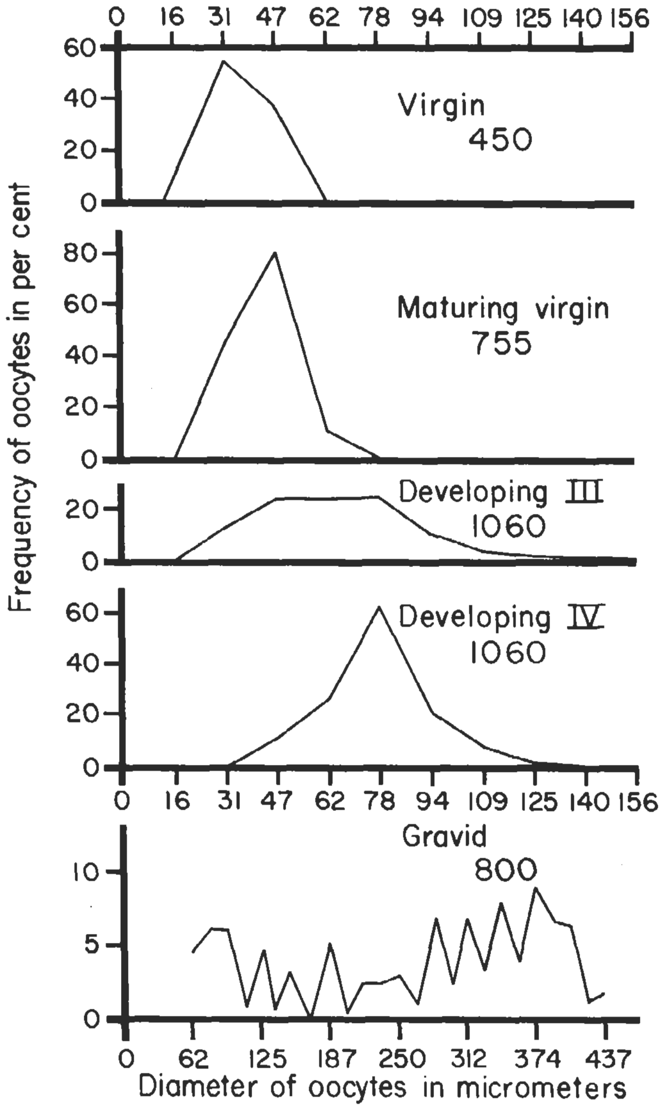


Figure 3. Length-frequency in percent of diameter of oocytes from fish in different stages of maturity.

and associated boundry cells. Within each cyst, synchronous development of the various stages was easily distinguished (Figures 23–27).

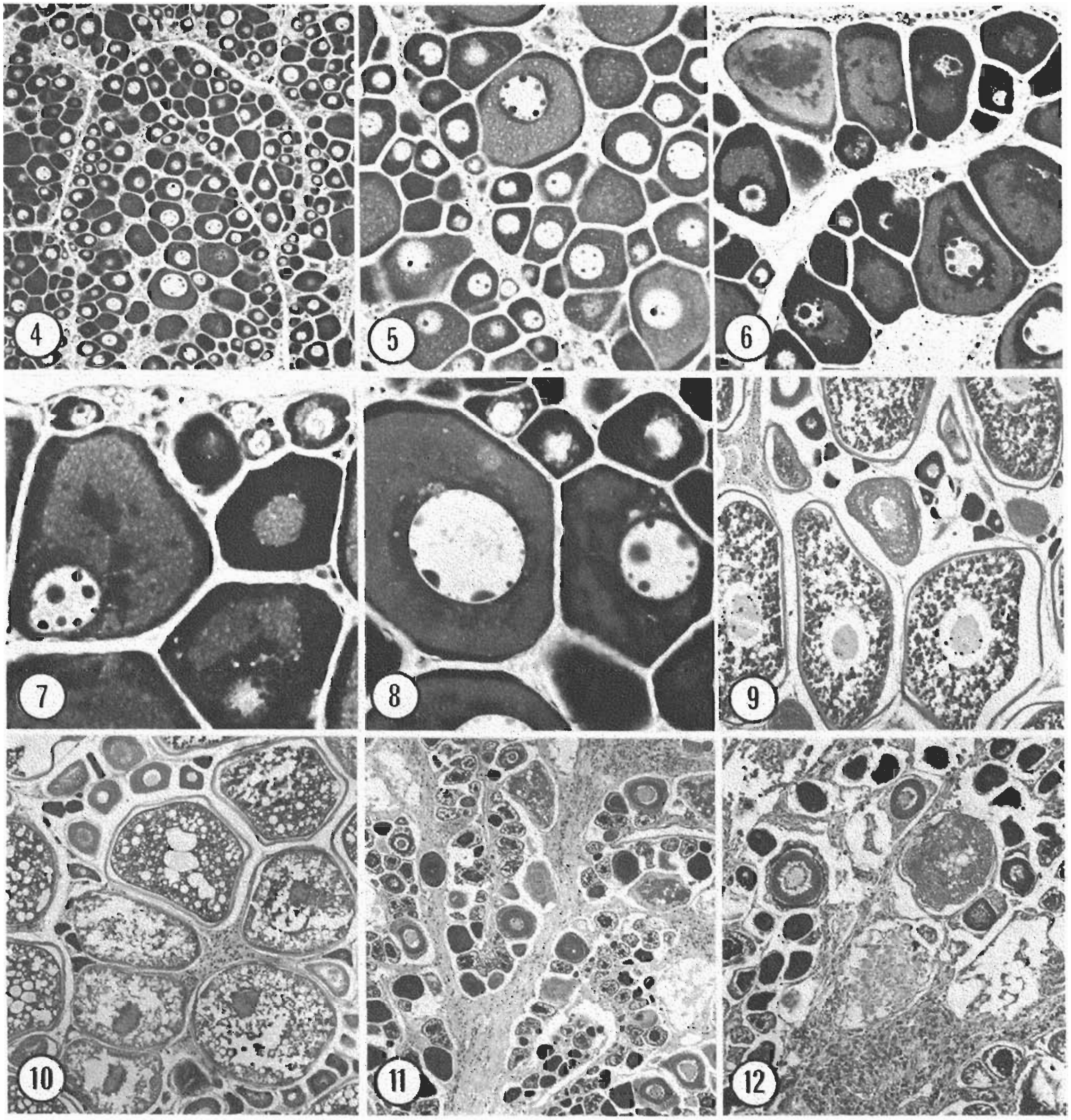
Testes of post-spawning fish in October retained an abundance of residual spermatozoa (Figures 28–30). Components of intralamellar septa increased in amount (e.g., Figure 31). Spent testes not undergoing extensive spermiogenesis occasionally exhibited foci of inflammatory reactions (Figure 32).

The red drum oocyte needs to be prepared for rapid lipogenesis and vitellogenesis so that it can produce a large number of eggs over a relatively short period. The large amounts of highly basophilic material may be the means. Even present in small oocytes, the material may be similar to that referred to as the pallial substance of Balbiani's vitelline body (Beams and Kessel 1973, Guraya 1979). It or portions have been implicated as an essential precursor substance necessary for oocyte growth and vitellogenesis. Perhaps an ultrastructural study on the oocytes by D. E. Roberts, Jr., and developmental studies on the gonads in progress by Ruth Reese (Roberts, personal communication) will help solve this. The abundance of basophilic substance in the ooplasm, the eccentric nucleus, and the irregular shape constitute some of the differences between oocytes of the red drum and related spotted seatrout (Overstreet 1983). Another conspicuous difference between gonads of those two fish is the abundance of PAS-positive granular leukocytes in the red drum. This cell appears similar to that investigated by Barber and Westermann (1975, 1978). Several different leukocytes exist among different fish species, some referred to as eosinophils, but many of their various functions remain mostly unsolved (Hawkins et al. 1981). The PAS-positive granular cell in the drum at least associates with atretic oocytes. Stott et al. (1980) studied the testes of several fishes exposed to petroleum and mentioned that acidophilic cells, apparently similar to the one mentioned above in the drum, occurred in 50% of the testes. They were not clear about which species of fish contained such a cell, but they figured a focus in *Archosargus probatocephalus* (Walbaum).

Spawning

Actual spawning has not been observed in natural settings, possibly because it seems to occur near dusk (Arnold et al. 1977, Roberts, Harpster, and Henderson 1978). Most circumstantial data pertain to that collected in 1979. While aboard a commercial purse seiner several kilometers south of Horn Island on 24 August 1979, I noted one out of every nine handled large fish was a male that spewed milt. In spite of holding down large females to measure and tag them, none of them or any of the thousands of relatively smaller fish placed in the hold released ova. The two females returned to the laboratory were gravid and probably represented the average developmental stage of females in the stock. The catch included mostly 7 kg fish, but also included several 25 to 30 kg presumed females as well as others as small as 4.5 kg. Commercial fishing shortly after that period was suspended, and, soon before Hurricane Frederic on 12 September, schools disappeared, apparently migrating offshore to spawn. On 5 October, six confirmed spent females occurred among an especially large commercial catch of black drum. Thomas Fraser (Environmental Quality Laboratory, personal communication) has observed spent fish in Boca Grande, Florida, during the end of October.

The date and length of spawning almost certainly vary according to temperature, photoperiod, and possibly other factors. Pearson (1929) collected postlarvae near Texas passes from 11 October to 15 November 1926 and observed spent females in mid-November. King (1971) collected postlarvae from 13 August to 29 October 1968 with a peak in the second week in October and a shorter period from the last of September through October in 1969. Spawning even occurs off Chesapeake Bay in September to November as



Figures 4–12. Sectioned ovarian tissue from *Sciaenops ocellatus.* 4. Oocytes in lamellar folds of "maturing virgin" female in September at a time when adult fish had nearly ripe oocytes. 5. Close-up of ovary in Figure 4 illustrating primary oocytes and their typical irregular-shape. These later stage oocytes are undergoing early stage of lipogenesis, as shown by minute yolk vesicles in ooplasm. 6. Ovary designated as "developing IV" in December, with typical nutmeg-appearing mottled ooplasm and eccentric nuclei. The innermost, compact, basophilic zone surrounding the nucleus as well as the peripheral zone is probably the pallial substance of Balbiani's vitelline body. Note the rather large, spherical nucleoli located near the periphery of the nucleus. Also note the cluster of young "chromatin nucleolus stage" oocytes located centrally along the lamellar margin. 7. Close-up of various-sized oocytes in same ovary as Figure 6 showing initial lipogenesis in oocytes with moderately basophilic ooplasm. 8. Close-up of oocytes in developing IV fish in March for comparison with oocytes in Figure 7. Note the prominent chromosomes, the more apparent activity associated with the pallial substance of Balbiani's vitelline body with included yolk vesicles and spongy fat vesicles, and the more dense peripheral zone in the largest oocyte. 9. Oocytes in various stages in a gravid fish in August. Note the medium-sized oocytes undergoing vitellogenesis, the large oocytes with fat vesicles surrounding the nucleus, and small

shown by 20 to 90 mm TL fish entering the Bay (Mansueti 1960). Other authors indicate presumed spawning from September through February. Loman (1978) reported postlarvae in inshore nursery grounds in Mississippi beginning in October of 1974 and September of 1975 and 1976. In 1975, postlarvae appeared until November. Offshore necton samples showed some larvae in September 1974 and August 1976. On 8 and 9 October 1980, Wayne Laroche (Joanne Laroche, personal communication) dipped 9 mm SL postlarvae from a retaining wall at Point Cadet, Biloxi. Colura (1974), Arnold et al. (1977) and Roberts, Harpster, and Henderson (1978) have all successfully spawned red drum in culture systems. Without using gonadotropin injections, spawning could be induced by manipulating temperature and photoperiod combinations to simulate optimal conditions or seasonal variations (Roberts, Harpster, and Henderson 1978). Basically temperature was increased, sometimes to 29 or 30°C or so, the fish was triggered to spawn at 21 to 25°C, and the temperature was subsequently dropped to 21°C while the period of light that had been increased to 16 hr was dropped to 10 hr 15 min. By maintaining the temperature constant at about 23 to 24°C and light constant for 10 hr 15 min per day, spawning continued for up to 100 days. The number of these floating eggs per spawn typically dropped off from about one million per spawn for several spawns during the first 45 days to from ten to a hundred thousand thereafter. The maximal spawn on one night was 2,058,000 eggs per fish. One closely examined fish spawned 31 times over 90 days. Typically, 10 to 12 spawns per fish occurred over 90 to 100 days. During this period, four females (2 to 8 kg) produced an average of 23,400 embryos per fish per day, whereas captive fish (9 to 15 kg) in Texas produced 26,000 embryos per fish per day in 52 spawns over 76 days (Arnold et al. 1977). Arnold's group induced spawning in the fish by using variations in photoperiod and temperature regimes simulating those of different seasons. Fertilization was greater than 99%, with hatching success over 90%. Colura reported 11.4 million fry collected from a single female of unspecified length in a 1893-liter tank over a 2-week period (Anonymous 1979). Nevertheless, optimal conditions seldom, if ever, exist for long periods in nature, and spawning probably occurs during a few week period that presumably differs in length for fish in different regions. A maximal single spawn apparently exists (estimated by Colura as 30,000,000 eggs for a 9 to 14 kg fish) and that over a spawning season is probably somewhat consistent with fecundity values presented earlier. The number of oocytes actually undergoing vitellogenesis and the size at which they begin that process presumably depend indirectly on temperature, photoperiod, and other factors.

Migration and Estimation of Abundance

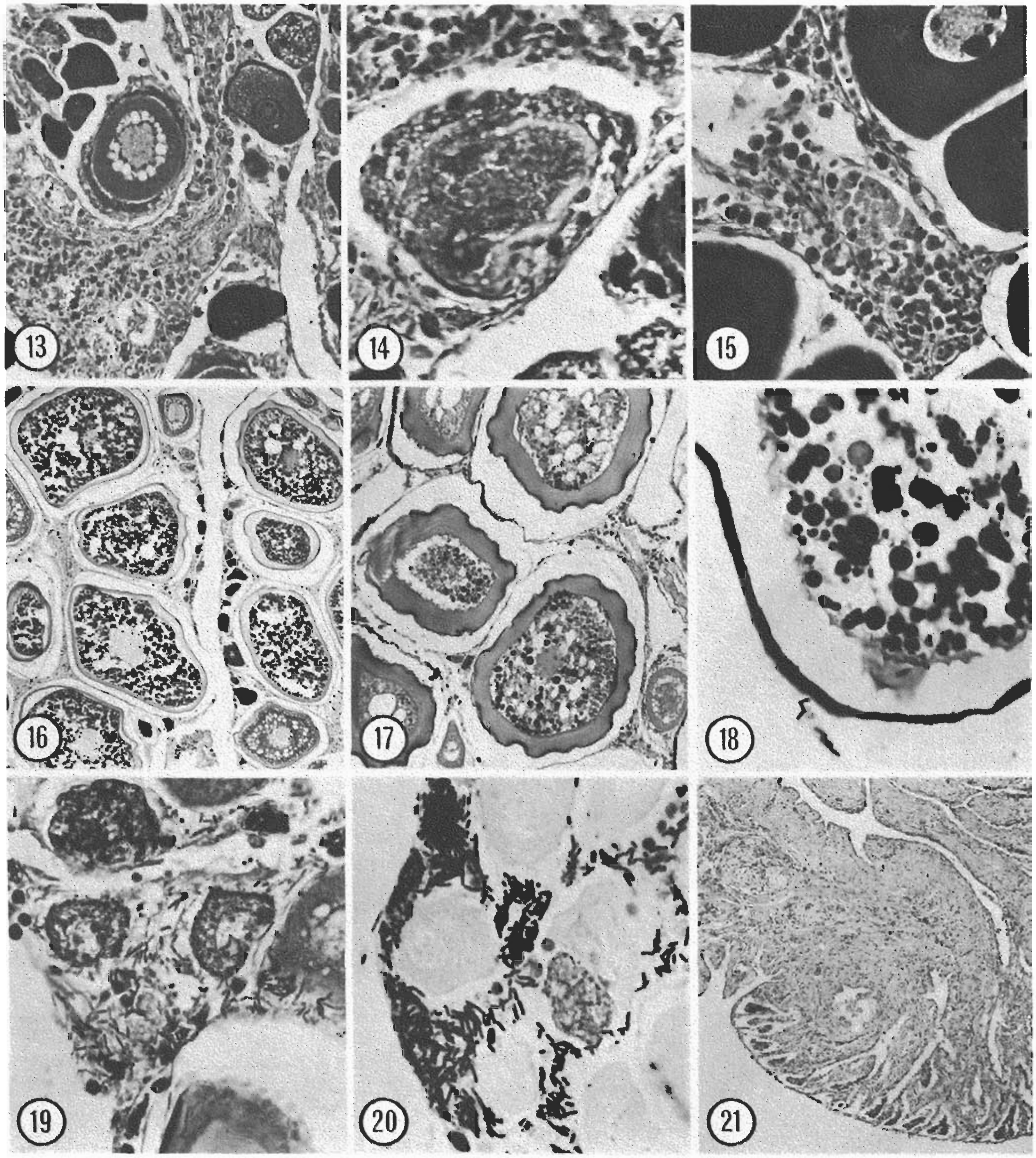
A total of 448 fish were tagged to evaluate migration of the red drum. Those included 88 relatively young individuals from inshore estuarine areas and 360 older ones from near barrier island marine habitats in the Gulf of Mexico. To date, commercial and recreational fishermen returned data on 33 (7.4%) of those tagged fish. Of those, 20 fish 172 to 350 mm SL long were released and recaptured in bayous; four were caught near that site within a week, six were caught there within 47 and 464 days, and the other ten traveled a minimum of 4 to 33 km within 4 to 316 days.

Data from 13 fish tagged offshore suggest a more extensive migration for large offshore fish, especially when followed over a period of time. Four fish about 650 to 850 mm long did not move more than a few km in 4 days, and another was caught in the same area after 4 months. On the other hand, an apparently healthy 690 mm individual moved 16 km into Mississippi Sound within one day. After 92 to 160 days, five fish 790 to about 850 mm long had migrated at least 24 to 63 km westward. Another fish, initially 810 mm long, was caught off a jetty at Galveston, Texas, 778 km westward after 752 days.

Eastward migration was also recorded. A 760 mm long fish moved eastward at least 316 km within 399 days; it was caught near St. Joseph Point, Florida. A fisherman cut open the stomach of a medium-sized individual of a red drum he caught in Miflin, Alabama, to determine on what it was feeding. There he found a specimen of the spot, *Leiostomus xanthurus* Lacépède, tagged in Davis Bayou, Ocean Springs, 6 days earlier. Depending on whether the drum traveled by a tortuous inland route or along the coastline, the minimum distance traveled was 121 or 156 km. Less likely, of course, is the possibility that the spot traveled a long distance before being eaten.

Another method of estimating migration and estimating abundance involves observations of changes in locations of schools of large fish by commercial fishermen and by pilots that have training in spotting menhaden and other fish for commercial purposes. A compilation of their observations, observations that agree with ours, provide the following scenario. Adult red drum occur singly or in schools. When they make major seasonal migrations and during most of the time when in the Gulf of Mexico, they occur in schools. These schools often occur near black drum, Atlantic tarpon, and pompano, at least when near shore. The red drum can

oocytes all in the same field. The separations between oocytes and follicles and among oocytes are postmortem artifacts. 10. Ripening oocytes with yolk and fat vesicles coalescing to form a central "oil droplet." A few dark staining yolk globules can be seen, but most had already fused to form the lighter staining yolk material. 11. A spent ovary in October showing various stages of atretic oocytes, empty follicles, and prominent intralamellar septa. 12. Close-up of ovary in Figure 11 suggesting absorption of atretic oocytes. Note cellular infiltrate that includes numerous PAS-positive granular leukocytes.



Figures 13–21. Sectioned ovarian tissue from *Sciaenops ocellatus.* 13. An atretic oocyte with fat vesicles pressed against irregularly-shaped nucleus. The PAS-positive granular leukocytes surround the atretic oocyte and occur abundantly in adjacent connective tissue. 14. Close-up of degenerated oocyte surrounded by infiltrate including several PAS-positive and two basophilic granular leukocytes. 15. PAS-positive granular leukocytes in connective tissue among "resting oocytes." They are involved with central mass of necrotic cells still exhibiting pycnotic nuclei. 16. Apparently atypical oocytes with the eosinophilic zona pellucida wider than normal. Even though some postmortem artifacts exist, most of the oocytes in this gravid ovary in late August have a narrow zona pellucida. 17. Oocytes nearby to those in Figure 16 undergoing atresia and exhibiting an especially wide zona pellucida. 18. Similar to Figure 17, but showing the red staining outer layer and yellow staining inner layer when stained using Taylor's method for bacteria. 19. Degenerating oocytes in different region of same ovary as in Figures

almost always be readily distinguished from those fishes by trained spotters because of its color and because schools of red drum do not randomly intermix with others. When interspecific schools are not separate, mixing is restricted to the respective fringes. When feeding along the shoreline of islands or mainland, they spread out in water having a depth more than 1.2 meters. Rarely have they been observed from the air for more than a 2 hr period. They appear immediately prior to low tide up to the flood tide, but never during the slack of high tide. Individuals from most schools typically weigh between 5 and 15 kg.

Schools occasionally group tightly. The largest observed compact school also included black drum and tarpon and occupied an 8 hectare area in and around Cat Island Pass. It was estimated conservatively by a pilot and a fisherman at 4.5 million kg, which included 50 to 60% red drum. Large schools of red drum occasionally contain 150,000 to 250,000 fish. On one daily airplane trip, flying over water from the mouth of the Mississippi River, Louisiana, to Mobile Point, Alabama, Timothy Stevens, an experienced menhaden spotter, observed several schools and made a conservative estimate totaling 50 million kg of red and black drum, with 50 to 60% comprising red drum. The total amount from Texas to south Florida and along the Atlantic seaboard must indeed be tremendous. According to two commercial sources, schools in the northern Gulf of Mexico appear to be larger and more numerous during the last 10 years than during the previous 14 or so years.

Large schools of red drum first appear about April. Usually this occurs off Alabama and by the appearance, disappearance, and (re)appearance of similar-sized schools, there tends to be a general migration to Breton Island and Cameron areas of Louisiana. By September or October, the schools disappear offshore, presumably to spawn. A few spent fish appear along the beaches in October and November. During summer months, schools often spread out more than during spring and autumn, occurring all over Mississippi Sound and adjacent regions. Numerous fish occur around the mouths of the Pascagoula River and various bayous.

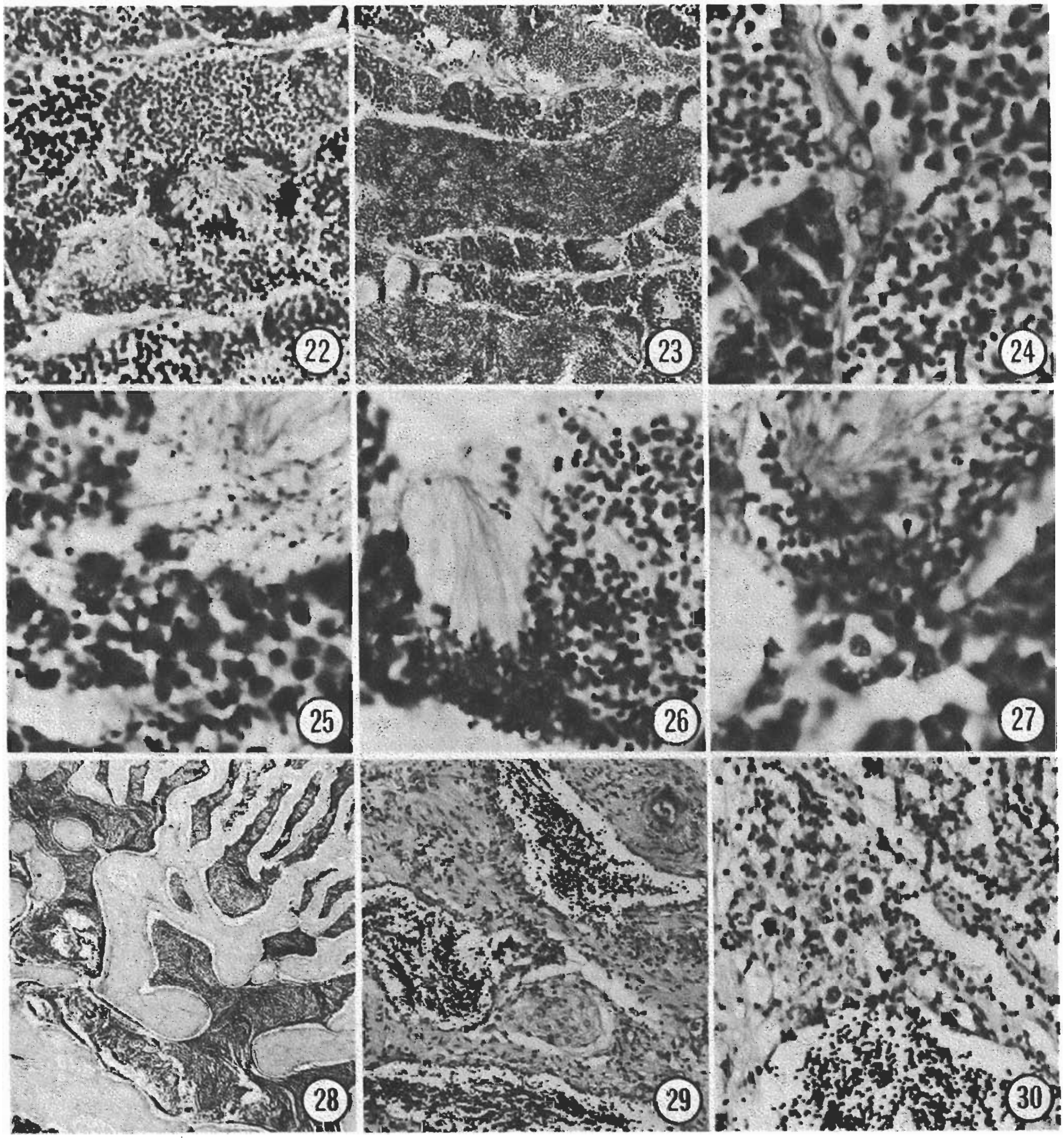
Schools may utilize a portion of the Yucatan current for migration from October to April; their appearance along beaches apparently varied as did the current. While setting purse seines for carangids, commercial fishermen have recently unintentionally caught schools of up to 34,000 kg of red drum underneath those fish at a depth of 37 meters (Anonymous 1982). Ralph Horn, a commercial seafood dealer, says that schools of red drum have been monitored commonly at depths of approximately 40 to 70 meters of water. Simmons and Breuer (1962) reported schools 19 km offshore.

The above patterns are not presented in most recent literature sources on the red drum, and generally that fish is thought not to undergo extensive migrations (Perret et al. 1980). Data from Mississippi and from all references, however, can be superimposed on the patterns described above. The large sample of returned tagged fish, 47.5% of 690 fish from five Schlitz tagging programs in Florida, produced 91.2% of those recoveries from near the location of release (Beaumariage 1969). Similar results also occurred in Texas (Bryan 1971, Matlock and Weaver 1979) and Louisiana (Adkins et al. 1979). Those and other authors assume no more than a short spawning migration for two primary reasons. First, 1- and 2-year-old fish and occasionally older ones that they tagged probably did not enter the offshore migrating schools. Matlock et al. (1977) reported fish remaining in Texas bays for three to four years to mature before they migrated to the Gulf of Mexico. Second, most older fish appear to remain in one general area for several months, at least during some seasons in the northern Gulf of Mexico. They presumably remain when food is readily available (Overstreet and Heard 1978). The immigration of large fish to near shore and bay areas in spring and migration to the Gulf have been reported in Texas by Pearson (1929), Gunter (1945), Miles (1950), and Simmons and Breuer (1962), although the latter thought the movements might be less pronounced and cover shorter periods. Pearson (1929) thought an apparent decrease in the number of large fish in bays and lagoons during summer could be explained at that time by an increase of power boats, water traffic, and other disturbances by people. Apparent migrations based primarily on catch records and on observations by a menhaden spotter pilot are also reported along the Atlantic coast. Adults apparently move north to North Carolina capes from Florida in spring and south in fall (Yokel 1966). Some of these fish apparently migrate as far as Virginia and into Chesapeake Bay (Yokel 1966), and Welch and Breder (1924) discussed a possible summer migration to New Jersey from the south, arriving in May and remaining until October. Some fish apparently spent winter just south of Cape Hatteras (Pearson 1932, Yokel 1966).

Individual foraging while in estuarines may be considerable, even if a fish remains within a small general area. Carr and Chaney (1976) attached an ultrasonic transmitter to a 3.2 kg fish in the Intracoastal Waterway in Florida. It moved south about 1.6 km within 1½ hrs after release and then 1.2 km north during the next 5½ hrs, always traveling against

16 and 17 showing an infection by a gram negative rod bacterium. The bacterial involvement appeared localized to a general central focus as did the oocytes with the wide zona pellucida (= zona radiata). 20. Taylor's method for bacteria showing small concentration of gram-negative, rod bacterium.

Figure 21. Testis of virgin 333 mm SL specimen of *Sciaenops ocellutus* in May with few spermatozoa in peripheral tubule lumens.



Figures 22–30. Sectioned testicular tissue of *Sciaenops ocellatus.* 22. Typical area of compact, active, gravid testis in 710 mm SL fish in August showing all stages of development. 23. A different gravid testis than in Figure 17 in August with tubule lumens expanded with spermatozoa. 24. Spermatogonia associated with Sertoli cells. Note vacuolated primary spermatocysts and other stages of spermatogenesis through the spermatid. 25. A composite showing secondary spermatocytes, early (relatively large and light staining) and late (smaller and stained more darkly) spermatids, and flagellated spermatozoa. 26. Germinal cysts with flagellated spermatozoa in middle and flagellated, larger spermatids to the right. Note spermatocytes to the left. 27. Spermatozoa with typical vacuolated spermatocytes near lower portion of field. 28. Post-spawning testis of 665 mm SL fish misdiagnosed as "developing IV" in October. This testis has no actively producing areas, but the lumens are filled with residual spermatozoa. The testes of some other larger fish diagnosed as developing IV in October had few or no spermatozoa. 29. Resting stage of 728 mm SL fish misdiagnosed as "gravid" in October, but filled with considerable residual spermatozoa. 30. One of relative few "active" areas in same testis shown in Figure 29 showing a few PAS-positive granular leukocytes.

tidal flow and entering the mouths of almost every creek encountered. At night, it laid in a deep hole 140 meters up a small creek. Even though a malfunctioning receiver terminated the project on the third day, long-lasting tracking devices should prove rewarding in critically following movements of both young and old fish.

As indicated by tagged 1- and 2-year-old red drum in Mississippi and elsewhere, movements apparently consist mostly of foraging and of responses to temperature and salinity. Recreational fishermen caught large numbers of 0.68 to 0.77 kg fish from protected areas of Back Bay of Biloxi, with the larger ones caught in or near the relatively high salinity of Mississippi Sound (McIlwain 1978). Catches began in summer and increased into autumn.

Fluctuations in the first two year classes are especially apparent because fish grow so rapidly during those years. These depend on several factors, mostly abiotic ones, but also on biotic ones. Of the especially critical abiotic factors, temperature and photoperiod control spawning, temperature controls hatching, currents control dispersal, and a variety of environmental conditions and toxicants affect the health of larvae and juveniles. These latter factors will be discussed in more detail in a later section. Added to these barriers is the amount of available food for the different stages. In the laboratory, larvae required food on day 3 after hatching, at least when fed rotifers, or a reduction occurred in their growth and survival. If not fed by day 5, all fish died, even though survival was prolonged for a few (Roberts, Morey et al. 1978). The location and in some cases number of spawning adults relative to sufficient food and the conditions in estuaries where young develop probably determine local abundance of year-classes.

Parasites, Diseases, Mortalities, and Abnormal Conditions

All fish utilized in this study did not undergo a critical examination for parasites. Nevertheless, several were examined as were others before many aspects of this study began. In some cases, only specific or conspicuous parasites were noted. These records as well as records reported by other workers occur in Table 9. Limitations concerning these records are the same as discussed for *Cynoscion nebulosus* (see Overstreet 1983).

Several microbial organisms also occur in or infect the red drum. Most of these have not been identified or reported. One agent that has produced epizootics occurred along the Texas coast. This anaerobic bacterium, either or closely related to *Eubacterium tarantellus* Udey, Young, and Sallman 1977, caused the red drum to become disoriented and swim in an uncoordinated manner (Henley and Lewis 1976). The infection that localized in part of the ovary of a fish in the present study (Figures 19–20) probably had little influence on the host's health, but others involved with secondary infections may. Some red drum from ponds in Alabama had the pathogenic *Vibrio anguillarum* Bergman 1909 in kidney and liver tissue, *Aeromonas hydrophila* (Chester) from kidney tissue and a lesion, and an unidentified light-brownish colored fungus on gills, skin, and fins (Trimble 1979). Colura (personal communication) found vibriosis in red drum in Texas (Palacios) ponds, and that or other bacteria killed many fingerlings in the same ponds at a later date when reared in fresh water from a well containing less than 15 ppm $CaCO_3$ but not when in water from a different well with a higher concentration of $CaCO_3$ (Stickney and Davis 1982).

Red drum in Mississippi Sound and associated bayous and probably most other estuarine regions where it lives is susceptible to many of the same or similar parasites and diseases as the spotted seatrout (e.g., Figure 33, Overstreet 1983). Figure 34 shows a ciliate and Figure 35 shows an isopod, both infesting and harming young fish from a bayou. Overstreet (1983) discussed the apparent effect by that isopod on the seatrout. Some of the adult copepods can also damage gill tissue (e.g., Causey 1953b), whereas the chalamus can harm larval and postlarval fish (Overstreet 1983) (Figure 36). The red drum also is vulnerable to additional diseases and stresses not normally encountered by seatrout, especially when in the Gulf of Mexico with its relatively high salinity. One atypical case involved a barnacle, *Balanus improvisus,* which covered the epithelium of much of the flanks in four areas on the right side and three larger areas on the left side of a 642 mm SL fish and exhibited associated inflamed lesions (Figures 37–38). The single infested red drum was caught in a trammel net along with black drum and striped mullet at Marsh Point, Ocean Springs, on 20 March 1980. Perhaps the initial set of larvae or even all the barnacles attached to areas abraded from a net or some other source and then subsequently caused further inflammation and secondary infection. *Balanus improvisus,* a species that can live in brackish water, typically occurs on rocks, wood, shore installations, ships, and molluscan shells, but has been reported from algae, crustaceans, and fish (Henry and McLaughlin 1975).

An unknown condition or conditions kill many large drum. Possible explanations occur for many cases. As an example, on 18 May 1979, 125 specimens of dead red drum were examined; they had washed ashore onto Petit Bois and Horn islands. They measured 86 ± 5 cm SL, their gills were pale, and they appeared to have died a few days earlier. No other species of dead fish were observed. Fishermen called GCRL to complain that on 17 May about 400 such fish occurred floating up to a distance of 1.5 km from shore. According to Thomas McIlwain (personal communication) a mass of water with high salinity, low temperature, and low concentration of dissolved oxygen (0.7 ppm) which could explain these deaths with pale gills was identified on the bottom south of the barrier islands at that time. In September 1969 during a period characterized by 30°C water containing organic pollution, with a low concentration of dissolved oxygen (0.0 to 0.6 ppm) and variation in salinity throughout the water column, 320 red drum 300 to 600 mm TL plus large numbers of other fishes died in the Arroyo Colorado in Texas (Bryan 1971).

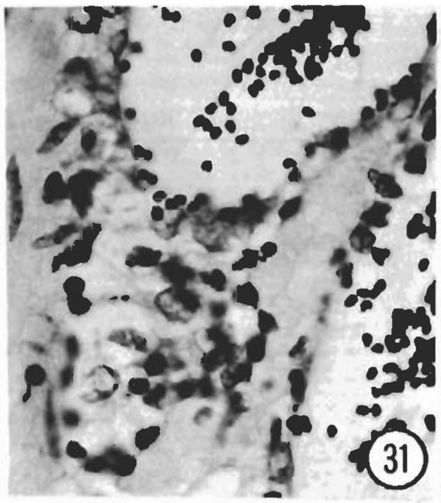
The 3 July 1983 *The Times-Picayune/The States-Item* (New Orleans) showed a picture of a large red drum that was apparently one of thousands that had died from an unknown cause and washed ashore along a 16 km stretch of Padre and Mustang islands in Texas. Over the years, commercial fishermen have talked about many thousands of floating dead red drum in the Gulf of Mexico or adjacent waters that they thought had died from "redtide" or some other factor. When local people recall mass mortalities, they often mention ones limited to red drum, as are some of those mortalities indicated above. Kenneth Melvin (personal communication) reported to me another such case restricted to red drum, but these fish, about 2,000 in number, were fingerlings; these dead fish were floating off Bellefontaine Point near Ocean Springs on 25 July 1978. Cause for some "mysterious" deaths can be assumed, such as those resulting from freshwater that accompanied the opening of the Bonnet Carré Spillway in 1973 to relieve water pressure on Mississippi River levees and those resulting from rapidly decreasing temperatures in January 1977 and February 1978 (Adkins et al. 1979, Kenneth Melvin, personal communication).

The red drum can survive most environmental conditions tolerated by hardy fishes. In summary from Simmons and Breuer (1962), they live in fresh water to that with at least 50 ppt, but as adults they occur most abundantly in 30 to 35 ppt. The red drum has been observed in 2 to 33°C in natural waters, but it moves into deep water when extreme temperatures occur. Like seatrout and most fishes (Gunter 1941, Overstreet 1974, 1983) it cannot withstand a rapid drop in temperature. Small juveniles are probably more sensitive to cold than large ones (Moore 1976). Because of the habits of young fish, they are especially vulnerable to environmental stresses. On one occasion, Bryan (1971) counted over 1,100 dead first year red drum trapped around the base of a dam on the Cayo Atascosa in Texas which had been established to impound water in winter. Juvenile fishes entered the impoundment each spring seeking low saline water. Of those that became established near the dam in summer during low tides, some or all frequently became trapped and died in the resulting hot stagnant water. Actually, more potentially stressful conditions occur for both adults and juveniles in estuaries and in culture conditions than in the Gulf of Mexico.

Eggs and larvae are especially vulnerable to environmental conditions. Eggs are fertilized and hatch favorably at 30 ppt at 22 to 23°C, and larvae developed favorably in 23 to 25°C (Holt, Johnson et al. 1981). When reared at 30°C, the yolk-sac stage lasted 40 hr compared to 84 hr at 20°C. The optimum condition for both hatching and 24 hr survival was determined to be 30 ppt at 25°C (Holt, Godbout, and Arnold 1981). That study showed the importance of a high salinity concentration for both hatching and survival during the first 24 hr, if the temperature was not 25°C. The acceptable salinity range of 10 to 40 ppt at 25°C decreased to a range of 5 to 30 ppt with a corresponding decrease in hatching as the temperature varied from 25°C. Below 25 ppt, eggs sank to the bottom. Salinity played little role in 2-week survival of the larva, but temperature became increasingly important as the larva developed. Assuming that spawning typically occurred in water with a high salinity, Holt, Godbout, and Arnold (1981) pointed out that spawning success and subsequent strength of the resulting year-class of fish can be adversely affected by early onset of seasonal low temperatures. Fingerlings as small as 40 mm TL introduced into freshwater over a 3 hr period survived, but showed stress; those 125 to 140 mm TL showed little or no stress (Lasswell et al. 1977). Temperature and salinity combinations that cannot be tolerated by fry and fingerlings have not been well established, but, as suggested earlier, such combinations probably influence greatly the abundance of a year class.

All sizes of fish are sensitive to high salinities combined with high temperature, but to a different degree (Simmons 1957). In the Laguna Madre of Texas, individuals of red drum 13 to 23 cm long occurred abundantly in the upper area, provided that the salinity there was not above 45 ppt. Populations in Texas were severely limited by 50 ppt (Simmons 1957). Juveniles stocked into ponds receiving heated discharge water from a power plant near Baytown, Texas, grew well and survived in water up to 35°C (Luebke and Strawn 1973). Some fish, however, apparently died from handling stress followed by introduction of 39°C water to refill a pond. Fry in ponds cannot survive low dissolved oxygen concentrations of 0.6 to 1.8 ppm (Colura et al. 1976). As mentioned above, when water masses with unusually low dissolved oxygen concentration develop, even in the Gulf of Mexico, numerous adult fish apparently succumb before avoiding the poor conditions. Simmons and Breuer (1962) and Davis (1980) suggested that environmental

Figures 31–39. Micrographs showing testes and symbionts of *Sciaenops ocellatus*. 31. Close-up of an area with germinal cells in same testis shown in Figure 29. 32. Inflammatory focus in developing IV, 855 mm SL fish in April, showing an abundance of PAS-positive granular leukocytes and lymphocytes as well as four giant multinucleate cells. 33. A 1.67 mm long metacestode phase of *Rhinebothrium* sp. occurring in the lumen of the intestine and causing no harm to the fish host. 34. A rather heavy trichodinid ciliate infestation on a gill lamella of a juvenile red drum that had just been caught in a bayou. 35. The isopod *Lironeca ovalis* eroding the gills of a juvenile red drum from a marsh. 36. A larval caligid attached by its frontal filament to the base of the dorsal fin of a 9 mm SL postlarval red drum. Another copepod occurred in the dorsum. 37. Rear portion of a red drum with "fin-rot syndrome" and an infestation of *Balanus improvisus* attached to epithelium overlying scales. Note the multiple ocelli on the fish. 38. Close-up of Figure 36 showing barnacles and inflammation. 39. Larval specimen of the nematode *Contracaecum multipapillatum* encapsulated along periphery of liver.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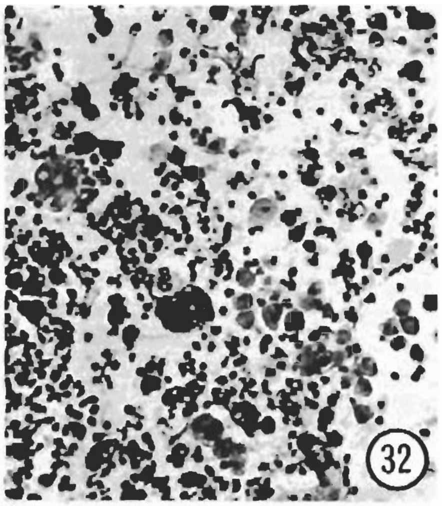
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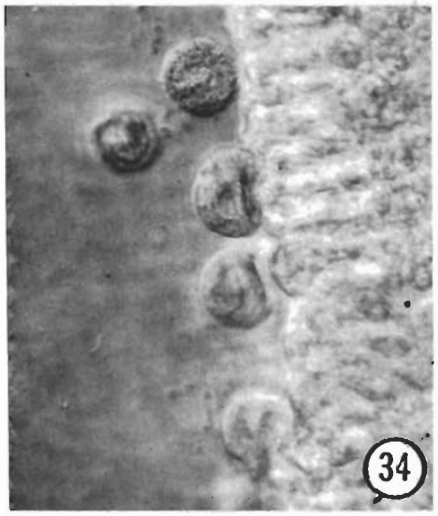
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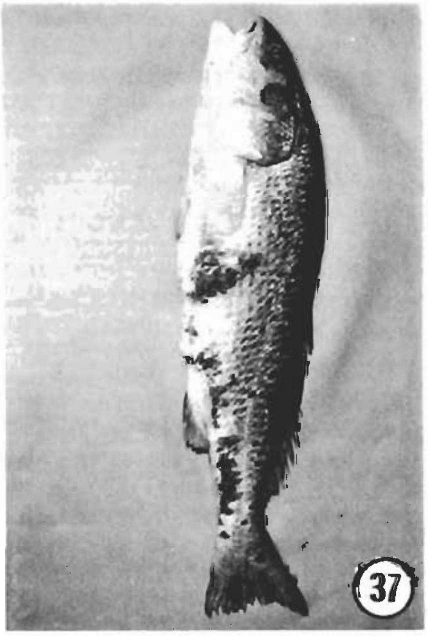
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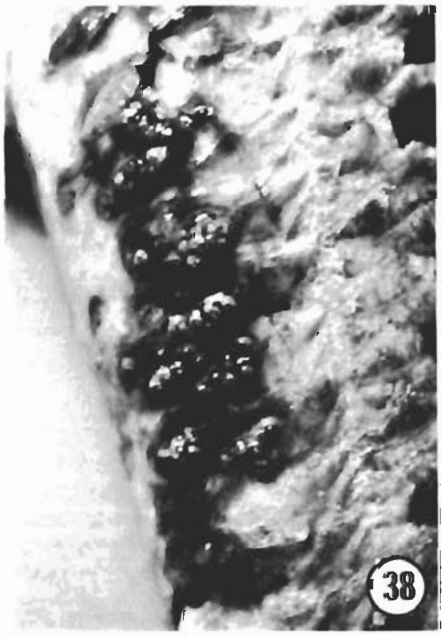
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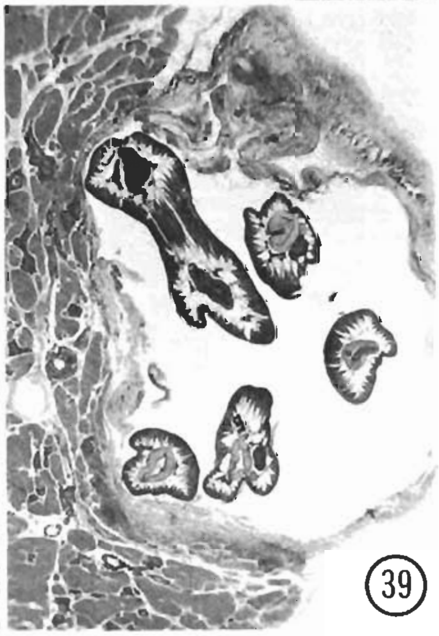
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TABLE 9.

Partial list of parasites from *Sciaenops ocellatus*.

Parasite	Site	Geographical locality	Reference
Sarcomastigophora			
Blastodidiidae			
Amyloodinium ocellatum (Brown 1931)	Gills and skin	Alabama (ponds)	Trimble (1979)
	Gills	Experimental infection	Lawler (1980)
Cryptobiidae			
Cyrptobia sp.	Gills	Alabama (ponds)	John Hawke (Personal communication)
Microspora			
Microsporida			
Pleistophora sp.	Liver	Mississippi	Present study
Ciliophora			
Hymenostomatia			
Cryptocaryon irritans Brown 1951	Gills, body	Palacios, TX (ponds)	Colura (Personal communication)
Peritrichia			
Trichodina spp.	Gills, fins, skin	Alabama (ponds)	Trimble (1979)
		Mississippi, St. Marks, FL, Palacios, TX (ponds)	Present study
Tripartiella obliqua Lom 1963	Gills	Alabama (ponds)	Trimble (1979)
Ambiphrya sp.	External	Alabama (ponds)	Trimble (1979)
Myxozoa			
Myxosporea			
Henneguya ocellata Iversen and Yokel 1963	Intestinal and cecal epithelium	Beaufort, NC; Everglades National Park, FL	Linton (1905), Iversen and Yokel (1963)
Cestoda			
Tetraphyllidea			
"Scolex polymorphus"	Intestine, pyloric ceca	North Carolina	Linton (1905)
"Scolex spp., type large"	Intestine, pyloric ceca	Mississippi	Present study
"Scolex spp., type small"	Intestine, rectum	Mississippi	Present study
Rhinebothrium sp.	Intestine	Mississippi, St. Marks, FL	Present study
Tetrarhynchea			
Poecilancistrium caryophyllum (Diesing 1950)	Muscle	Florida	Hutton (1964)
(also as *P. robustum*)		Texas	Schlicht and McFarland (1967)
		Mississippi	Overstreet (1977, 1978)
"Spaghetti worm" similar to P. *robustum*	Muscle	Laguna Madre, TX	Simmons and Breuer (1962)
Monogenea			
Udonellidae			
Udonella caligorum Johnston 1835		Palacios, TX (pond)	Present study
Spoiled specimens		Port Aransas, TX	Koratha (1955)
Digenea			
Acanthocolpidae			
"*Stephanostomum tenue*"		Beaufort, NC	Linton (1905)
Aporocotylidae			
Cardicola sp.	Heart, branchial vessels	Mississippi	Overstreet and Lawler, Present study
Bucephalidae			
Bucephaloides megacirrus Riggin and Sparks 1962	Intestine	Grand Isle, LA; Alligator Harbor, FL	Sparks (1958), Loftin (1960), Riggin and Sparks (1962)
	Pyloric ceca and intestine	West Florida	Hutton (1964), Nahhas and Short (1965)
		Barataria Bay, LA; Mississippi	Corkum (1968), Present study
Cryptogonimidae			
Metadena spectanda Travassos, Freitas, and and Bührnheim 1967	Intestine, pyloric ceca	Mississippi, Palacios, TX (pond)	Present study
Metadena spectanda metacercaria	Fins	Mississippi	Present study

TABLE 9 (Continued)

Partial list of parasites from *Sciaenops ocellatus.*

Parasite	Site	Geographical locality	Reference
Didymozoidae			
Metacercaria	Intestine, body cavity	Mississippi; St. Marks, FL	Present study
Hemiuridae			
Lecithochirium mecosaccum Manter 1947	Stomach	Alligator Harbor, FL	Nahhas and Short (1965)
Stomachicola rubea (Linton 1910)	Encysted in muscle tissue	Sapelo Island, GA	Sinclair et al. (1972)
Lepocreadiidae			
"*Lepocreadium areolatum*"		Beaufort, NC	Linton (1905)
Opecoelidae			
Opecoeloides fimbriatus (Linton 1934) (as *Fimbriatus f.*)	Intestine	Alligator Harbor; Mud Cove; St. George Island, FL	Nahhas and Short (1965)
		Grand Isle, LA	Sparks (1958)
		Experimental	Hutton (1964)
(as *Distomum vitellosum* in 1905)		Beaufort, NC	Linton (1905, 1934)
Opecoeloides vitellosus (Linton 1900)	Rectum	St. Marks, FL	Present study
Unidentified larva		Everglades National Park, near Chokoloskee, FL	Yokel (1966)
Acanthocephala			
Polymorphidae			
Polymorphid cystacanth	Mesentery	Mississippi	Present study[1]
Southwellina hispida (VanCleave 1925) cystacanth	Mesentery and embedded in gonad	Mississippi	Present study[1]
Nematoda			
Anisakidae			
Hysterothylacium reliquens (Norris and Overstreet 1975)	Stomach and intestine	Northern Gulf of Mexico 30°10′N, 87°45′W, 11 meters, Mississippi Sound	Deardorff and Overstreet (1981 a), Present study
"*Ascaris* sp."	Digestive tract?	Sandy Hook, NJ	Linton (1901)
?*Hysterothylacium reliquens* larva	Mesentery	Mississippi	Deardorff and Overstreet (1981b)
"*Ascaris* sp." immature	Peritoneum	Woods Hole Region	Linton (1901)
Goezia pelagia Deardorff and Overstreet 1980	Intestine	Mississippi	Present study
Goezia sp.		Palacios, TX (pond)	Deardorff and Overstreet (1980a)
Contracaecum multipapillatum (von Drasche 1882) larva	Mesentery	Mississippi	Deardorff and Overstreet (1980b)
	Kidney, liver, other visceral tissue	Mississippi, Everglades National Park	Present study
"*Contracaecum collieri*"		South Carolina?	Lawler (1978)
Contracaecum sp.	Mesentery of gut	Everglades National Park	Hutton (1964),Yokel (1966)
Camallanidae			
Spirocamallanus cricotus Fusco and Overstreet 1978	Intestine	Mississippi	Present study
Cucullanidae			
Dichelyne fastigatus Chandler 1935	Intestine	Galveston Bay, TX	Chandler (1935)
"*Dichelyne lintoni* (Barreto 1922)"		North Carolina	Lawler (1978)
Dichelyne sp. (as *Heterakis* sp.)		Beaufort, NC	Linton (1905)
Dichelyne sp.	Intestine	Mississippi	Present study
"Small roundworm"	Ovary - egg cases	Texas	Elam (1971)
Annelida			
Hirudinea			
Piscicolidae			
Calliobdella vivida (Verrill 1872)	Mouth cavity	Mississippi	Present study
Myzobdella lugubris Leidy 1851	Mouth cavity, branchial cavity	Mississippi	Sawyer et al. (1975)
Branchiura			
Argulidae			
Argulus bicolor Bere 1936	Fins	Mississippi	Present study[2]

TABLE 9 (Continued)

Partial list of parasites from *Sciaenops ocellatus*.

Parasite	Site	Geographical locality	Reference
Copepoda			
Anthosomidae			
Lernanthropus longipes Wilson 1932		Beaufort, NC	Pearse (1948, 1952)
Lernanthropus paenulatus Wilson 1922	Gill	Texas	Causey (1953b)
Lernanthropus sp.	Gill	Mississippi	Present study[2]
Caligidae			
Caligus annularis Yamaguti, 1954	Mouth	Sapelo Island, GA	Present study[3]
Caligus bonito Wilson 1905	Body	Upper Laguna Madre, TX	Simmons (1957), Simmons and Breuer (1962)
Caligus haemulonis Krøyer 1836 (as *C. haemuronis*)	Mouth	Texas, Grand Isle, LA	Pearse (1952), Causey (1953a, 1953b)
Caligus latifrons Wilson 1905		Upper Laguna Madre, TX	Simmons and Breuer (1962)
Caligus mutabilis Wilson 1905		Beaufort, NC	Pearse (1948)
Caligus rapax Edwards 1840 (as *C. repax*)		Upper Laguna Madre, TX	Simmons (1957), Simmons and Breuer (1962)
Caligus sciaenops Pearse 1952a	Gills	Texas	Pearse (1952)
Echetus typicus Krøyer 1864	Gills, branchial cavity, operculum	New Orleans, LA	Krøyer (1864)
		Port Aransas, TX, Grand Isle, LA	Causey (1953a, 1953b, 1955)
		West Florida	Bere (1936)
		Texas	Pearse (1952)
		North Carolina to Apalachee Bay, FL	Ho (1966), Yokel (1966)
		Mississippi	Present study
Sciaenophilus tenuis van Beneden 1852	Gills	Mississippi	Present study[2]
Lepeophtheirus cf. *longipes* Wilson, 1905	Gills	Mississippi	Present study[3]
Lernaeopodidae			
Neobrachiella gulosa (Wilson 1915) comb. n. (previously as *Brachiella g.*)	Gills, branchial cavity, and under operculum	Wilmington, NC	Yokel (1966)
		Sapelo Island, GA	Present study[2]
		New York-Texas	Wilson (1915, 1932), Ho (1977)
		Texas	Causey (1953b, 1955), Simmons and Breuer (1962), Pearse (1952)
		Grand Isle, LA	Causey (1953a)
		West Florida	Bere (1936), Hutton (1964), Yokel (1966)
		Mississippi	Present study
Neobrachiella intermedia (Bere 1936) comb. n. (previously as *Brachiella i.*)	Gills and inner surface of operculum	West Florida	Bere (1936), Yokel (1966)
		Sapelo Island, GA	Present study
		Wilmington, NC	Yokel (1966)
Pennellidae			
Lernaeenicus radiatus (Lesueur 1824)		Wilmington, NC	Yokel (1966)
	Dorsal fin	Barataria Bay, LA	Hein et al. (1982)
		Sapelo Island, GA, Mississippi	Present study[2]
Isopoda			
Cymothoidae			
Anilocera laticauda Edwards 1840		Texas	Pearse (1952)
Lironeca ovalis (Say 1818)	Gills	Mississippi	Present study
Nerocila acuminata Schioedte and Meinert 1910		Laguna Madre, TX	Simmons and Breuer (1962)
	Dorsal fin	Mississippi	Present study
Cirripeda			
Balanus improvisus Darwin, 1854	Scales	Mississippi Sound	Present study[4]

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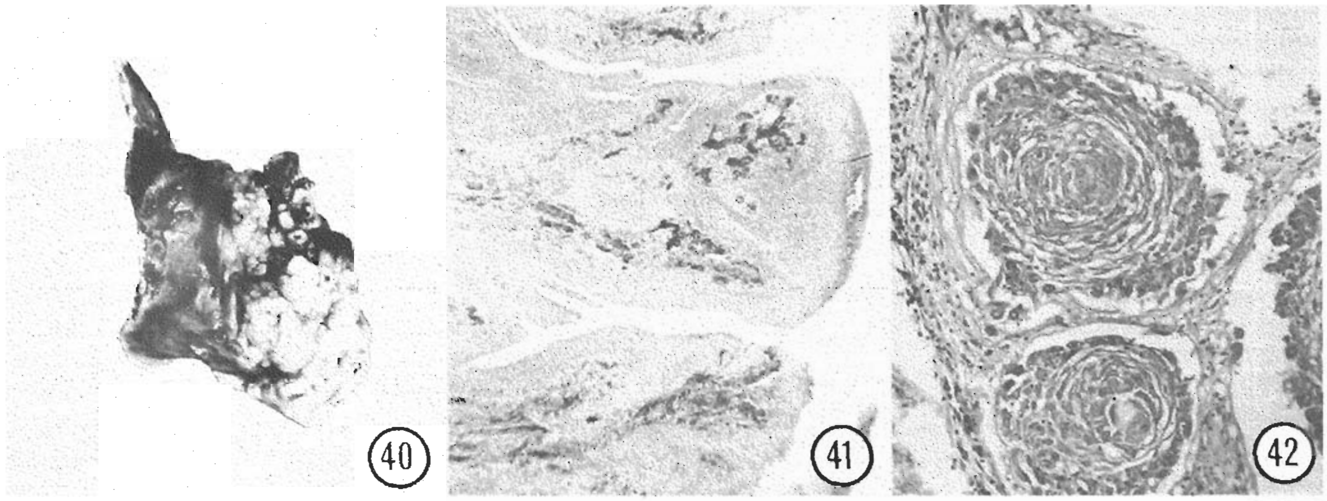
[1] Identified by Gerald D. Schmidt, University of Northern Colorado.

[2] Verified by Z. Kabata, Fisheries Research Board of Canada, Nanaimo, British Columbia.

[3] Identified by Z. Kabata.

[4] Identified by Patsy A. McLaughlin, Florida International University, Miami, Florida.



Figures 40–42. Epidermal papilloma on *Sciaenops ocellatus.* 40. Gross view of 7 by 5 by 4 cm papilloma attached to snout (photo by John Harshbarger, Smithsonian Institution). 41. Low-power view showing papillomatous lesion. The darkly stained spaces are highly vascular fibrotic areas. 42. Medium-power view of pegs of epithelial cells in vertical section.

conditions influenced variations in stocks, at least in Texas and Everglades National Park.

When in culture, the drum can be susceptible to similar diseases that affect the spotted seatrout (Overstreet 1983). *Amyloodinium ocellatum* was held responsible for at least 18% of the mortalities in a study in Alabama (Trimble 1979) and considered the most serious disease agent on red drum in ponds in Palacios, Texas (Colura, personal communication). *Cryptocaryon irritans,* the marine counterpart of *Ichthyophthirius multifiliis* Fouquet 1876 infesting freshwater fishes, also caused mortalities in Texas.

The same parasites that represent a potential public health problem (*Hysterothylacium* type MB larva Deardorff and Overstreet 1981b) and esthetic-economic problems (*Poecilancistrium caryophyllum* and *Stomachicola magna*) in the spotted seatrout may also infect the red drum, but to a lesser degree (e.g., Overstreet 1977, 1983). Additionally, the red drum often has a relatively large, about 2 cm long, conspicuous nematode infecting the kidneys, liver (Figure 39), serosa of alimentery tract, and mesentery. This worm, the juvenile of *Contracaecum multipapillatum,* also infects mullets and causes numerous people to discard or not eat either wormy or all mullet. People typically react the same way with infected red drum, but usually only younger fish exhibit infections. The worm matures in cormorants, pelicans, the anhinga, and at least the Louisiana heron and green heron, and it did not survive or cause pathological responses in tested experimental mammalian hosts. Presumably, it does not harm man (Deardorff and Overstreet 1980b).

Several taxonomic and systematic problems concerning parasites need to be solved. Do all the copepod species of *Caligus* Müller 1785 listed in Table 9 infest the red drum? The finding of *Caligus annularis* represents the only report of that species in other than the Indo-Pacific area, and perhaps the species also infests several other Atlantic fishes. Before this study, *Neobrachiella gulosa* and *N. intermedia* had been considered in the genus *Brachiella.* Kabata (1979) revised the genus *Brachiella* and erected *Neobrachiella* for several species formerly in *Brachiella,* and the two closely related species from the red drum belong among them. Seldom do closely related sympatric speices infest the same individual, as these do, and the factors which allow both to occur together should be investigated. Does more than one nematode species of *Dichelyne* Jägerskiöld 1902 infect the red drum? Chandler (1935) described *D. fastigatus* from the red drum on the basis of one male and an immature female. He noted that the male's ventral sucker was "practically absent." Stromberg and Crites (1972) examined Chandler's material, concluded that it was adequately described, and considered a preanal sucker absent and the intestinal cecum dorsally located. Representative material from Ocean Springs which may or may not be conspecific had a preanal sucker and an intestinal cecum located dorsally, laterally, or ventrally. Specimens of cucullanids from the red drum along the Atlantic and from the Gulf of Mexico coasts need further study. Stromberg and Crites "discarded" the name *D. lintoni* and described *D. bullocki* Stromberg and Crites 1972 for the species from *Fundulus heteroclitus* (Linnaeus) in New Hampshire. I find the same species commonly in *Fundulus grandis* Baird and Girard and *F. similis* (Baird and Girard) in Mississippi, and it differs from that species in the red drum. The digenean *Opecoeloides vitellosus* infects the red drum at least at St. Marks, Florida, but the record of that species figured by Linton (1905) is clearly *O. fimbriatus* as later cleared up by Linton (1934). The two species are not conspecific as suggested by Stunkard (1978).

A few anomalous specimens of red drum have been reported. A 686 mm TL fish from Texas had no eyes (Ward and Gunter 1962). Another specimen appeared eyeless, but had abnormal eyes that were covered with partially translucent skin, perhaps in response to the high salinity water of Laguna Madre, Texas (Gunter 1945, 1956). Also, three specimens caught at different times but from the same general area in Texas had reversed scales (Gunter 1948). The red drum typically has a large black ocellus, or spot, above the lateral line at the base of each side of the caudal peduncle, occasionally with one or a few additional ocelli located anteriorly. Simmons and Breuer (1962) counted 219 ocelli on one fish; the fish with the attached barnacles in this study had 35 on the right side and 30 on the left. Several adult fish being tagged had regenerated portions of their caudal fins. A few other fish being tagged had a golden coloration. Rather than anomalous, I considered that coloration a normal result, perhaps metabolic in nature, from having recently spent time in low salinity or fresh water. I have noticed that the tarpon, *Megalops atlantica* Valenciennes, from fresh water in southern Florida had a similar golden color, whereas individuals from salt water appeared silvery. A courting male red drum has a different coloration than a female or noncourting male. Above the lateral line, the body becomes dark red to bluish-gray and below that line it becomes pale (Arnold et al. 1977).

The red drum is susceptible to tumors. In 1978, A. G. Johnson sent to the Smithsonian Instutition a portion of the snout of a fish caught by Gerald P. Kershner at St. Andrews State Park, Panama City, Florida, with a benign epidermal papilloma (RTLA 1904). Well-differentiated epidermal cells extended as pegs and crypts into the dermis (Figures 40–42). A basal cell boundary of these extensions with the intervening connective tissue of the dermis suggests that invasion had not taken place and that the neoplasm was not malignant. Additionally, Elam (1971) found, but did not examine, large tumors in the ovaries collected from two spawning females in Texas.

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