SPAWNING, AGE DETERMINATION, LONGEVITY, AND MORTALITY OF THE SILVER SEATROUT, *CYNOSCION NOTHUS*, IN THE GULF OF MEXICO[1, 2]

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ABSTRACT

Cynoscion nothus females from the Gulf of Mexico off Texas matured at 140-170 mm SL as they approached age I. Spawning occurred from early May through late October but primarily in two periods, May and August-September. Greatest spawning occurred in the August-September period when two distinct spawned groups (intrayear class cohorts) were produced. The multiple-spawned group structure within a year class may be important to the population dynamics and stability of *C. nothus*. This species reached 130-190 mm SL at age I. Only one year class occurred or dominated in any one month, and only two year classes were ever present at once. The largest specimen captured was 190 mm SL, and 99% were <160 mm. The maximum life span (t_L) was only 1-1.5 years off Texas but might be 2 years in the northcentral gulf. The total annual mortality rate was best estimated at 99.83% and probably is no lower than 90% if the life span is as long as 2 years. Larger *C. nothus* almost disappeared during winter suggesting an offshore movement for overwintering.

The silver seatrout, *Cynoscion nothus*, smallest of four congeners found along the U.S. Atlantic coast, ranges from Chesapeake Bay to the Bay of Campeche (Hildebrand and Schroeder 1928; Hildebrand 1955). *Cynoscion nothus* is one of the more abundant fishes of the nearshore waters of the northern Gulf of Mexico (Hildebrand 1954; Moore et al. 1970; Gutherz et al. 1975). It is not considered an estuarine species (Ginsburg 1931; Hildebrand and Cable 1934), but small numbers of *C. nothus* have been taken in bays throughout the year (e.g., Gunter 1938, 1945; Swingle 1971; Dahlberg 1972).

Despite its abundance, no published study has been directed at *C. nothus* in the gulf. Little is known about its life history, although Mahood (1974) described spawning and monthly size composition in Georgia waters. General notes on *C. nothus* appear in many faunal studies, including Hildebrand and Cable (1934), Gunter (1938, 1945), Chittenden and McEachran (1976), and in a literature review by Guest and Gunter (1958).

This paper describes age determination for silver seatrout, spawning seasonality and periodicity, growth, mortality, diel changes in availability, and total weight-standard length, girth-standard length, and standard length-total length relationships.

METHODS

Collections were made monthly from February through December 1977 and in March 1978 in the Gulf off Port Aransas, Tex., aboard the Texas Parks and Wildlife Department's RV *Western Gulf*, using a 13.7 m otter trawl with 5.1 cm stretched mesh in the cod end. Stations were usually occupied at 11 m depth at night and at 7, 15, and 18-24 m during the day. Additional night collections were made from May through October 1977 at 20-22, 29-31, and 38 m.

Cynoscion spp. were fixed in 10% Formalin[5] and transferred to 40% isopropanol before processing. *Cynoscion nothus* were separated from *C. arenarius* primarily by comparing the anal fin base to the eye width, a procedure based on the comparatively low anal fin ray counts and larger eye size that Ginsburg (1929) reported in *C. nothus*. The anal fin width equals or is only slightly greater than eye width in *C. nothus*, but

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it is about 1.5-2 times the eye width in *C. arenarius*. Standard length (SL) was measured on all fish captured off Port Aransas. A random number table was used to select 300 specimens each month for intensive processing to determine age, total weight (TW), standard length, girth (G) at the anterior origin of the dorsal fin, sex, gonad weight to the nearest 0.1 g, and gonad maturity stage. All specimens were processed if <300 were collected in any month, and all fish larger than the following sizes were processed: 150 mm SL in April, 75 mm in September, 75 mm in October, 150 mm in November, and 110 mm in December. Maturity stages were assigned to immature and female fish (Table 1) using a slight modification of Kesteven's system (Bagenal and Braum 1971). Scales were taken above the lateral line over the anal fin, where they normally persisted. Cellulose acetate impressions were examined, using a scale projector initially, but a dissecting microscope was employed for a second reading made a year later. No scales were taken from fish <60 mm SL. Annuli were identified knowing the size and collection date of each fish and using standard criteria (Tesch 1971) and procedures used for *C. nebulosus* and *C. regalis* (Klima and Tabb 1959; Tabb 1961; Massman 1963; Merriner 1973). Specific characters used to identify annuli included 1) a definite clear zone between circuli in the anterior field (Fig. 1), 2) appearance of secondary radii *in conjunction with* the clear zone, 3) cutting over of circuli in the lateral field, and 4) appearance of these characters on all or most scales examined. Marks interpreted as false annuli appeared on only a few scales from a fish, usually lacked cutting over, or lacked a clear zone between circuli in conjunction with secondary radii.

TABLE 1.—Description of gonad maturity stages assigned to *C. nothus*.

Stage	Description
Immature	Gonads not visible or barely visible, sexes indistinguishable.
Maturing virgin	Gonads visible but very small, sexes indistinguishable to naked eye.
Early developing	Ovaries small, reddish, occupy 10% or less of body cavity, individual eggs not visible to naked eye.
Late developing	Ovaries orangish yellow, extend length of body cavity and occupy 25-50% of it, opaque eggs clearly discernible to naked eye.
Gravid	Ovaries occupy 50% or more of body cavity, up to half the eggs translucent.
Ripe	Ovaries fill over half the body cavity, no fat along inner margins of ovaries, over half the eggs translucent.
Spawning/spent	Ovary flaccid, partially or completely empty, no opaque eggs.
Resting	Ovaries small but distinguishable in fish large enough to be mature.

Additional specimens were collected monthly from October 1977 through July 1978 off Freeport, Tex., using double-rigged 10.4 m (34 ft) shrimp trawls with 4.4 cm stretched cod end mesh. These collections were made during the day at 7-9, 11, 15-17, 18, 27, 37, and 46 m. Total length (TL) was measured on all fish captured and converted to standard length, using regression relationships presented herein. These length frequencies were used to support findings based on collections off Port Aransas.

Spawned group identities (intrayear class cohorts) within each year class were indicated by specifying the year and probable month when they hatched, e.g., August$_{76}$. Spawning periodicity and group identities assume that a 30 mm TL

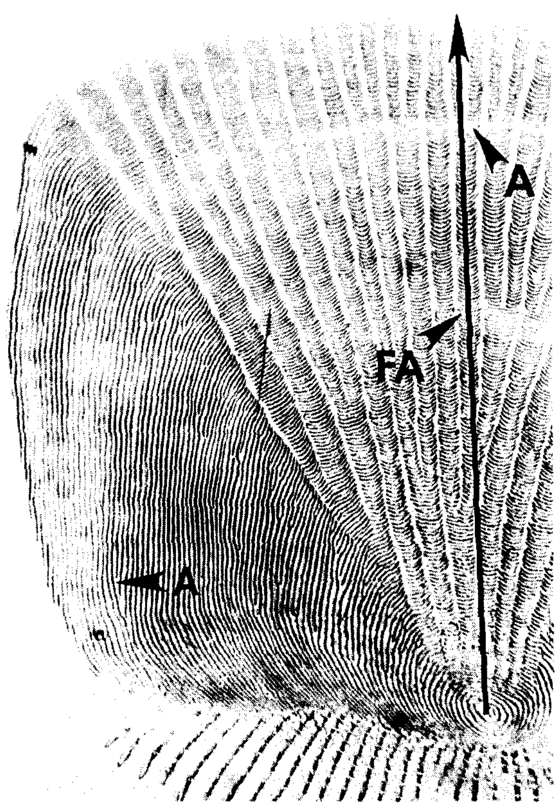

FIGURE 1.—Scale from a 177 mm SL *C. nothus* captured in June showing one annulus (A). The annulus is identified by cutting over in the lateral field and secondary radii in conjunction with a clear zone between circuli. A false annulus (FA) lacks cutting over and was absent on several scales. The axis depicted by the long arrow indicates where scale measurements were made.

(about 21 mm SL) at 1 mo of age for *C. regalis* (Welsh and Breder 1923) can be extrapolated to *C. nothus*. Size descriptions of spawned groups (Table 2) were based upon major portions of specific frequency distributions cited; approximate modes and/or midranges were used to describe central tendency as judged best, often ignoring extreme sizes. Ages when spawned groups disappeared (Table 3) assume hatching at the beginning of months specified in the group identity. Maximum life span was approximated in the sense of the Beverton-Holt model parameter t_L (Gulland 1969) following Alverson and Carney's (1975) definition that only about 0.5-1% of the catch exceeds age t_L or its corresponding lengths.

RESULTS

Spawning

Cynoscion nothus mature at 140-170 mm SL as

TABLE 2.—Growth data for spawned groups of *C. nothus* from the Gulf of Mexico off Port Aransas and Freeport, Tex. Unadjusted growth increments between indicated collection dates were converted to growth/30 d and plotted in Figure 7. Blank spaces in columns for modes and growth increments represent instances in which we consider size data (Figs. 3, 4) too unclear to warrant further analysis.

Spawned group and collection date	Age (mo)	Size range (mm SL)	Mode (M) or midrange (MR) (mm SL)	Unadjusted growth increment (mm SL)
		PORT ARANSAS		
September$_{77}$				
10-11 Nov. 77	2	30-60	47	
1 Dec. 77	3	40-75	55	8
August-September$_{76}$				
9 Feb. 77	5-6	40-75	49 (M)/57 (MR)	
14, 29 Mar. 77	6½-7½	40-90	57 (M)/65 (MR)	8 (M)/8 (MR)
5-6 Apr. 77	7-8	45-100	64 (M)/73 (MR)	7 (M)/8 (MR)
22-26 May 77	9-10	85-120	103 (MR)	30 (MR)
29-30 June 77	10-11	105-140	123 (MR)	20 (MR)
19 July 77	10½-11½	130-170	150 (MR)	27 (MR)
August-September$_{77}$				
8 Mar. 78	6-7	45-115		
May$_{76}$				
5-6 Apr. 77	11	130-160		
22-26 May 77	12½-13	155-170		
7 June 77	13	155-180		
29-30 June 77	14	160-185		
May$_{77}$				
19 July 77	2½	52-61		
2 Aug. 77	3	78		
20-28 Sept. 77	4½	70-115		
5 Oct. 77	5	80-125		
10-11 Nov. 77	6	100-155		
1 Dec. 77	7	115-150		
August$_{77}$				
20-28 Sept. 77	1½	25-70	41 (M)	
5 Oct. 77	2	35-85	56 (M)	15
10-11 Nov. 77	3	55-100	77 (M)	21
1 Dec. 77	4	75-115	95 (M)	18
		FREEPORT		
September$_{77}$				
5 Nov. 77	2	22-55	40 (M)	
2-3 Dec. 77	3	25-75	50 (M)	10
August-September$_{77}$				
19-20 Feb. 78	5½-6½	48-110	79 (MR)	
21-22 Mar. 78	6½-7½	42-112	77 (MR)/42 (L)	
14-15 Apr. 78	7½-8½	55-125	90 (MR)/55 (L)	13 (MR)/13 (L)
8-9 May 78	8½-9½	72-122	97 (MR)/72 (L)	7 (MR)/17 (L)
14-15 June 78	9½-10½	98-145	122 (MR)/98 (L)	25 (MR)/26 (L)
15-16 July 78	10½-11½	125-168	147 (MR)/125 (L)	25 (MR)/27 (L)
May$_{77}$				
1 Oct. 77	5	90-140		
5 Nov. 77	6	125-160		
14-15 Apr. 78	11½	140-160		
8-9 May 78	12	160-190		
14-15 June 78	13½	165-185		
August$_{77}$				
1 Oct. 77	2	25-85	55 (MR)	
5 Nov. 77	3	55-110	85 (M)	30
2-3 Dec. 77	4	70-118+	90 (M)	5

TABLE 3.—Periods of time, sizes, and ages when spawned groups of *C. nothus* were last captured off Port Aransas and Freeport, Tex.

Spawned group and location	Period	Size (mm SL)	Age (mo)	Comments
Aug.-Sept. 76				
Port Aransas	20, 21, 28 Sept. 77	150-190	12-13	A few specimens of uncertain ID in Nov. 77 may be 14-15 mo.
Freeport	5 Nov. 77	160-190	14-15	A few specimens of uncertain ID may belong to this month class.
May 76				
Port Aransas	29, 30 June 77	160-185	13	ID and sizes unclear
May 77				
Port Aransas	1 Dec. 77	115-150	7	A few specimens of uncertain ID in Mar. 78 may be 10 mo.
Freeport	14-15 June 78	165-185	13	ID and sizes unclear
Aug. 77				
Port Aransas	1 Dec. 77	75-115	4	Group not distinct after Dec. 77
Freeport	2, 3 Dec. 77	70-118	4	Group not distinct after Dec. 77
Sept. 77				
Port Aransas	1 Dec. 77	40-75	3	Group not distinct after Dec. 77
Freeport	2, 3 Dec. 77	25-75	3	Group not distinct after Dec. 77
Aug.-Sept. 77				
Port Aransas	8 Mar. 78	45-115	6-7	Still dominant in last collection
Freeport	15, 16 July 78	125-168	10-11	Still dominant in last collection

they approach age I. Many females were classified as early developing at 100-135 mm SL (Fig. 2). Most of the 15 fish classified as ripe or gravid were 140-170 mm SL. Age compositions and sizes at age presented later indicate that *C. nothus* mature to first spawn at 12 mo.

Silver seatrout in the northern gulf spawn from early May through late October. The collection of fish 45-55 mm SL in late June and 50-60 mm in mid-July indicates that spawning begins by early May off Port Aransas (Fig. 3). Spawning must have continued to late October, because fish 25-30 mm SL were collected from mid-August through early December. It appears that no spawning occurred from November through March or April because we captured no fish <40 mm SL after early December, and the smallest fish from February to May (Figs. 3, 4) belong to groups that were hatched before November and continued to grow through the winter.

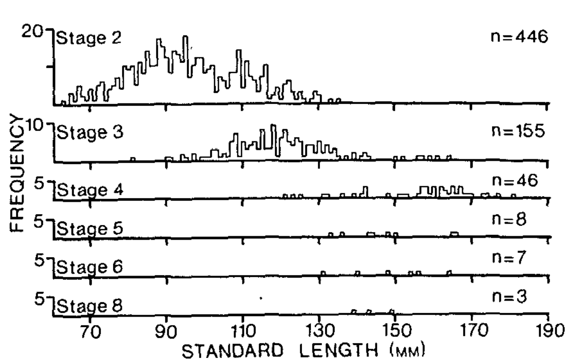

FIGURE 2.—Sizes of immature and female *C. nothus* in maturity stages two through eight. Maturity stages are 2) maturing virgin, 3) early developing, 4) late developing, 5) gravid, 6) ripe, 7) spawning/spent, and 8) resting. No stage 7 fish were caught.

Spawning occurs in two main periods each year—spring and late summer—and within each year class may produce at least three intrayear class cohorts or spawned groups, two of which may be produced in the late summer period. This is indicated by the polymodal length frequencies of fish collected off both Port Aransas (Fig. 3) and Freeport (Fig. 4), a pattern also evident in a reanalysis of Chittenden and McEachran's (1976, fig. 10) data from mid-January 1974 (Fig. 5). The polymodal frequencies do not reflect individual year classes nor do they reflect changes in size with depth. The length-frequency modes represent spawned groups that can be traced readily as follows: 1) The August$_{77}$ and September$_{77}$ groups off Freeport and Port Aransas in the period September-December 1977, 2) the August-September$_{76}$ and August-September$_{77}$ groups, which represent composites of the two individual spawned groups, in the periods February-July 1977 off Port Aransas, March 1978 off Port Aransas, and February-July 1978 off Freeport, and 3) the less distinct modes which we interpret as May$_{76}$ and May$_{77}$ groups in the periods April-June and September-December 1977 off Port Aransas and October 1977-May 1978 off Freeport. The identity of a distinct group 95-130 mm SL off Port Aransas in August 1977 is not certain. It might have hatched in spring 1977, or more probably represents survivors of the August-September$_{76}$ group. Similarly, the identity

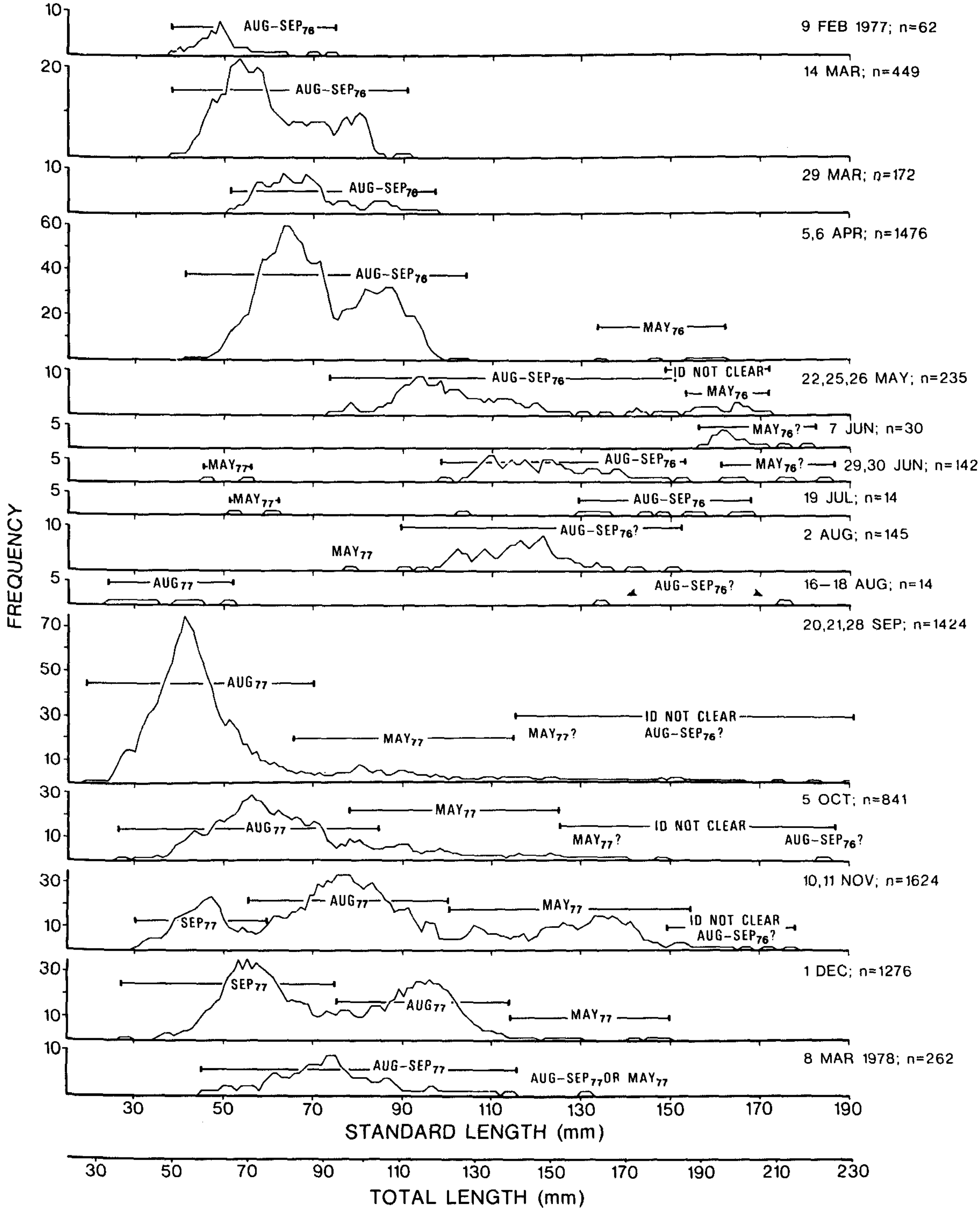

FIGURE 3.—Monthly length frequencies (moving averages of three) of *C. nothus* captured off Port Aransas. Group identity (ID) often is not clear where spawned groups meet.

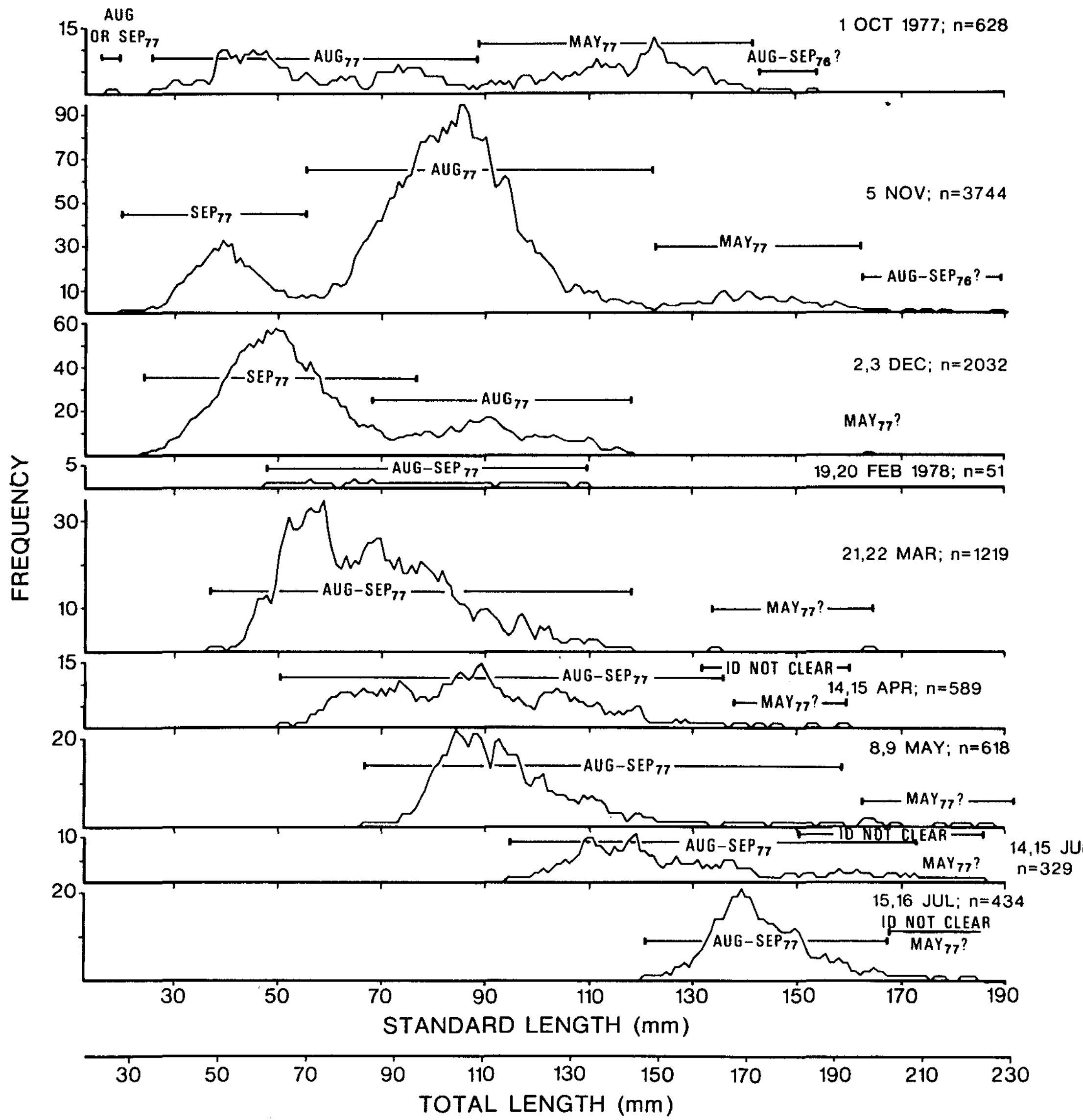

FIGURE 4.—Monthly length frequencies (moving averages of three) of *C. nothus* captured off Freeport. Group identity (ID) often is not clear where spawned groups meet.

of most large individuals off Port Aransas in fall 1977 is not certain.

Greatest or most successful spawning occurs during late summer. Many fish 25-65 mm SL were taken at 11, 12, and 29 m off Port Aransas in late September (August$_{77}$ group in Figure 3). This August-spawned group was collected at widely separated locations and formed a principal mode off Port Arnasas through early December. Fish of this size also formed a dominant mode off Freeport from October through December (August$_{77}$ group in Figure 4). Similarly, a group hatched in September formed a principal mode off Port Aransas and Freeport during November and December (September$_{77}$ group in Figures 3, 4). In contrast to these late summer groups, fish hatched in late spring did not form dominant modes.

Gonad maturity data suggest that *C. nothus* spawns from May through September in agreement with the spawning season indicated by length frequencies. Gravid or ripe females were

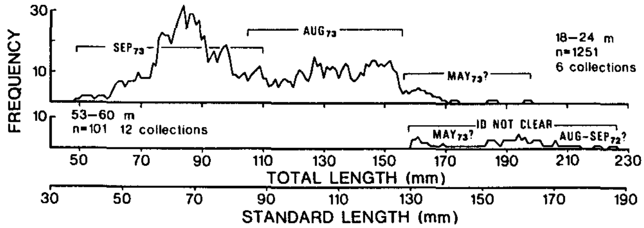

FIGURE 5.—Length frequencies (moving averages of three) of *C. nothus* captured off Freeport, Tex., 6-15 January 1974, by depth. Frequencies were reanalyzed from Chittenden and McEachran (1976, fig. 10). Group identity often is not clear where spawned groups meet.

captured during late May, June, and late September (Fig. 6), and other females 130 mm SL or larger were in the late developing stage. Some males had large gonads from May through September, and running ripe males were captured off Freeport in June and off Port Aransas in September. Females were only in the developing and resting stages in November and December, and no large females were captured from February through April.

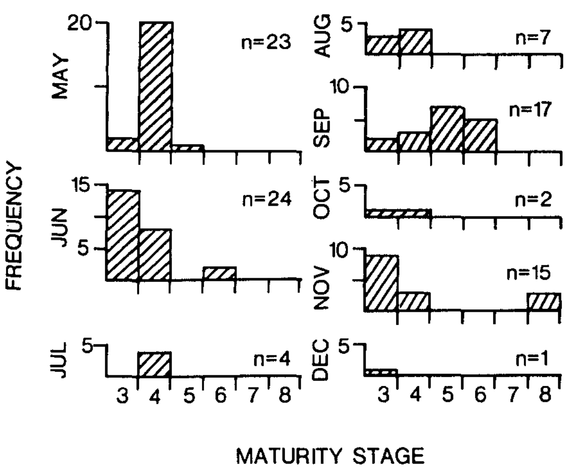

FIGURE 6.—Monthly maturity stages of female *C. nothus*. Maturity stages are 3) early developing, 4) late developing, 5) gravid, 6) ripe, 7) spawning/spent, and 8) resting.

Growth and Age Determination by Length Frequency

Only one year class of *C. nothus* occurred or dominated in any 1 mo. Fish of the 1976 and 1977 year classes occurred off Port Aransas during June, July, and August 1977 (Fig. 3). These were the only months when two year classes were clearly evident, although the comparatively few large individuals of uncertain identity in September-October 1977 probably were of a second year class. Only the 1976 and 1977 year classes occurred off Freeport from October 1977 through July 1978, but the comparatively few individuals of the 1976 year class appeared only in October and November (Fig. 4).

Cynoscion nothus reached 130-190 mm SL at age I. Fish of the dominant August and September spawned groups averaged 145-150 mm SL at 11 mo, although individuals ranged from 125 to 170 mm SL (Table 2). Similarly, the few survivors of the May groups were 130-190 mm SL at 11-14 mo. These observed sizes at age agree with the mean back-calculated length of 156 mm SL presented later.

Growth increments varied between months. The August and September spawned groups grew fastest in June and September, averaging about 25-30 mm SL/30 d (Fig. 7). Growth of recently hatched young steadily decreased from October to December and was smallest during the December-March period when increments averaged 5 mm SL/30 d. Growth increments then steadily increased to about 15-20 mm SL/30 d from March to June. The apparent pattern of greatest growth during the warm months and slowed growth during winter might be misleading. We have no growth data for the late summer period when the August-September groups

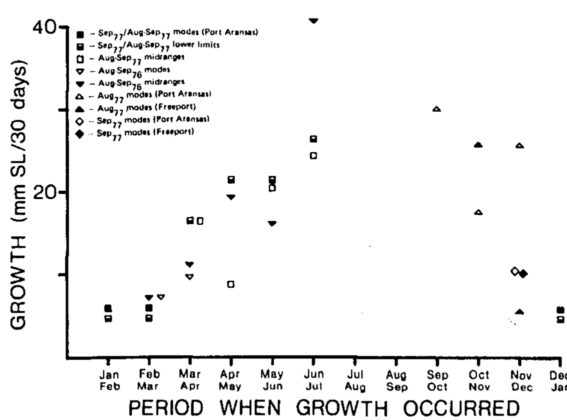

FIGURE 7.—Monthly growth increments of *C. nothus*. Unadjusted growth increments (Table 2) were adjusted to growth/30 d.

would have spawned. Growth from July through September could have been high as the apparent pattern suggests, or it might have slowed down and/or ceased as these fish matured and spawned.

Age Determination Using Scales

Silver seatrout can be aged using scales, although few fish had scales with either an annulus or false annulus. Only 38 of 1,483 fish (2.6%) had an annulus, and no fish had more than one. Only 41 fish (2.8%) had a false annulus, and they included 5 fish with an annulus. These percentages overemphasize the frequency of annuli and false annuli because the stratified sampling used to select specimens for intensive processing also selected all the large fish which would most likely show these marks.

Repeated examination suggests that age determination of *C. nothus* is consistent. We had 90% agreement in a second reading of scales from 225 fish, which included 123 fish >150 mm SL and all 38 fish first determined to have an annulus. The second reading identified an annulus in 45 specimens, including 30 of the 38 fish (79% agreement) first determined to have an annulus. The eight fish for which an annulus was not confirmed were collected in May and June about when the annulus forms; their scales had small marginal increments after an indefinite clear zone, and secondary radii and/or cutting over were not distinct. The second reading was done without knowing sizes or collection dates. This would minimize agreement between readings.

May-spawned *C. nothus* form an annulus from April (or earlier) to June when they reach 130-190 mm SL and 1 yr of age, but time of annulus formation may vary between spawned groups and is not clear for August- or September-spawned fish. Marginal increments were smallest from April to June and generally increased thereafter (Fig. 8), suggesting the first annulus forms from April (or earlier) to June. The smallest fish with an annulus was 139 mm SL and most exceeded 150 mm SL. The proportion with an annulus increased with increasing size, percentages being 16% at 150-159 mm SL ($n = 55$), 24% at 160-169 mm SL ($n = 54$), 60% at 170-179 mm SL ($n = 10$), and 100% at 180 mm SL and greater ($n = 6$). The proportion of the fish >150 mm SL with an annulus (Fig. 9) was significantly higher in May and June, when most of these large fish were May-spawned, than it was in September and November, when most were August- or September-spawned. Fish with an annulus in the period August-November all exceeded 170 mm SL and probably were survivors of the May_{76} group; those without an annulus then were 150-170 mm SL and probably August- or September-spawned.

Back-calculated lengths agree with length frequencies. Lengths at age I back-calculated using the Lee method (Lagler 1956) varied from 132 to 176 mm SL in comparison to 130-190 mm SL based on length frequencies. The mean back-calculated length was 156 mm SL with 95% confidence limits of 153-159 mm.

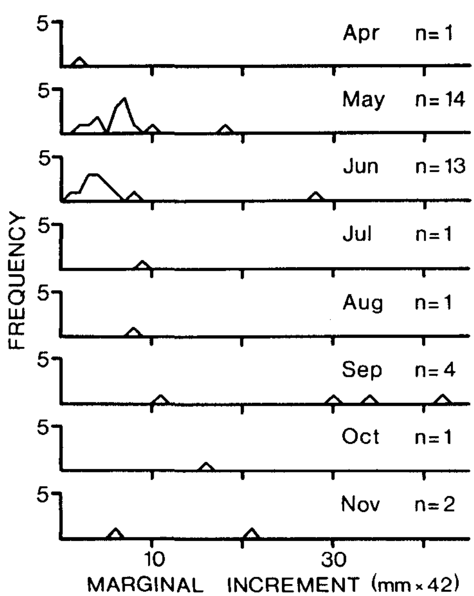

FIGURE 8.—Monthly marginal increments for *C. nothus* with one mark.

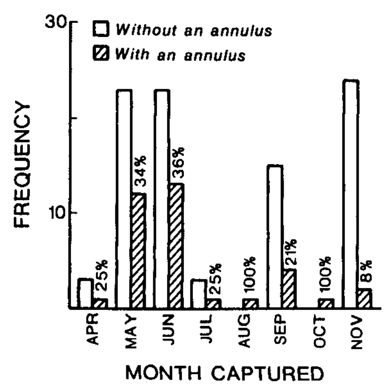

FIGURE 9.—Histogram showing by month the number and percentage of *C. nothus* >150 mm SL with and without an annulus.

Maximum Size, Life Span, and Mortality

Silver seatrout off Texas are small fish whose maximum life span (t_L) is about 1-1.5 yr. The largest of the 17,820 specimens that we captured were only 190 mm SL (230 mm TL). Almost 90% of the *C. nothus* captured off Port Aransas were <110 mm SL (Fig. 10), 99.1% were <160 mm SL, and 99.9% were <180 mm SL. Off Freeport, 85% were <110 mm SL, 99% were <160 mm SL, and 99.9% were <180 mm SL (Fig. 11). All *C. nothus* disappeared off Texas when they were slightly older than age I (Table 3).

The total annual mortality rate of *C. nothus* in the gulf off Texas approaches 100% and has a best estimate of 99.83%. Values of total annual mortality ($1 - S$) in each of the 9 mo from October 1977 through July 1978 off Freeport were 100% based on the expression $S = N_t/N_0$ where S = rate of survival and N_0 and N_t are the number of fish in consecutive year classes 0 and t. Only one year class was present off Freeport in those months so that $N_t = 0$. For the same reason, $1 - S$ was 100% off Port Aransas in each of the 4 mo from February through May 1977, during November and December 1977, and during March 1978. Mortality estimates were 98% and 99.9% for September and October off Port Aransas, assuming that fish >140 and >150 mm SL were from the older year class. For June, July, and August, $1 - S$ could not be estimated from the Port Aransas data, because the younger year class had just hatched and was incompletely recruited. However, if the predominant group in August had hatched in spring 1977, then $1 - S$ would approach 100% in that month also. Following the first procedure of Robson and Chapman (1961), we calculated an average value of $1 - S = 99.83\%$ by pooling the identifiable N_0 and N_t values for each month.

Distribution and Availability

Larger *C. nothus* seem more susceptible to trawling during the day. Few fish >100 mm SL were taken in night collections at 11, 18-24, and 29-31 m (Fig. 12), but many were taken in day collections at 7, 13-15, and 18-24 m.

Large silver seatrout almost disappeared during winter. Fish >120 mm SL from the May$_{77}$- and August-September$_{76}$ spawned groups were common during November off Port Aransas (Fig. 3) and during October and November off Freeport (Fig. 4), but very few were captured

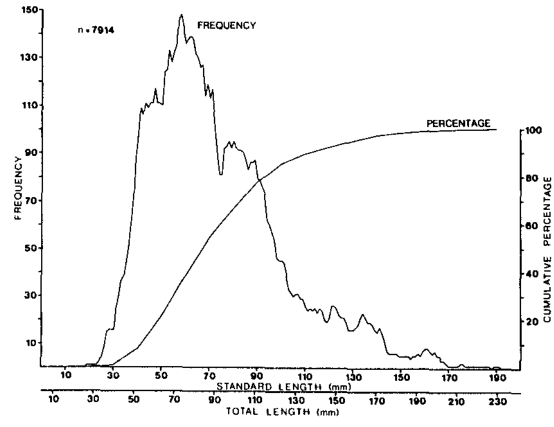

FIGURE 10.—Length frequency (moving averages of three) and cumulative percentage of all *C. nothus* collected off Port Aransas, Tex., February-December 1977.

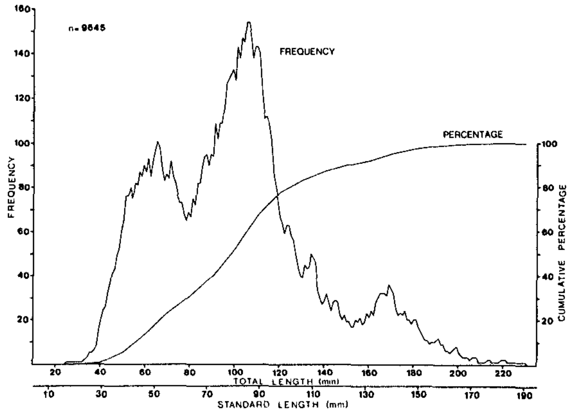

FIGURE 11.—Length frequency (moving averages of three) and cumulative percentage of all *C. nothus* collected off Freeport, Tex., October 1977-July 1978.

from December through March. The larger specimens of the August$_{77}$-spawned group also disappeared about December, which may be why the August- and September-spawned groups were not distinct thereafter. Many large fish were again taken in May or June.

Total Weight- and Girth-Standard Length and Standard Length-Total Length Relationships

Regression and related analyses for total weight-standard length, girth-standard length, and standard length-total length relationships are presented in Table 4. All regressions were

TABLE 4.—Analyses of total weight-standard length, girth-standard length, and standard length-total length relationships for *C. nothus*. Lengths and girths are in millimeters and weights are in grams.

Equation	n	Residual MS	Corrected total SSx	Corrected total SSy	$\bar{x}$	$\bar{y}$
$\log_{10} TW = -4.7582 + 3.0077 \log_{10} SL$	2,451	0.0014	63.75	580.16	1.9056	0.9733
G = 6.64 + 0.63 SL	2,451	12.87	2,429,280	996,341	86.0	60.8
SL = −7.48 + 1.54 G	2,451	31.37	996,341	2,429,280	60.8	86.0
SL = −3.76 + 0.84 TL	303	7.48	587,667	420,074	101.5	81.8
TL = 4.98 + 1.18 SL	303	10.46	420,074	587,667	81.8	101.5

significant at $\alpha = 0.01$. Coefficients of determination (100 r^2) were 97% for girth-standard length relationships but 99% for total weight-standard length and standard length-total length relationships. All relationships were based on fish whose standard length range was 26-188 mm.

DISCUSSION

Spawning

Our findings on *C. nothus* reproduction agree with the limited literature. The finding of spawning from May to late October is consistent with reports of 1) fish about 35-40 mm TL (26-30 mm SL) or smaller from June to December (Hildebrand and Cable 1934; Hoese 1965; Christmas and Waller 1973; Mahood 1974), 2) ripe individuals in mid-May (Miller 1965) and throughout August (Gunter 1945; Hildebrand 1954), and 3) late-developing specimens in August and September (Mahood 1974). Our finding of peak spawning in late summer agrees with Gunter (1945) and Chittenden and McEachran (1976), and with the dominance of a late summer-spawned group in Mahood (1974, fig. 13). The small size at maturity is consistent with Miller's (1965) report of running ripe females only 135-140 mm TL (110-114 mm SL), although the smallest fish that Mahood (1974) collected in late-developing or spent condition was 205 mm TL (168 mm SL). Our finding of May-, August-, and September-spawned groups is similar to the spring peak and late summer or fall peak of reproduction reported for *C. nothus* (Mahood 1974) and for *C. arenarius* (Shlossman and Chittenden 1981). The latter workers suggested that the spawning periodicity of *C. arenarius* was timed to coincide with the two major periods of rising sea level in the northern Gulf of Mexico each year when surface currents could transport eggs and/or larvae to inshore or estuarine nurseries. Spawning of *C. nothus* in the Gulf of Mexico probably is timed also to take advantage of such current transport. We have observed that *C. nothus* exhibits two distinct peaks of spawning within the August-September major spawning period. It is not yet clear 1) whether multiple-spawned group production consistently occurs within the late summer reproduction period, which would imply spawning keyed to regular intraperiod cues, or 2) whether multiple-spawned group production in the late summer period reflects irregular happenstances such as the increased survival and recruitment that could occur if reproduction at times coincided with unusually favorable current transport (Hjort 1914, 1926; Nelson et al. 1977), or if a critical larval period (Marr 1956; May 1974) irregularly coincided with an unusually great food supply.

Growth and Age Determination

Our estimates that *C. nothus* in the northern Gulf of Mexico reach 130-190 mm SL and average 150 mm or more when they disappear at age I agree with Chittenden and McEachran (1976) and Chittenden (1977) that *C. nothus* reaches 120-150 mm SL (150-185 mm TL) at age I. Gunter's (1945) estimate that fish 75-110 mm SL (93-138 mm TL) taken in May were about 1 yr old is low and may have been based on fish that actually would not have reached age I until the major spawning period of August-September. None of these cited workers, though, recognized the multiple-spawned group composition of this species and their estimates of age could be in error. Our estimates for *C. nothus* agree with estimates for *C. nebulosus* of 157-165 mm SL at age I (Pearson 1929; Moody 1950; Tabb 1961), although lower estimates of 116 and 130 mm SL have been reported (Klima and Tabb 1959; Moffett 1961). The growth of *C. nothus* also agrees with estimates for *C. regalis* of 143-180 mm SL at age I (Merriner 1973). Seasonal growth of August-September spawned *C. nothus* appears comparable to that of *C. nebulosus* and *C. regalis*. Pearson (1929) found

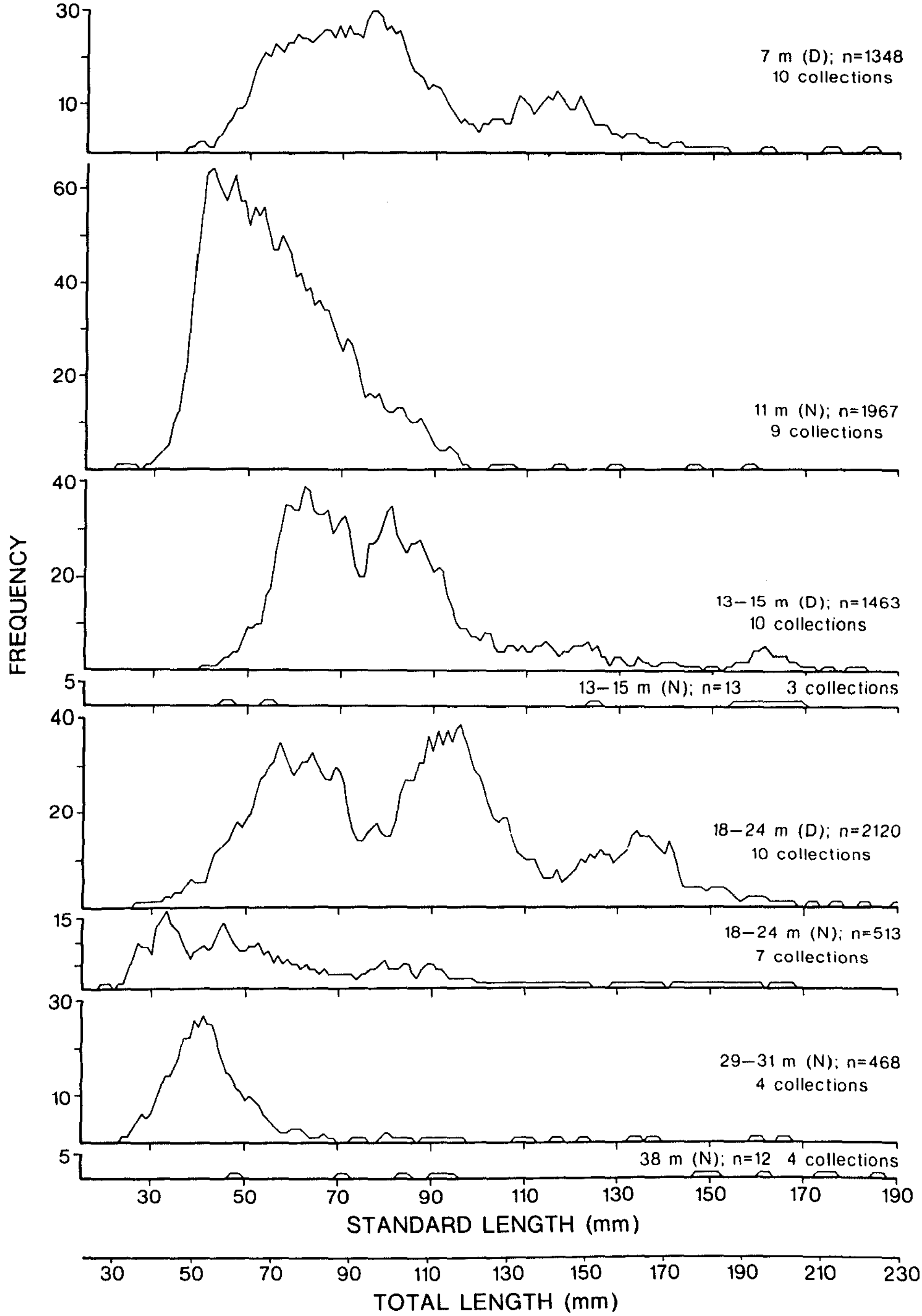

FIGURE 12.—Pooled length frequencies (moving averages of three) of *C. nothus* collected by day (D) and night (N) off Port Aransas, Tex., at each depth.

a similar seasonal growth pattern for *C. nebulosus* from Texas, but he did not calculate monthly increments. Estimates of monthly growth for *C. regalis* at age 0 are about 30-55 mm TL during the summer (24-45 mm SL) and about 10 mm TL in October (Welsh and Breder 1923; Hildebrand and Cable 1934; Pearson 1941).

Scales can be used to age *C. nothus*, but age determination would probably be as accurate from intensive length frequencies alone. The long spawning season and multiple-spawned group compositions complicate age determination. Exact age determination may be difficult for the few fish age II or older. The few fish of these ages might not be distinct in length frequencies and a spawned group probably could not be assigned. Growth and mortality estimates for *C. nothus* should be based upon individual spawned groups to avoid misinterpretation.

Maximum Size, Life Span, and Mortality

The largest specimen of *C. nothus* that we captured (190 mm SL = 230 mm TL) is similar to the maximum sizes typically reported (Hildebrand and Cable 1934; Gunter 1945; Hildebrand 1954; Christmas and Waller 1973; Chittenden and McEachran 1976). The only published records of fish much >190 mm SL include a specimen 315 mm SL (380 mm TL) from the Gulf of Mexico off Mississippi (Franks et al. 1972), a few specimens to 259 mm SL (312 mm TL) from industrial fish catches in the gulf (Thompson 1966), and Mahood's (1974) report of two fish 255 mm SL (308 mm TL) from the Atlantic Ocean off Georgia. Net avoidance and/or behavioral change to a midwater life-style probably does not explain the absence of *C. nothus* >190 mm SL off Texas, because we collected many *C. arenarius* to 283 mm SL. Large *C. nothus* apparently do not occupy water deeper than 46 m off Texas, because twice monthly day and night collections at 55-100 m in the period June 1979-August 1980 have not captured larger fish (Chittenden, unpubl. data). The absence of large *C. nothus* off Texas might indicate movement to rough, normally untrawled substrate or possibly a spawning or postspawning movement to the northcentral gulf. Large *C. nothus* to 225-250 mm SL occur in deep water in the northcentral gulf (E. Gutherz and B. Rohr[6]), but the comparative percentage of these large fish needs further study. Based on our data and the published literature, however, it appears that *C. nothus* does not exist in significant numbers at sizes >190 mm SL. Even Mahood's (1974) data indicate that only 4% of his specimens were >188 mm SL.

[6]E. Gutherz and B. Rohr, Fishery Biologists, Southeast Fisheries Center Pascagoula Laboratory, National Marine Fisheries Service, NOAA, Pascagoula, MI 39567, pers. commun. January 1981.

The maximum life span of *C. nothus* is only 1-1.5 yr off Texas, although it might be as long as 2 yr in the northcentral gulf or off the southeast United States. A value of t_L = 1-1.5 yr seems reasonable for Texas waters because fish >160-180 mm SL (the average size at age I) made up <1-0.5% of our catch. Our estimate is supported by the absence of fish with more than one annulus and by the complete disappearance of fish after age I. This agrees with Chittenden and McEachran's (1976) estimate that the life span is little more than 1 yr. A t_L value as large as 2.0 yr seems tenable only for Mahood's (1974) data and, possibly, for the northcentral gulf where some fish reach larger sizes than we observed.

Our observed mortality estimates agree with theory (White and Chittenden 1977; Royce 1972: 238) that the total annual mortality rate is 90-100% if the life span is only about 1-2 yr. Our best estimate that $1 - S$ is 99% may be a slight overestimate, particularly if large fish exhibit significant spawning or postspawning migration to the northcentral gulf. However, it seems unlikely that many fish survive beyond 2 yr and that $1 - S$ is <90%. This is supported by Mahood's (1974) data which suggest a 96% mortality rate for *C. nothus* off the southeast coast of the United States, assuming that all his specimens >188 mm SL were age II fish. The high mortality rate that we have found explains why few *C. nothus* had an annulus. Most fish probably die before or while a mark forms on the scales.

Distribution and Availability

The disappearance of large *C. nothus* that we found during winter agrees with Mahood (1974, table 8), who reported only six specimens (of 947 fish) >130 mm SL (160 mm TL) from October through April, and with Hildebrand and Cable (1934), who reported no *C. nothus* captured off Beaufort Inlet, N.C., during winter although they were rather common in summer. The disappearance of large *C. nothus* during the colder months and their subsequent reappearance in spring probably reflects an offshore overwintering movement of large fish. This interpretation is supported by 1) reanalysis of Chittenden and McEachran's (1976, fig. 10) data on distribution of *C. nothus* in mid-January (Fig. 5) which indicates that fish >140 mm SL were most abundant in deep water, and 2) Miller's (1965) report that large *C. nothus* occurred in deep water from February through April.

General

The production of several spawned groups over a broad time period in each annual spawning season is extremely important to the population dynamics of *C. nothus*. This species is short-lived and appears little more than an annual crop whose abundance could fluctuate greatly from year to year. However, the multiple-spawned group structure would buffer against population instability just as a multiple year class structure buffers population size in longer lived species. The multiple-spawned group feature may average over a longer period each year the effects of environmental variation on spawning success, may dampen fluctuations in annual spawning success associated with environmental extremes, and may stabilize population sizes. Similarly, the effects of fishing would be averaged over a greater number of spawned groups in 1 yr, so that the multiple-spawned group structure might minimize the possibility of recruitment overfishing. In that event, stock assessments based on dynamic pool models and growth overfishing would be more valid.

Many features of the population dynamics of *C. nothus*—short life span, high mortality rate, and rapid turnover of biomass—are similar to those in the Atlantic croaker, *Micropogonias undulatus*, of the Carolinean Province (White and Chittenden 1977; Chittenden 1977). This supports the suggestion (Chittenden and McEachran 1976; Chittenden 1977) that the abundant species of the white and brown shrimp communities in the gulf have evolved towards a common pattern of population dynamics. Because of their similar population dynamics, the implications of Chittenden's (1977) simulations on croaker could serve as a first approximation of the effects of harvesting *C. nothus*, so that this species also should have a great biological capacity to resist growth overfishing.

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