REPRODUCTION OF WEAKFISH, *CYNOSCION REGALIS*, IN THE NEW YORK BIGHT AND EVIDENCE FOR GEOGRAPHICALLY SPECIFIC LIFE HISTORY CHARACTERISTICS

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ABSTRACT

Reproduction characteristics for weakfish, *Cynoscion regalis*, in the New York Bight were examined. Spawning in 1980-81 occurred from May to early July with spawning time dependent on parental size. Maturity for both sexes occurred by age 1 but at a greater size in females. Annual fecundity estimates were compared with literature values for North Carolina weakfish and were found to be considerably lower at size, yet cumulative fecundities were nearly equivalent. The latitudinal variations in fecundity may be a behaviorally and environmentally induced phenomena, and influence the long-term population stability of weakfish.

Weakfish, *Cynoscion regalis*, are a member of the family Sciaenidae and are a common inshore species occurring between Cape Cod, Mass., and southern Florida. The species undergoes a spring migration from offshore waters of Virginia and the Carolinas to appropriate estuarine spawning areas, then a return migration in late fall to overwintering grounds (Nesbit 1954). The center of greatest abundance occurs within the Middle Atlantic Bight in quantities sufficient to support a recreational and commercial fishery. In 1979 commercial fishermen landed 13,000 metric tons (t) of weakfish and nearly 5,000 t were caught by recreational anglers (Wilk 1981). Abundance has, however, undergone some dramatic fluctuations over the last several decades. Commercial landings averaged 8,800 t from 1940 to 1949, then dropped to 2,915 t by 1950, and remained at these low levels until the mid-1970's (Wilk 1981). The exact cause of these variations remains a mystery, although speculations include overfishing, DDT-induced mortality, and environmentally induced recruitment failure (Massman 1963; Joseph 1972; Merriner 1976). To adequately assess the mechanisms controlling recruitment success or failure, we must first have a thorough understanding of the reproductive biology of weakfish.

Merriner (1976) has examined reproduction of weakfish in North Carolina, and Daiber (1957) mentioned spawning behavior of weakfish in Delaware Bay, but the reproductive biology of weakfish in their northern range has never been fully investigated. Furthermore, there is reason to believe that reproduction may vary throughout the geographic range. Leggett and Carscadden (1978) have shown latitudinal variations in reproduction and growth of American shad, *Alosa sapidissima*, and White and Chittenden (1977) have likewise shown geographic differences in another sciaenid, the Atlantic croaker, *Micropogonias undulatus*. Growth differences have already been established for weakfish between the New York Bight and North Carolina (Perlmutter et al. 1956; Shepherd and Grimes 1983), so there is reason to suspect possible reproductive differences. The purpose of the study was to investigate weakfish reproduction in the Middle Atlantic region, to determine if any geographic variations exist, and to consider possible reasons for geographically specific characteristics.

METHODS AND MATERIALS

Sample Collection

Samples (n = 1,208) were collected during the National Marine Fisheries Service (NMFS) groundfish survey from 1980 to 1983 at stratified random stations north of Chesapeake Bay (Fig. 1). Fish were collected with a #41 Yankee trawl in spring and a #30 Yankee trawl in summer and fall at depths between 5 and 200 m (Grosslein 1969). NMFS samples were supplemented by 461 fish collected between May 1980 and June 1981 from commercial pound nets in Gardiners Bay, N.Y., (n = 61) and Sandy Hook Bay, N.J., (n = 115) and

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Manuscript accepted February 1984.
FISHERY BULLETIN: VOL. 82, NO. 3, 1984.

from pair and otter trawl fisheries in Delaware Bay ($n = 285$).

At each NMFS station, weakfish catches were stratified into 10 cm size intervals and 10-15 fish sampled per interval. Total length to the nearest centimeter, sex, and maturity stage were recorded. Weakfish from Gardiners Bay were randomly sampled, total length measured to the nearest millimeter, sex, and maturity stage recorded, and gonads removed and weighed to the nearest 0.1 g. Sandy Hook and Delaware Bay samples were collected by random selection of 50-lb (22.5 kg) boxes in each market category available from the catch, and total length to the nearest millimeter and weight (whole and gutted) to the nearest gram recorded. Gonads and livers were also removed and weighed to the nearest 0.1 g. Gonads were preserved in modified Gilson's solution (Bagenal and Braum 1971) for several weeks, then removed, washed with distilled water and stored in 95% isopropyl alcohol.

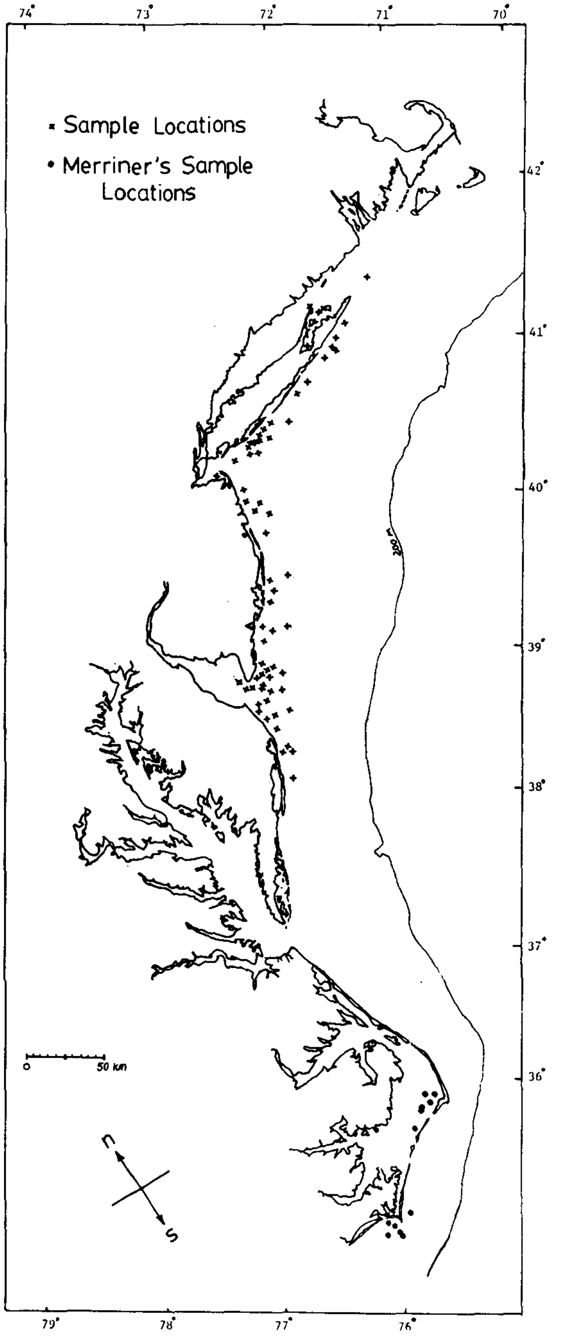

FIGURE 1.—Sampling locations for weakfish, *Cynoscion regalis*, in the New York Bight and North Carolina site of Merriner (1976).

Maturity and Fecundity Methods

The maturity stage of each sample was categorized as immature, developing, ripe (spawning), spent, or recovering as modified from Nikolsky (1963). The maturity stages were further subdivided as mature or immature for calculation of length at 50% maturity using probit analysis (Finney 1971).

Seasonality of reproduction was determined from changes in the gonad condition. A gonosomatic index (GSI) was calculated to show changes in gonad weight relative to somatic weight (gutted body weight). The index was computed as

$$\text{GSI} = (\text{gonad weight}/\text{somatic weight}) \times 100.$$

To examine physiological changes associated with spawning, liver condition was assessed using a hepatosomatic index (HSI) computed by substituting liver weight for gonad weight in the above relationship (Htun-Han 1978). The differences in monthly mean HSI between sexes were analyzed statistically using a Wilcoxon test (Patzner and Adam 1981).

The number of spawnings in the season were investigated by analyzing the seasonal frequency distribution of oocyte diameters (Hickling and Rutenberg 1936). In each of 15 samples collected between 5 May and 22 July 1980-81 in Delaware and Gardiners Bays, three subsamples were taken per ovary and about 500 oocyte diameters were randomly measured using an ocular micrometer.

Fecundity estimates were determined from 28 fish macroscopically classified as developing, which were captured during May 1981 in Delaware and Gardiners Bays. An oocyte diameter of 0.20 mm was determined from diameter frequency distributions and the degree of yolk accumulation as the size between oogonia and developing ova, and was used as the lower size limit of ova in the fecundity estimates. Each sample was diluted with distilled water, stirred, then several aliquots removed from the solution to provide a density of about 10,000 ova in a 6 × 6 cm gridded petri dish. About 800-1,000 ova were counted from six randomly selected squares, then adjusted for a total subsample count. Two subsamples were counted per sample and three if the ova sample was from a large fish (>60 cm). The sample and subsample were oven dried at 40°C for a minimum of 24 h then weighed to the nearest 0.001 g on a Mettler[3] balance. Total fecundity was calculated as

Total fecundity = [number in subsample × (sample wt/subsample wt)] + number in subsample.

Predictive equations of fecundity from length and weight were fit to a geometric mean (GM) functional regression (Ricker 1975) following log-log transformation.

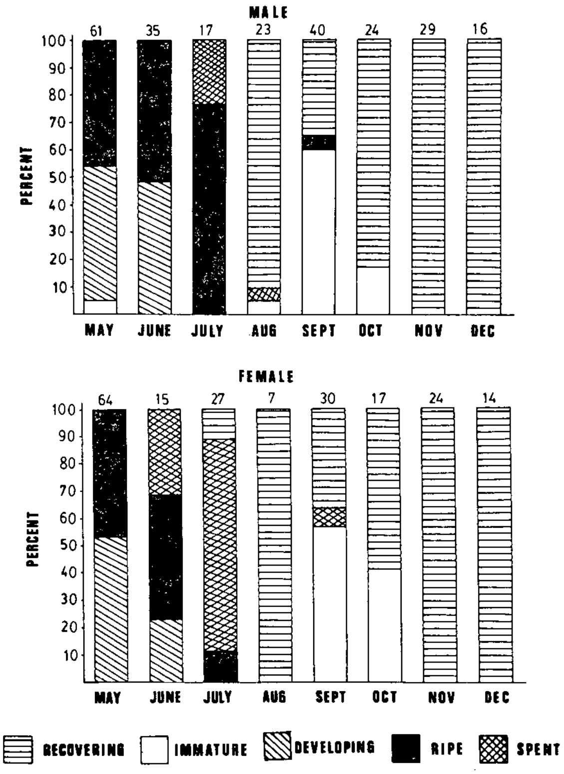

FIGURE 2.—Changes in visual maturity stage of weakfish, *Cynoscion regalis*, in 1980-81 for the New York Bight. *N* indicated for each month.

RESULTS

Seasonality

The changes in maturity stages during the year indicate spawning takes place from May to mid-July for weakfish in Delaware Bay and north to Long Island (Fig. 2). In May, all 122 mature fish examined of both sexes were in the developing or ripe stage of gonad development. The 50 fish that were inspected in June included 100% of the males and 70% of the females in a developing or ripe stage. Several of the ovaries examined in a June sample from Gardiners Bay had the appearance of being partially spent. The ovary was flaccid, slightly hemorrhaged and the lumen filled with fluid, but a few transparent ova were still visible. Spawning weakfish in Delaware Bay were captured as late as 12 July, when 11% of the females and 76% of the males were classified as ripe. In the same month, 84% of the females were in spent condition. By August, all of the fish examined at all locations were in postspawning condition. Weakfish from Sandy Hook Bay were not available until June and all the samples examined from this area were in postspawning condition, either spent or recovering.

This seasonality of spawning at each of the sample locations was suggested by seasonal changes in the GSI. Mean GSI values (percent gonad weight relative to somatic weight) ± 95% C.I. (Confidence Interval) of all females rose from 5.75 ± 1.29 in May to a peak value of 6.04 ± 1.43 in June, then declined to 1.76 ± 0.40 by July (Fig. 3). Male GSI were at a yearly high of 4.88 ± 1.45 in May but declined to only 2.51 ± 0.85 by July. The mean GSI values for females were consistently higher in all months except July. Gonad size reached the lowest levels for both sexes in August with mean GSI values of 0.71 ± 0.07 and 0.19 ± 0.02 for females and males, respectively. The GSI values remained low until the last samples were collected in November.

Specific spawning time, as reflected in GSI, was dependent on the size of the individual fish (Fig. 4).

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[3] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

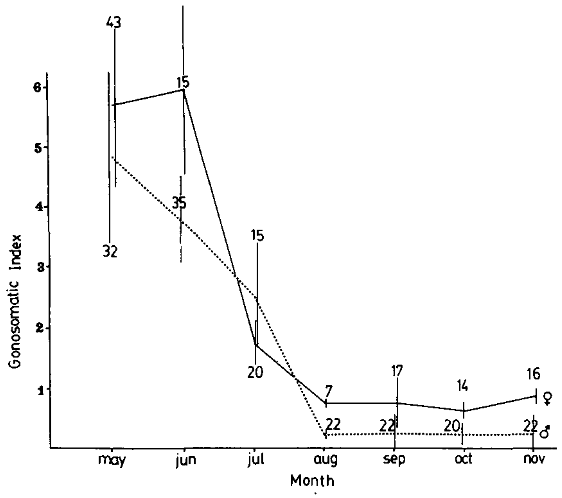

FIGURE 3.—Mean monthly gonosomatic indices ±95% C.I. of weakfish, *Cynoscion regalis*, for 1980 in the New York Bight. *N* values at each point.

TABLE 1.—Wilcoxon (Mann-Whitney) test comparing hepatosomatic indices between sexes of weakfish, *Cynoscion regalis*, from the New York Bight for June through November 1980 and May 1981. S = Wilcoxon test statistic, Z = critical value.

	S	*N*	Z	Probability level
1980				
June	622.0	50	5.081	0.0001***
July	194.0	34	−1.767	0.0865
August	106.0	28	0.265	0.7928
September	274.0	37	−0.904	0.3658
October	252.0	35	0.017	0.9867
November	283.5	40	−1.215	0.2318
1981				
May	332.0	48	−3.782	0.004***

*** = highly significant differences.

Mean index values and lengths ±95% C.I. for developing fish in Delaware and Gardiners Bays during May was 2.48 ± 0.67 at a mean length of 551 ± 47.0 mm for females and 1.13 ± 0.85 at a length of 391 ± 98.9 mm for males. Spawning fish captured during May had GSI of 8.65 ± 1.64 at mean length of 702 ± 25.2 mm for females and 6.49 ± 1.58 at mean length of 619 ± 33.1 mm for males. In June, spawning fish had mean GSI values of 6.72 ± 1.83 with mean length of 544 ± 95.6 mm for females and 4.54 ± 1.04 with mean length of 570 ± 56.3 mm for males. These index variations confirmed observations of earlier spawning by large fish.

Seasonal variation in mean HSI of Delaware and Sandy Hook Bay samples indicates that changes in liver weight occurred at the time of spawning and prior to fall migration (Fig. 5). Mean HSI values ±95% C.I. for females decreased from a high in May of 2.80 ± 0.35 to a low in September of 0.87 ± 0.30. The index values for males followed the same pattern declining from 1.89 ± 0.27 in May to 0.96 ± 0.18 in September, but the maximum values occurred in November with a mean HSI of 2.57 ± 0.29. The indices were tested for differences between sexes and the differences were found to be significant in May and June ($P < 0.001$) with the values for females being greater (Table 1). No significant differences were found in a comparison of the July through November samples.

Frequency distributions of oocyte diameters from 15 fish, ranging from 55 to 81 cm and collected between 6 May and 22 July show one seasonally progressing mode of developing ova (Fig. 6). The position of the mode varied according to the development stage of the individual ovary. A sample from 5 May had a mode between 0.02 and 0.45 mm and was skewed toward a prominent peak at 0.12 mm. In the 13 May sample, a second mode appeared around 0.35 mm and this mode increased to a size of 0.63 mm in the 20 June sample. The 22 July sample contained only oogonia. Maximum ova diameter observed was 0.95 mm from a sample on 26 May. That ovum was filled with fluid between the yolk and chorion, indicative of an ova immediately prior to release (Bagenal 1967). This corresponds to the size of weakfish eggs, 0.870-0.975 mm, which have been identified in the water column (Harmic 1958).

Maturity, Sex Ratio, and Fecundity

Length ±95% C.I. at which 50% of the total sampled population reached maturity was similar for both sexes. Females attained 50% maturity at 25.6 ± 1.2 cm, while males were slightly lower at 25.1 ± 1.1 cm (Table 2). The corresponding age at maturity for both sexes was 1 yr. The smallest mature male and female was 20 cm. The maximum size of immature weakfish was 40 cm for females and 33 cm for males.

The overall population sex ratio approached equality (Table 3). The sex ratio of the population, divided into 5 cm length intervals, was 48:52 females to males and was not significantly different from 50:50 as determined from a chi-square analysis ($\chi^2 = 1.81$, $\chi^2_{0.05} = 3.84$, $n = 1{,}669$). Sex ratio at size data did reveal significant differences from 50:50 for several length intervals. At 40 cm, the ratio was 52:48 female to male but increased to

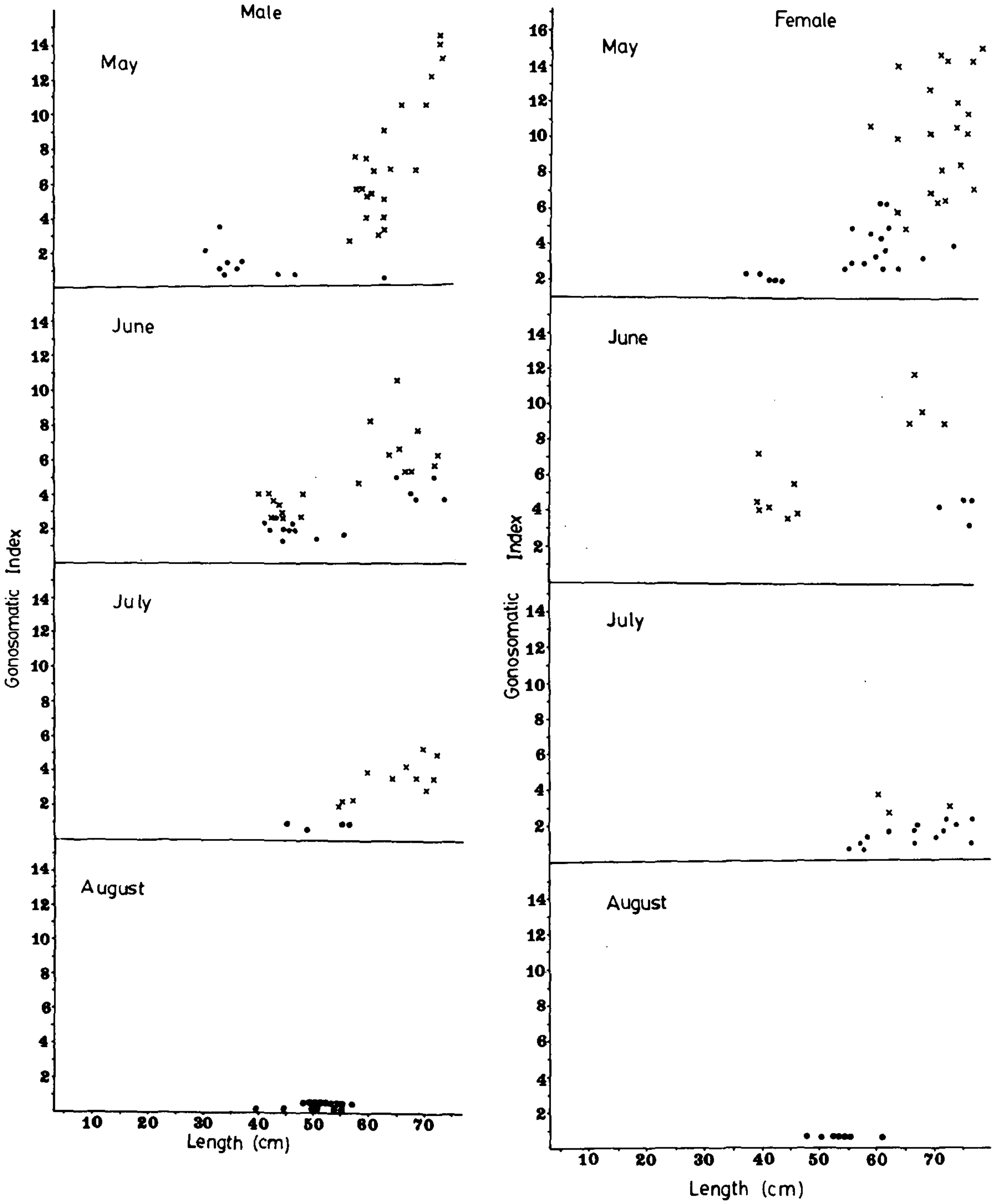

FIGURE 4.—Monthly gonosomatic indices of individual weakfish, *Cynoscion regalis*, by sex for 1980. Spawning fish indicated by x.

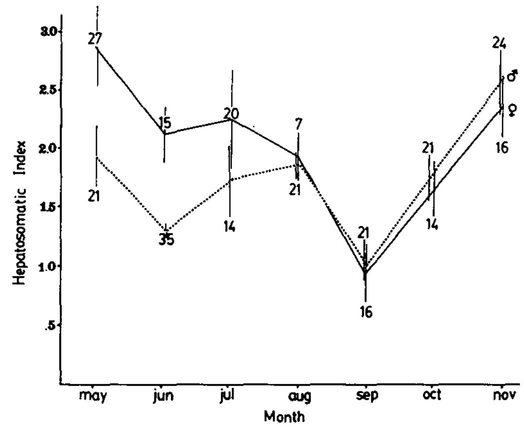

FIGURE 5.—Mean monthly hepatosomatic indices ±95% C.I. of weakfish, *Cynoscion regalis*, for 1980 with N indicated at each point.

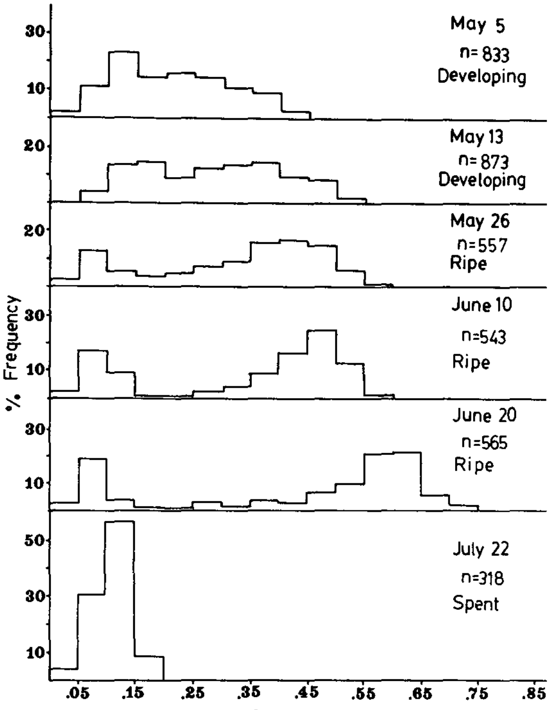

FIGURE 6.—Monthly frequency of oocyte diameters for weakfish, *Cynoscion regalis*, in the New York Bight for 1980-81.

TABLE 2.—Length at maturity for weakfish, *Cynoscion regalis*, from 1980 to 1983.

Length (cm)	Female		Male	
	N	% mature	N	% mature
18	15	0.0	16	0.0
19	7	0.0	11	0.0
20	8	12.5	11	9.1
21	11	18.2	5	40.0
22	8	37.5	9	33.3
23	13	53.8	16	31.3
24	11	45.5	12	50.0
25	13	46.2	12	75.0
26	14	71.4	15	86.7
27	17	88.2	14	71.4
28	10	80.0	20	65.0
29	17	82.4	22	63.6
30	19	100.0	17	82.4
31	18	88.9	14	85.7
32	16	93.8	20	85.0
33	10	90.0	17	94.1
34	14	85.7	15	100.0
35	7	85.7	3	100.0
36	10	80.0	8	100.0
37	9	77.8	12	100.0
38	15	100.0		
39	14	85.7		
40	13	92.3		
41	4	100.0		
42	10	100.0		
43	10	100.0		
Total	313		269	
Size at 50% mature	25.6		25.1	
95% Confidence Interval	24.4-26.8		24.0-26.2	

TABLE 3.—Sex ratios (female:male) of weakfish, *Cynoscion regalis*, in the New York Bight.

Length[1]	Ratio	χ^2
15	27:40	2.52
20	72:73	0.01
25	149:174	1.93
30	148:157	0.27
35	72:73	0.01
40	71:65	0.26
45	42:72	5.25*
50	35:40	0.33
55	34:60	7.19**
60	36:35	0.01
65	35:27	2.00
70	31:28	0.15
75	28:17	2.69
80	18:1	15.21***
85	4:0	4.0*
Total	807:862	1.81

[1] Midpoint of length interval (12.5 to 17.5, etc.).
* = significant difference $P < 0.05$.
** = significant difference $P < 0.01$.
*** = significant difference $P < 0.001$.

60.5% ($\chi^2 = 5.25$, $\chi^2_{0.05} = 3.84$, $n = 119$) and 63.8% ($\chi^2 = 7.19$, $\chi^2_{0.01} = 6.64$, $n = 94$) males at 45 and 55 cm, respectively. The sex ratio of combined length intervals above 55 cm had a ratio of 58.5:41.5 which was significantly dominated by females ($\chi^2 = 7.45$, $\chi^2_{0.01} = 6.64$, $n = 260$).

Regression models indicated that length and weight were equally predictive of fecundity. The relationships between total length or gutted weight, and fecundity were best described by a power curve. The GM functional regression (Ricker 1975) of the $\log_e$ transformed data ± standard error of the regression were

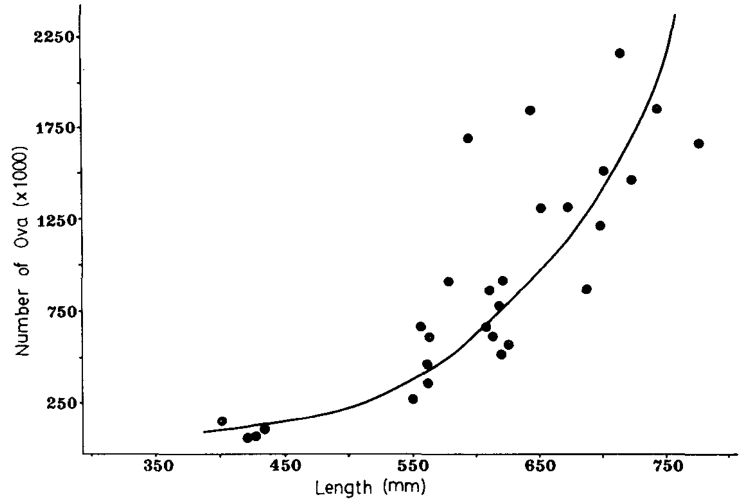

FIGURE 7.—Fecundity as a function of length for weakfish, *Cynoscion regalis*, in New York Bight for 1981.

$$\ln \text{fecundity} = -16.322 + 4.659 \ln \text{total length (mm)} \pm 0.368$$

$$r^2 = 0.835 \qquad n = 28 \qquad \text{Figure 7}$$

$$\ln \text{fecundity} = 1.975 + 1.542 \ln \text{gutted weight (g)} \pm 0.364$$

$$r^2 = 0.839 \qquad n = 28.$$

Fecundities were also estimated for six weakfish collected in June from Gardiners Bay which appeared to be spent, although they had ova remaining in the gonad. These ova were 0.55 to 0.65 mm which were similar in size to those present in a ripe ovary. All six samples were significantly different ($P < 0.001$) than expected values based on a Students t-test (Table 4). These June samples were 60-75% lower than the predicted fecundities at length.

TABLE 4.—Difference between expected fecundity (based on ln fec = −16.322 + 4.659 ln TL) and observed fecundity for 6 weakfish, *Cynoscion regalis*, collected 27 June 1981, in Gardiners Bay, N.Y.

Total length (mm)	Fecundity estimate		% Difference
	Expected	Observed	
590	650,171	196,891	69.7
613	777,718	93,579	88.0
615	789,675	105,919	86.6
704	1,487,262	438,909	70.5
737	1,843,210	650,600	64.7
644	979,893	313,054	68.1
			$\bar{x}$ = 74.6

DISCUSSION

Weakfish spawning in northern estuaries is a seasonal event which occurs following the spring inshore migration. (Welsh and Breder 1923; Hildebrand and Schroeder 1928). Our study found the spawning period for weakfish in Delaware Bay and Gardiners Bay, as determined from maturity stages, to be from May to mid-July. Ichthyoplankton surveys have found weakfish eggs and larvae present in New York Bight from May to July (Colton et al. 1979). The spawning period was further substantiated by changes in GSI. The mean GSI values reached a maximum in May for males and in June for females, then both declined to minimum values by August. The gonad weights were maintained at this low level until the fish disappeared from the coast in late November. The spawning period of weakfish in North Carolina is somewhat longer, extending from March to September with the peak period from April to June (Merriner 1976). The duration of the ripe maturity stage in Delaware and Gardiners Bays was greater for males, with ripe males captured as late as 22 July. The protracted spawning season of males was also evident in the GSI values. July was the only month in which male indices were greater than those of females, indicating that the gonad weight per unit body weight was larger in males. In other months, female GSI values were as much as 2.8% greater than males.

Sex differences were also evident in physiological changes associated with spawning. HSI values were near maximum in May, during spawning season, and as expected higher in females. Development of ovaries demands higher energetic costs than testicular development (Nikolsky 1963); therefore, the necessary energy reserves in the liver would be proportionately larger in females (Timashova 1982). After spawning, the sexual dimorphism disappears and HSI values for both sexes increase similarly prior to the fall migration.

The peak spawning period in the New York Bight estuaries varied with different size weakfish. Generally, among migratory fishes, the larger individuals will return to an estuary prior to their smaller counterparts (Briggs 1955; Nikolsky 1963). Weakfish exhibit a similar behavior, as the largest individuals or "tiderunners" enter the bays in early May and spawn by mid-May, whereas the smaller weakfish arrive later and reach peak spawning during June. The GSI values for fish >60 cm generally decline from May to June, while smaller fish increase to maximum values in June. This differential spawning based on parental size results in two spawning peaks and the subsequent appearance of bimodal length-frequency data for juvenile weakfish (Daiber 1954; Thomas 1971; Shepherd and Grimes 1983).

Sex Ratio, Maturity, and Fecundity

The overall sex ratio of the population is not different from 1:1, but one sex was dominant at certain length intervals. We believe the deviations from a 1:1 ratio at various lengths were attributable to differential growth between sexes (Wenner 1972). Female growth begins to exceed male growth at about 45-55 cm (Shepherd and Grimes 1983), at which point the sex ratio becomes dominated by males. Females grew beyond that size interval faster and occupied the majority of the 60-85 cm length intervals. Although males have growth potential equal to females, the numbers attaining maximum size were greater for females.

In northern waters, the size at which weakfish attained 50% population maturity was similar for both sexes. Females matured by 25.6 cm at age 1 while males attained maturity at 25.1 cm, also at age 1. Apparently, greater differences exist between northern weakfish (Delaware Bay and north) and southern weakfish (North Carolina). Although ages were similar, southern females spawned at 23 cm and males by 18 cm (Merriner 1973).

Estimates of fecundity for New York Bight weakfish differ from estimates for southern weakfish. Weakfish in North Carolina did not reach sizes much beyond 45 cm but had fecundities, relative to length, several times higher than northern weakfish (Merriner 1976) (Table 5). For example, at 50 cm TL female weakfish from New York Bight produced 306,159 ova, while the fecundity of southern fish of the same size was 2,051,080 ova. In spite of these large differences, lifetime fecundity would be approximately equal. Southern weakfish can potentially reproduce until age 5 and produce about 9,913,080 ova (based on the equation, fecundity = $0.152\,TL^{2.6418}$, from Merriner 1976), whereas northern weakfish reproducing for 10 yr have nearly equivalent total ova production of 10,008,167.

Batch spawning, involving two distinct groups of ova, was found for weakfish in North Carolina (Merriner 1976). In samples examined in 1980-81 from Delaware and Gardiners Bays, multiple spawns were not evident. The ova diameter frequencies of developing and ripe ovaries contained two modes, one consisting of reserve oocytes and another of developing ova. The developing ova had a wide size range ($\approx$0.3 mm) and may have been released during consecutive spawning events, but did not constitute separate batches within an ovary. Furthermore, all ova produced annually by weakfish may not be released during spawning. A study of Delaware Bay weakfish in 1954 proposed batch spawning, but spent ovaries were not examined to determine if all ova were released (Daiber 1954). Ovaries classified as spent which we examined still contained 25-40% of the ova expected for a fish of that size. These results suggest fertility may be 60-75% of estimated potential fecundity. Foucher and Beamish (1980) reported similar conclusions from studies of Pacific hake, *Merluccius productus*. We did not examine

TABLE 5.—Comparison of fecundity for weakfish, *Cynoscion regalis*, between Cape Hatteras (Merriner 1976) and New York Bight.

	Fecundity comparisons			
	Cape Hatteras		New York Bight	
Age	SL	Fecundity	TL	Fecundity
0	159	149,429		
1	225	391,688	203	4,593
2	286	762,258	323	39,978
3	357	1,410,550	479	250,685
4	421	2,229,220	578	601,544
5	562	4,969,940	638	953,027
6			677	1,256,487
7			701	1,477,902
8			728	1,762,445
9			758	2,127,278
10			763	2,193,448
Cumulative fecundity		9,913,085		10,667,387

enough spent weakfish ovaries to determine if this phenomenon was consistent from year to year.

The variable reproductive and age and growth characteristics for weakfish in different geographic areas suggest specific physiological responses to different environmental conditions. North Carolina weakfish had smaller sizes at maturity, smaller length at corresponding age after age 1, reduced longevity and maximum size, and higher relative fecundity than New York Bight weakfish. However, the lifetime reproductive potential was nearly equal for both groups. These life history characteristics for weakfish are similar to clinal variations between Labrador and Florida described for American shad (Leggett and Carscadden 1978), differences in reproductive characteristics between Atlantic herring, *Clupea harengus harengus*, in the Norway and the Baltic Sea (Schopka 1971), and north to south variations in North American populations of Pacific herring, *Clupea harengus pallasi* (Paulson and Smith 1977).

The different reproductive strategies in weakfish may result from varying environmental demands. When weakfish spawning occurs in northern estuaries, water temperatures are unpredictable and subject to sudden drops which are potentially lethal to eggs and larvae (Harmic 1958). Table 6 shows minimum estuarine temperatures during the spawning season in northern waters may drop below the temperature limits of 12°-16°C necessary for successful hatching (Harmic 1958). The higher probability of prereproductive mortality of progeny in northern estuaries results in a "bet-hedging" strategy in which fewer eggs are produced each year, but the possible number of annual spawnings are increased (Stearns 1976; Giesel 1976), thus maximizing potential contributions to the gene pool throughout a fish's lifespan. In contrast, southern weakfish spawn in a more predictable estuarine environment (Table 4) and, consequently, there is less chance of environmentally induced prereproductive mortality. However, southern fish are faced with greater postreproductive mortality (longevity observed by Merriner (1973) was 5 yr). Greatest reproductive success in this situation requires maximizing annual gamete production in the few years possible. In addition, weakfish migrating to northern estuaries (Nesbit 1954) may utilize energy reserves otherwise available for gonad growth, whereas southern fish having less distance to travel may reallocate energy towards reproduction.

TABLE 6.—Surface water temperatures (°C) for April-July in Plum Island, N.Y.; Cape May, N.J.; Gloucester Point, Va; and Beaufort, N.C.[1]

	April	May	June	July
Plum Island, N.Y.				
$\bar{x}$	5.6	9.7	14.6	18.8
Max	9.0	18.0	20.0	24.0
Min	2.0	4.0	9.0	15.0
$\bar{x}$max	7.7	13.4	17.7	21.4
$\bar{x}$min	3.3	6.4	11.4	16.3
Cape May, N.J.				
$\bar{x}$	10.2	14.5	20.0	22.6
Max	17.0	21.0	25.0	28.0
Min	6.0	9.0	12.0	18.0
$\bar{x}$max	14.6	18.9	23.8	25.6
$\bar{x}$min	7.0	10.8	15.7	19.9
Gloucester Point, Va.				
$\bar{x}$	13.1	19.1	23.8	26.5
Max	21.0	26.0	30.0	32.0
Min	7.0	13.0	17.0	21.0
$\bar{x}$max	17.1	22.4	27.0	29.0
$\bar{x}$min	9.6	15.6	20.4	24.1
Beaufort, N.C.				
$\bar{x}$	17.2	21.4	25.2	27.4
Max	21.0	26.0	32.0	30.0
Min	14.0	14.0	18.0	24.0
$\bar{x}$max	20.3	24.2	28.3	29.2
$\bar{x}$min	14.3	17.5	21.9	25.8

[1] National Ocean Survey. 1972. Surface water temperature and density; Atlantic coast, North and South America. 4th ed. NOS Publ. 31-1, p. 1-109.

Consequences of the area specific reproductive characteristics may be a reduced population stability for weakfish in the northern end of the range. Apparently, northern fish have a strategy to cope with potentially higher egg and larval mortality by spreading reproduction over more years and reducing annual fecundity, i.e., a "bet-hedging" strategy (Stearns 1976). Therefore, to fulfill their reproductive potential they must avoid premature adult mortality. If adult mortality (natural and fishing) in weakfish becomes excessive, the larger, most fecund individuals will be lost or reduced, thus shifting the burden of spawning to the smaller, less fecund fish. When the value of b in the fecundity equation $F = a\mathrm{TL}^b$ is >3, as in New York Bight weakfish, then truncation of the size/age structure in a spawning population will also result in a reduction of population fecundity (Hempel 1979). Concurrent high adult mortality and high prereproductive mortality could contribute to a decline in population abundance. The large fluctuations which have occurred in weakfish populations over the last several decades (Wilk 1979) may be due in part to these circumstances (i.e., high adult and prereproductive mortality). Although the correlation between population fecundities and recruitment is not usually strong for marine fishes (Cushing 1977), a decrease in population fecundity may eventually reduce any buffer that weakfish have of withstanding natural fluctuations in egg, larval, and juvenile survival. Therefore, if management practices are to effectively regulate the weakfish resources, geographic variations in reproductive potential should be considered.

ACKNOWLEDGMENTS

The authors would like to thank Ken Able and J. Richard Trout for their helpful guidance. Dan Dzenkowski and crew of the *Dan Dee*, Greenport, Long Island, were more than generous in allowing us to sample their catches, and personnel of NMFS, Woods Hole, Mass., especially Ambrose Jearld, kindly provided samples from the groundfish surveys. We would also like to thank Steve Turner, Chuck Idelberger, and Susan Toogood for their assistance and Hannah Goodale for her assistance in preparing the manuscript. Funding for this project was provided by NMFS (contract No. NA-79-FAC-00041) and the New Jersey Agricultural Experiment Station (NJAES publication No. D-12409-14-83).

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