SPAWNING OF SPOTTED SEATROUT IN A LOUISIANA ESTUARINE ECOSYSTEM

STEPHEN HEIN, Louisiana Department of Wildlife and Fisheries, P.O. Box 37, Grand Isle, LA 70358
JOSEPH SHEPARD, Louisiana Department of Wildlife and Fisheries, P.O. Box 37, Grand Isle, LA 70358

Abstract: Biomodal spawning peaks, as determined by the gonadosomatic index, were noted for the spotted seatrout (*Cynoscion nebulosus*) in the Barataria Bay, Louisiana, system for 1976 and 1978. Males matured earlier in the season and at a smaller size than females. Males were found to have sound producing capabilities. Fish spawned throughout the bay regardless of water depth or substrate. Spawning seemed to occur in the northern portion of the bay later than in the southern portion. Photoperiod and temperature were the only exogenous factors found to have a direct relationship with spawning.

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The spotted seatrout is an important sport and commercial fish throughout a large portion of its range. Louisiana's commercial landings for the 2 years studied (1976 and 1978) were 1,500,000 and 680,000 pounds respectively. These landings have been declining during the past 5 years. More work is needed to follow this trend and to better understand the biology of this species. Some extensive studies employing various methods and techniques have been utilized by several workers to determine the spawning characteristics of this estuarine dependent species. Despite occasional reports of gravid fish in nearly every month of the year, most workers agree upon a spawning period for this seasonal breeder of April through September (Table 1). Although there is an apparent overlap of spawning activity throughout this period, there appears to be uncertainty as to the primary peak(s) of activity, spawning area and the associated physical paramaters. This study was initiated to provide data on the peak spawning period and any influences upon it by exogenous factors.

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MATERIALS AND METHODS

The study was conducted principally in the Barataria Bay, Louisiana, estuary with some samples taken west of this area as reported by Hein and Shepard (1977). The area has been described by Chabreck (1972) as an inactive delta zone and is located in southeastern Louisiana. North, east and west borders of the area are chiefly broken saline and brackish marshland with a maze of natural bayous, canals, small ponds, bays, lakes, and islands with a series of dikes and pipiline canals as well as physical structures associated with the oil and gas industry. The southern edge of the bay is bordered by a series of barrier islands, which act as buffers between the bay and Gulf waters.

Although 1% of the total area has a water depth varying up to 15.2 m in the deeper holes and channels, average depth of the bay is 1.4 m with 25% averaging 0.5m (Barrett 1970). Barrett also determined total water area as 17,624 ha. He reported that clay silt predominated sediment in the northern portions of the bay, while silty sand occurs in the lower portions of the bay. Chabreck (1972) reported soil organic matter ranging from approximately 15% along coastal areas to 50% in the upper bay areas. Additionally, submerged mud and sand bars, shell reeefs, and oyster beds are occasional changing features within the bay.

TABLE I. Spawning of spotted seatrout as noted by various authors.

Author	Date	Area	Spawning Period	Spawning Area	Methods Used to Determine Spawning Period
Pearson	1929	Texas Coast	March or April through Sept. Height of spawning in April and May.	Within bays and lagoons in water less than 10-15'. None in the open Gulf of Mexico.	Collections of young fish and observations of spawning adults.
Gunter	1945	Texas	First ripening gonads in April. Found some ripe femalses as late as mid-November.		Observation
Hedgepeth	1947	Laguna Madre, Texas		Spawn in bays, possibly less saline areas.	
Miles	1949	Aransas Bay, Texas	Found trout with fully developed gonads in March and April.		Observation
Miles	1950	Texas	Early April, diminishing by mid-November. May and June are probably the peak months.	Inland areas.	Mature, ripe and spent fish, young fish.
Moody	1950	Cedar Key, Fla.	Late March or early April through Sept. and probably into Oct. Found one mature female with roe in Feb. His Table I indicates a peak in July.	Probably over inshore grassy areas.	Examination of gonads to determine stage of maturity. Observation of abundance, presence, size and location of young.
Miles	1951	Texas	April through Oct., with a peak in July. Some full roe trout in Nov. (probably only in mild winter years).	Inland waters of the primary, secondary and tertiary bays.	Seven stages of gonadal development.
Breuer	1957	Baffin and Alazan Bays, Texas	No suitable spawning area in Baffin Bay - "with comparatively fresh, clear water and shallow grassy flats with sand bottoms."	No evidence of spawning in this area.	
Klima and Tabb	1959	NW Fla.	Latter part of April through Sept. Height of spawning season in late May and early June. Suggest the possibility of a fall spawn.		Six stages of gonad development.
Springer and Woodburn	1960	Tampa Bay, Fla.	First spawn in April		Collection of juveniles
Stewart	1961	Everglades Nat. Park, Fla.	Bimodal peaks in May and Aug. Ripe fish found in each month of the year.	Ripe fish found in bays and Gulf.	Six stages of sexual maturity.
Tabb	1961	East-Central Fla.	Mid-April-late July	Deep channels adjacent to vegetated shallow areas. Preference for deep water (8-15').	Six stages of gonad maturity based on macroscopic examination and observation of adults in spawning condition. Also daily movement of adults and location of young.
Sundararaj and Suttkus	1962	Lake Borgne, La.	July-August. Possible peak in July.		Fecundity measured by the gravimetric method. Also based on appearance of young.

Table I. (cont.)

Tabb	1966	Fla.	Spawn at night. Peak spawn in dry spring months when salinity in the estuary reaches 30-35 ppt. Also in unusually wet spring months.	Less turbulent portions of the estuary and non-tidal lagoons. Most often in deeper holes and scour channels in the grass flats.	
Fontenot and Rogillio	1970	Biloxi Marsh, La.	April and continued into Oct. Heavier spawn May through August.		Observation of gonadal condition.
Futch	1970	Fla.	March-October	Deeper portions of estuary.	
Jannke	1971	Everglades Nat. Park, Fla.	Year round, reduced in late fall and winter, peak variable.	At estuarine end of Passes and within Passes.	Observation of recently spawned larvae.
Mahood	1974	Georgia	April-August. Peak in May.	All areas of estuary, including beach. Ripe fish usually in 3-10' of water.	Stages of gonad maturity (I-VII). Closely follows Tabb (1961)
Rogillio	1975	SE La.	April-October Peak in May	Probably in deep water.	Observation of maturing, ripe and spent fish.
Peerler, et al.	1976			Deeper channels adjacent to vegetated areas.	Suggestion
Arnoldi	1978 (Pers. Commu.)	SW La.	1977 May-Sept., peak in mid-July. 1978 Bulk of spawning Aug. and early Sept.	channels or immediately offshore.	Catch of larvae by plankton net, catch of adults by seine and gillnet. Gonad condition by GSI.

Vegetative types present in the majority of the saline Barataria estuary consisted of these emergent species: oyster grass (*Spartina alterniflora*), glasswort (*Salicornia* sp.), black rush (*Juncus roemeriannus*), saltwort (*Batis maritima*), black mangrove (*Avicennia nitida*), and salt grass (*Distichlis spicata*). (*Chabreck* et al. 1968). The upper portions of the bay appeared to be brackish during much of the year.

The objectives of this project were fulfilled during 2 non-consecutive years, 1976 and 1978. Sampling during 1976 was carried out on a weekly basis between April and September and bi-monthly during the remainder of the year. Throughout the summer specimens were captured by 3 gear types: a 183 x 2 m. beach seine with 5 cm. stretch mesh, hook and line, and a 360 x 2 m. monofilament gill net with 7.6 cm. stretch mesh. Most of the specimens taken during the winter months of that year were sampled from the catches of commercial fishermen. Incoming boats were met at the fish house by biologists who selected fish at random from the holds of the boats. Following a review of the 1976 data, we concentrated 1978 sampling from April through September since this period included the primary spawning peak(s). Four stations were selected throughout the bay where fish were known to congregate: Station 1 was the southern most station nearest the Gulf of Mexico and Station 4 was the northern most station farthest from the Gulf. Sampling was conducted weekly with the 7.6 cm. stretch monofilament gill net, using the runaround mehtod described by Siebenaler (1955).

Approximately 15-25 females and an equal number of males were taken in each collection whenever possible. Standard length (SL) and total length (TL) measurements were obtained from each fish and were recorded to the nearest millimeter. All future length measurements will be referred to in total length unless stated otherwise. The weight of the fish was registered to the nearest gram, while gonad weights were recorded to the nearest 0.01 g.

Gonad maturity was determined from the gonadosomatic index (GSI) which is an expression of gonad to body weight as a percentage, i.e., $GSI = \left(\frac{\text{gonad weight}}{\text{body weight}}\right) X\ 100.$

The GSI tends to increase with ripening and maturity of the gonads until there is a release of the sex products, whereupon a decrease in the index occurs during the post-spawning period. This method was chosen in preference to the 6 stages of sexual maturity established by Tabb (1961), primarily due to possible overlapping and misinterpretation of stages by different workers.

RESULTS AND DISCUSSION

Size, Sex Ratio and Sexual Maturity

Length of females captured during the 1976 spawning season ranged between 277-578 mm and averaged 391 mm. Length of males ranged between 232-462 mm and averaged 354 mm. During the 1978 period the range for females was 244-629 mm, averaging 407 mm, and the range for males was 223 481 mm, averaging 320 mm. With the exception of 1 month in 1976, average length of males was always smaller than females although males as large as 462 mm were captured during the study. These findings agree with Pearson (1929) and Moody (1950). Klima and Tabb (1959), Tabb (1961), and Futch (1970) stated females grow faster than males which probably accounts for the larger size of females in this study and reported by Gunter (1945) and Tabb (1961). We also noted the overall size of fish increased from the northernmost station to the southernmost station.

Sex ratios were not recorded in 1976; however, in 1978 female: male sex ratio was 2.4:1. When broken down by station, the data showed an increase in the female: male ratio from the southern to the northern portion of the bay. This corresponds closely to the 2:1 ratio found by Pearson (1929) in Texas and 1.7:1 ratio of all fish examined by Mahood (1974) in Georgia waters. Klima and Tabb (1959) observed females outnumbered males in the older age groups of seatrout in northwest Florida. This was also indicated by Iversen and Tabb (1962) along the west coast of Florida.

The smallest ripening female in this study was 207 mm, and 163 mm SL for the smallest ripening male. Miles (1951) observed maturing males between 160 and 175 mm SL. Tabb (1961) noted fish of both sexes mature over 38 cm SL, while Klima and Tabb (1959) reported that all males mature at 25 cm SL and all females mature at 27 cm SL. They also found the smallest ripe male was 18 cm SL. Moody (1950) stated that females reached maturity between 210 and 250 mm; the smallest ripening males were between 200-240 mm.

Sound Production

One endogenous function believed associated with the spawning act is a "croaking" sound often heard during capture and handling. All sound producing specimens were examined and determined to be males. None of the females produced any discernible sound. Rogillio (1975) reported sound production in male spotted seatrout 14-16 inches long. Bulkenroad (1931) heard no croaking sounds from the pharyngelas of *Cynoscion nebulosus*, which is the apparent capability of some species of fishes, and concluded that the male spotted seatrout produce sound with the swim bladder apparatus. Tabb (1966) noted soft croaking by males in the spawning school and stated the males "have well-developed sound-producing apparatus at spawning time." Tower (1908) concluded that sound production results from a series of contractions by the drumming muscle at a definite rate, chiefly in conjunction with the swim bladder and its tense, pressure-filled elastic walls. Smith (1905) described the drumming muscle as being present and producing sound only in males and its primary function as sexual. Guest (1978) observed drumming and nudging prior to spawning in the red drum (*Sciaenops ocellata*) and presumed sound production to be by the males only. The drumming muscles of

Cynoscion regalis were well developed during the spawning season after which they regressed (Pers. Commun. of J. Merriner, VIMS, as reported in Chao 1978).

Our findings agree with those of the aforementioned authors. Only males had the red drumming muscle which is attached to the dorsal wall of the body cavity in association with the swim bladder. The muscle was not observed in females of this species. Only males are capable of producing the croaking sound.

Adult males had a deeper red color of the drumming muscle during the spawning season than at other times of the year and the muscle in juvenile males did not have the deep red color of the adult males. The smallest male in which the muscle was found was 175 mm and the smallest ripe male with the muscle was 193 mm. This suggests some correlation between the muscle and sexual maturity and therefore was helpful in sex determination of young fish. Croaking was pronounced throughout the spawning season and is thought to be primarily a sexual function; however, it was also noted at other times during the year when gonads had regressed, suggesting the organ might have secondary functions of defense or other possible uses.

Spawning

The gonadosomatic index (GSI) was used in this study to determine the spawning peak(s) and season for the spotted seatrout. Pickford and Atz (1957) believed the GSI to be a reliable indicator of the gonadal condition. It has been used successfully by Haydock (1971) and Killebrew (1973) on another important member of the Sciaenid family, *Micropogon undulatus.* Wiebe (1968a,b), in 2 studies on *Cymatogaster aggregata,* also used the GSI as a measure of sexual maturity.

According to various authors and the geographic location of their studies, there is a wide range for the spawning period of the spotted seatrout, including nearly every month of the year, as shown in Table 1. During this study 2 distinct peaks were noted (as was suggested by Gunter (1945) even though he could not prove 2 peaks due to inconclusive data). Stewart (1961), working in the Everglades National Park of Florida found bimodal peaks occurring in May and August. The GSI averaged higher for females than males for both years because of their larger mass, but males and females did have closely corresponding indexes. The index began a sharp rise in March 1976, reached a peak in May, declined in June and reached a second but smaller peak in July, decreasing until October when it leveled off (Fig. 1). Results of 1978 closely correspond to findings in

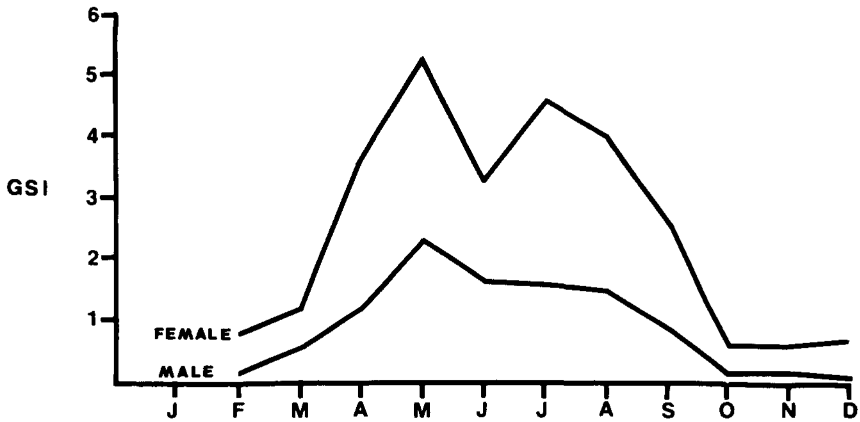

Fig. 1. Gonadosomatic Indices plotted monthly for the 1976 sampling period.

1976, except the second peak was one month later and slightly higher than the first peak of both years (Fig. 2). Arnoldi (Pers. Commun.). working in southwest Louisiana also found a later spawn occurring in August 1978, as compared to a peak in mid-July of 1977. Since most of the samples in 1976 were taken at random in the vicinity of station I-III, the northermost station (IV) was omitted for 1978 and results were again compared. With the omission of station IV the May peak was increased and the August peak was lowered (Fig. 3). Fish apparently spawned later in the season at stations further north in the bay as indicated by the higher GSI for August (Fig. 4). The GSI was further broken down to show peaks by week and stations (Fig. 5) for 1978. Gravid females and ripe males were found during the third week of May which was the primary peak for all stations. The second major peak in August revealed no distinct weekly peak, but varied among stations.

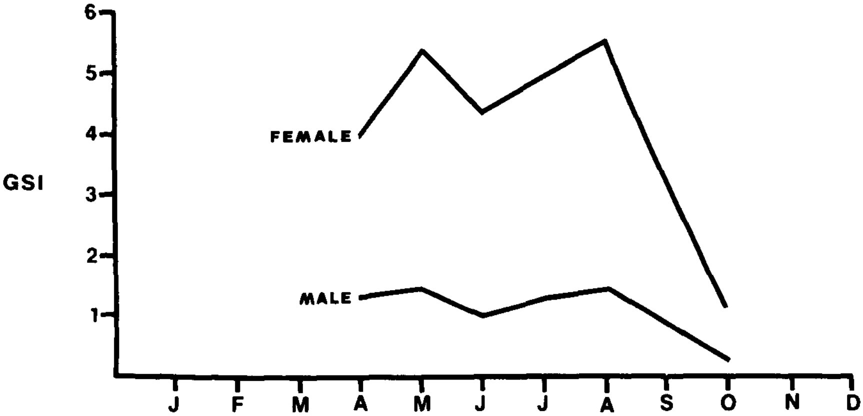

Fig. 2. Gonadosomatic indices plotted monthly for the 1978 sampling period.

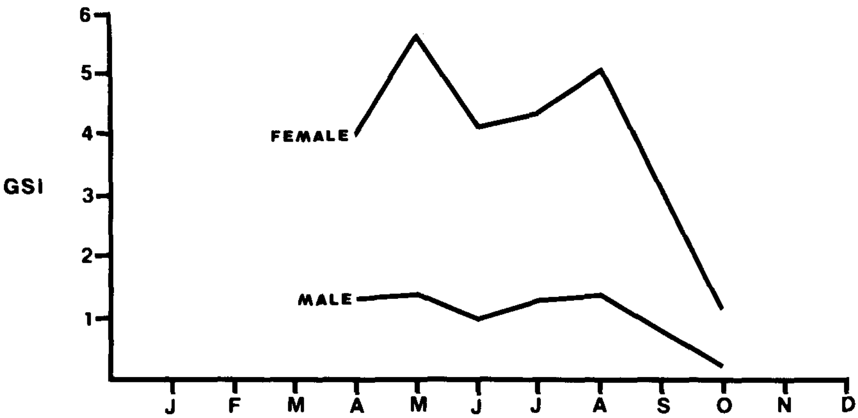

Fig. 3. Gonadosomatic indices plotted monthly for the 1978 sampling period, omitting Station IV.

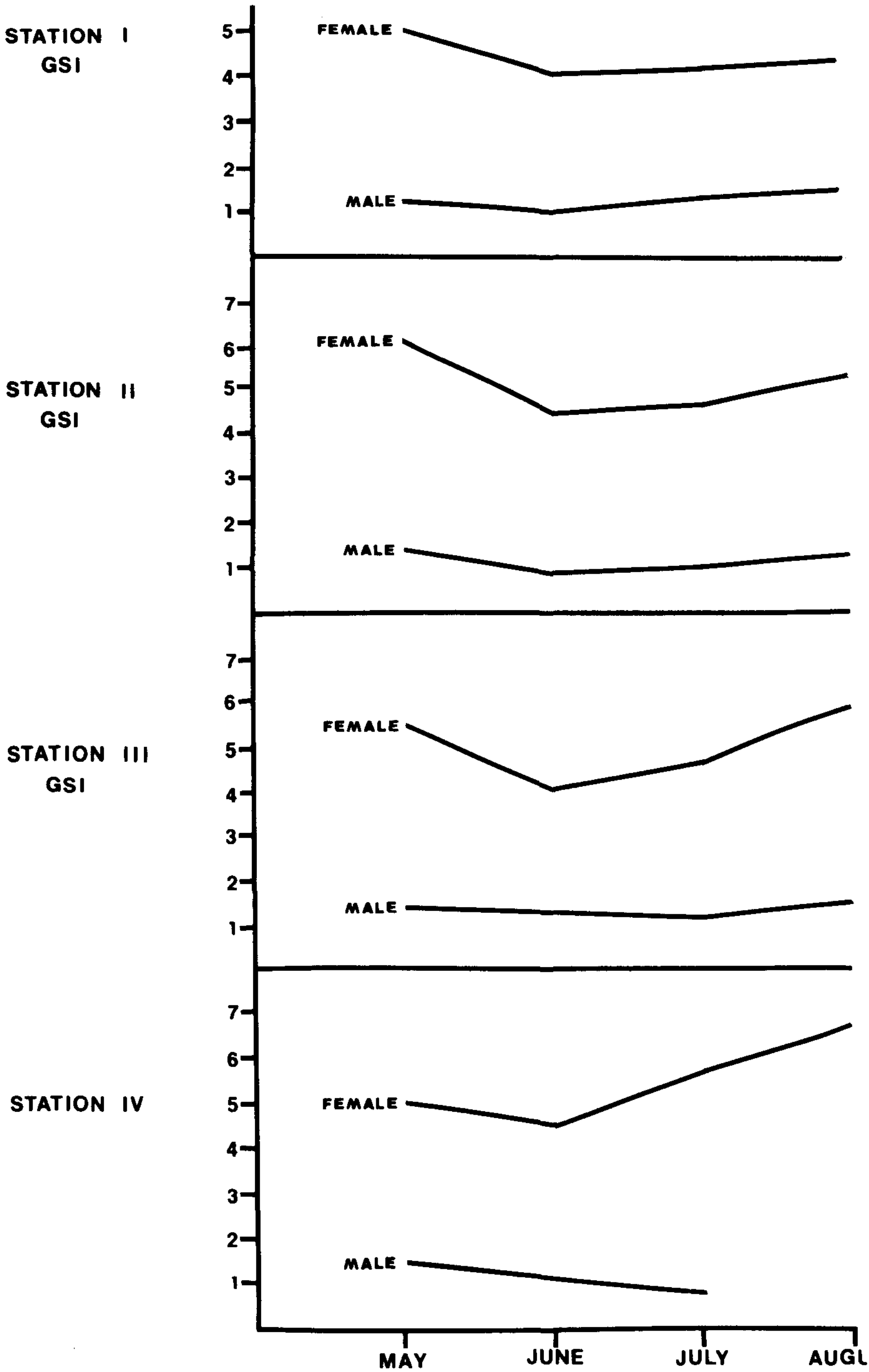

Fig. 4. Gonadosomatic indices plotted monthly for stations I-IV during the 1978 sampling period.

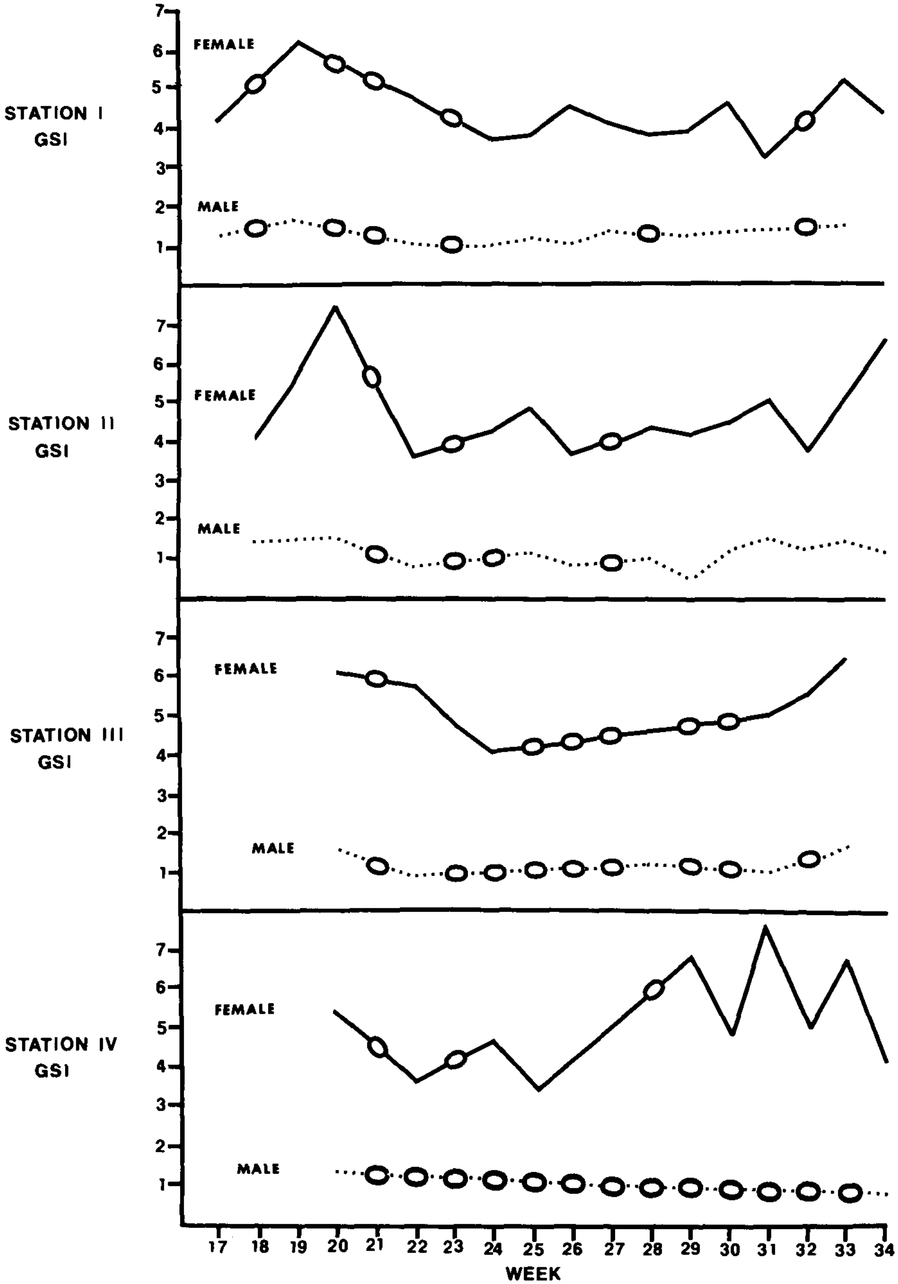

Fig. 5. Gonadosomatic indices plotted weekly for stations I-IV during the 1978 sampling. 0 indicates no fish taken.

Even though no gravid females were captured at stations I and IV, the high GSI value indicates spawning porbably occurred for these stations. Although there are numerous observations and suggestions concerning the physical area required for the spawning act (Table 1), we found the fish did not necessarily require areas of specific salinities and water depths, substrate or low turbulence. Gravid fish were collected in shallow water along the sandy beaches, in the turbulent passes, and on natural sand and shell reefs in varying depths of water. Sackett and Hein (1977) found a probable natural spawn of spotted seatrout in a 0.1 ha pond with a silt-sand substrate within the study area.

The first ripe males were taken 11 days prior to any gravid females. Miles (1951) also observed male seatrout running ripe as long as 2 weeks prior to the females. Haydock (1971) found male croakers maturing as early as 1 month prior to females. Ripe male and female seatrout were found at times other than the 2 major peaks but spawning activity chiefly centered around these peaks. Gravid females and running ripe males were easily captured during the peaks by hook and line fishermen.

Condition factors (K_{TL}) aided in determining the primary spawn for the first peak in both years but was not useful in determining the secondary peak. There was a buildup in the K_{TL} to a peak in April and a subsequent decline in May associated with spawning (Figs. 6 and 7). A gradual decrease in the K_{TL} followed throughout the remainder of the year. This pattern occurred consistently for all stations during 1978 (Fig. 8).

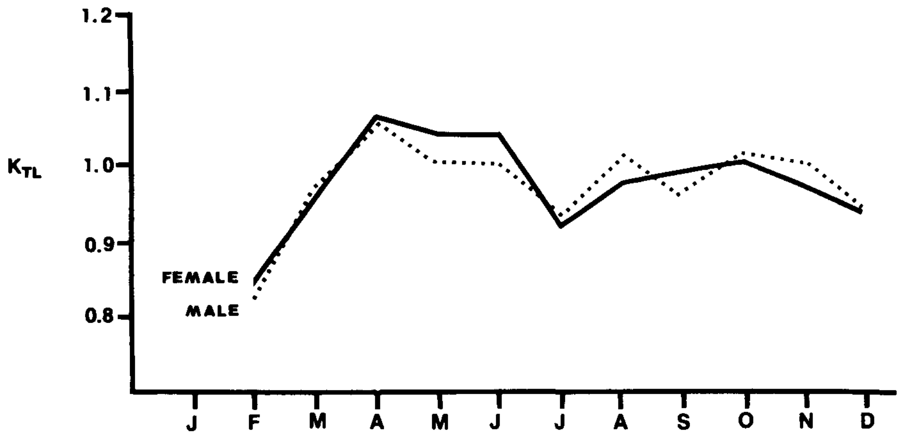

Fig. 6. Condition factors plotted monthly for the 1976 sampling period.

Physical Parameters

Numerous and oftentimes highly variable factors act upon each system affecting the prevailing conditions at any specific time. These factors, such as temperature, photoperiod, salinity, rainfall, tidal range, current pattern, wind, moon phase, turbidity and barometric pressure acting independently or collectively, are capable of influencing the system in varying degrees.

The majority of studies dealing with environmental factors which affect reproduction have been primarily concerned with photoperiod and temperature. As suggested by Hoar (1965) and Haydock (1971), photoperiod and temperature are the environmental regulators of reproduction in temperate and high latitude fishes. The importance of these factors often varies among different species (Hoar, 1965) where spawning peaks may occur earlier or later depending upon the overriding effect of one factor or the synergistic effect of both factors.

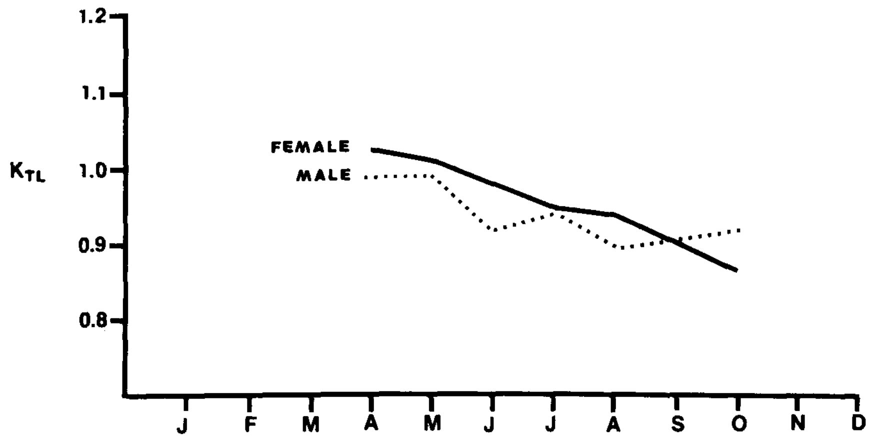

Fig. 7. Condition factors plotted monthly for the 1978 sampling period.

Photoperiod - Photoperiod, as determined by daylight hours from sunrise to sunset, followed a very close pattern in 1976 and 1978. The peak spawn in May for both years was recorded on an increasing photoperiod, while the second major peaks were recorded on a decreasing photoperiod for both years (Fig. 9). However, the amount of light during which gravid fish were captured remained relatively the same for 1976 at 13 hours, 42, 54 and 59 minutes, and for 1978 at 13 hours, 10, 33 and 41 minutes. Keeping in mind that the total amount of light hours in a day is greater than the amount between sunrise and sunset, it is conceivable that these findings would concur with those of Arnold et al. (1976) who reported a controlled spawn at 15 hours of daylight.

Temperature - Water temperature remained relatively the same for the 2 years studied although warmer temperatures occurred earlier for 1976 than for 1978. Despite daily and weekly fluctuations in temperature, average monthly temperatures increased throughout the prime spawning period for both study years. The average daily temperatures in which gravid fish were captured were 24.6-30.1C in 1976 and 24.1-29.7C in 1978. Tabb (1958) observed spawning in the spring when water temperatures averaged 25C and was largely completed by the time temperatures of lagoons averaged 28 C. Stewart (1961) found spawning peaked between 28-30 C in the Everglades National Park, but stated that it was doubtful that temperature triggered spawning. Rogillio (1975) reported that gonadal development was directly proportional to an increase in water temperature with the first spent individuals occurring at 21-25 C and the highest number of spent fish at 30-34 C. Fontenot and Rogillio (1970) described a range for spawning between 26 and 35 C. Jannke (1971) stated that a temperature of approximately 24 C appeared necessary to permit spring spawning but was not the sole requirement nor necessary for all spawning. In a controlled laboratory experiment, Arnold et al. (1976) observed that spotted seatrout would spawn at a temperatue of 26 C, coupled with a constant daylight period of 15 hours.

Tide and Moon Phase - Numerous effects on earth-bound life forms and processes are generally attributed to the position of the moon relative to that of the earth. Tidal fluctuation is 1 such associated factor. All phases of the moon were studied in relation to high GSI values, clearing eggs and gravid fish. These conditions were noted during all moon phases; therefore, no direct correlation was found. Tidal fluctuation correlated directly with the new and full moons which had the higher ranges while the quarters had the lowest ranges.

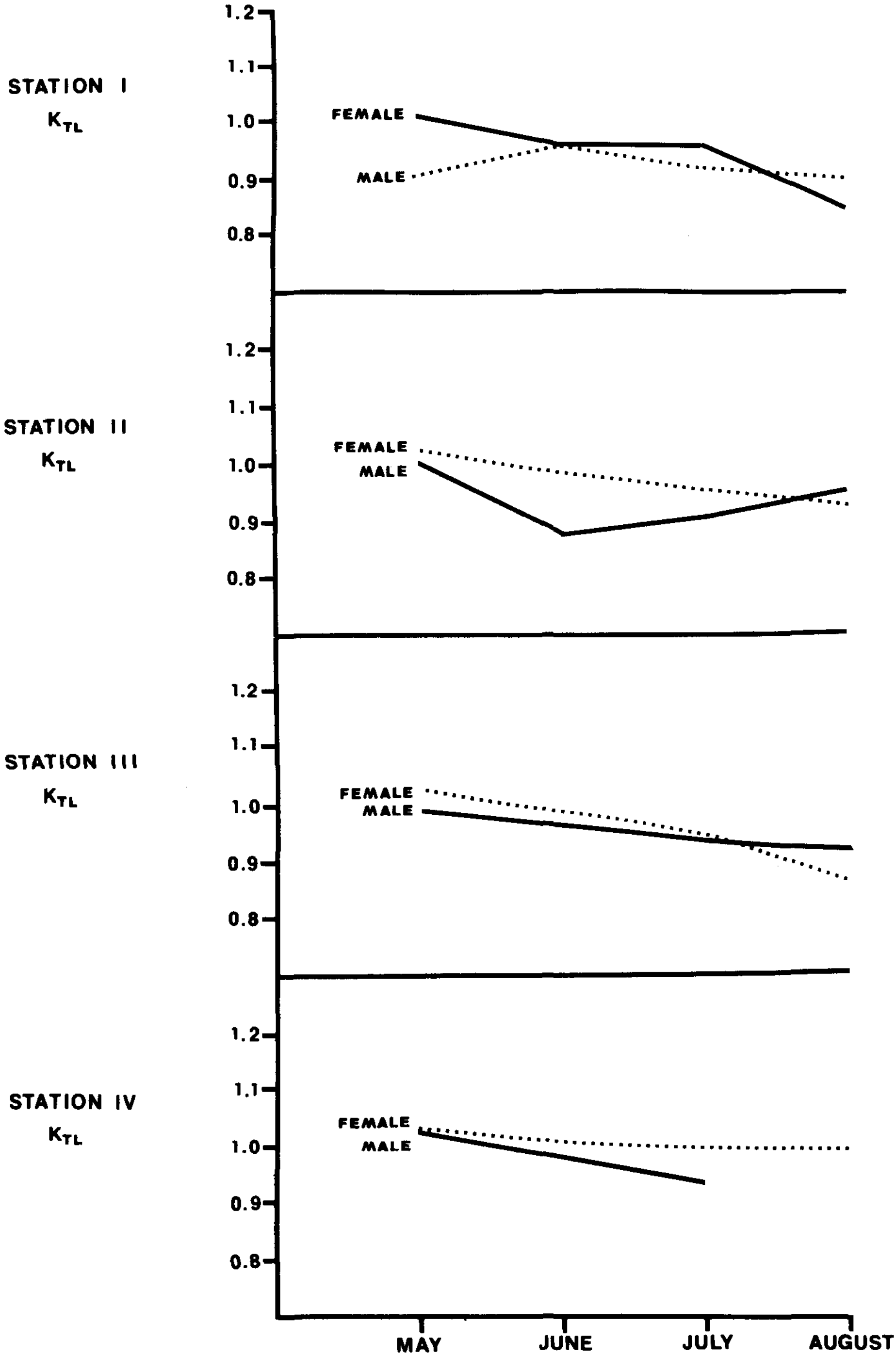

Fig. 8. Condition factors plotted monthly for stations I-IV during the 1978 sampling.

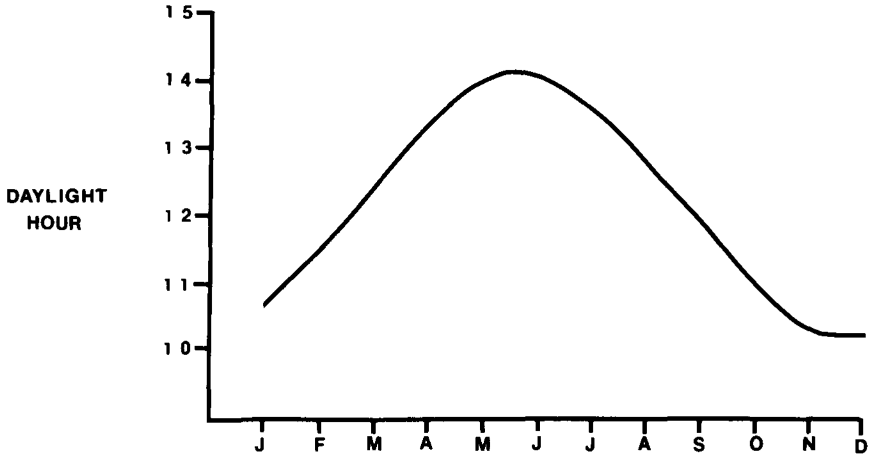

Fig. 9. Photoperiod plotted monthly indicating daylight hours throughout the year.

Salinity - Fluctuating salinity is a common factor of all productive seatrout grounds (Tabb, 1966). Tabb (1966) stated peak spawning in Florida waters occurred when salinities reached 30-35 parts per thousand (ppt) in the lagoons and estuaries during dry spring months. Salinity at the sample stations during the primary spawning months of May through August indicated a great deal of variation ranging from 7-29 ppt in 1976 and 20-26 ppt in 1978. By comparison, salinities were lower in 1978 than 1976 and were depressed during the spawning peaks of 1978. Clearing and gravid fish were captured in 21-26 ppt in 1976 and 17-26 ppt in 1978.

Turbidity - Throughout most of the area there is usually some degree of water turbidity primarily caused by the influence of the Mississippi River. Wave and wind action, as well as exchange of water by current and tidal movement, also increases turbidity by suspending substrate material (Moody 1950). Throughout the spawning period, average monthly turbidity for 1978 was highest during the spawning peaks.

Barometric Pressure - Barometric pressure plotted on a monthly basis indicated very little fluctuation for either year studied although some variations were noted. In 1976 barometric pressure ranged 29.43-30.18 and averaged 29.99, while it ranged from 29.71-30.24 and averaged 30.08 for 1978.

Rainfall - Rainfall varied throughout the period studied with an average of 14 and 8 cm for the 2 peaks in 1976 and 3 and 15 cm for the 2 peaks in 1978. Higman (1967) in relating his work to Stewart (1961) suggested rainfall influenced survival of larval and juvenile trout.

These and perhaps more subtle factors, such as pollution and habitat destruction, probably affect the behavioral responses of adult seatrout and may have deleterious effects upon the survival of the eggs, fry and juvenile fish as well. Hedgepeth (1947) stated the effects of physical alteration, industrialization and pollution is irreversible whereas natural mortality causes can be overcome if the environment remained unspoiled. Johnson et al. (1977) suggested considerable loss of larval seatrout in areas of chlorinated effluent disposal where the toxic products of sodium hypochlorite and seawater were above 0.17 ppm. Colura and Hysmith (1974) in a laboratory experiment found food and survival closely linked where complete mortality of larval seatrout occurred when they were held at food concentrations below the 3.5 organisms per ml level.

CONCLUSIONS

Female spotted seatrout are generally larger than the male seatrout and outnumbered them in this study at a ratio of 2.4 to 1. Males matured earlier in the season and at a smaller size than females. Only males have a well-developed sound-producing capability which is more evident during the spawning season. Fish were found to spawn throughout the estuary regardless of water depth or substrate. Spawning seemed to occur later in northern portions of the bay than in more southern areas. The mean size of fish increased from north to south. The gonadosomatic index (GSI) proved to be an acceptable indicator of the spawning peaks for seatrout. Two distinct spawning peaks were noted for spotted seatrout in this area for each of the two study years. Condition factors (K_{TL}) proved to be helpful in determining the initial peak, but were of little use throughout the remainder of the extended spawning season.

Of the physical parameters studied, photoperiod and temperature appear to be the two most important exogenous factors influencing spawning. Because temperature is dependent upon photoperiod it is difficult to determine which has the prevailing effect upon spawning. We believe that photoperiod is the most influential factor with temperature being secondary. Of the other factors, little if any correlation to spawning was noted; however, they might have lesser influences to varying degrees.

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