AN ANALYSIS OF THE FREQUENCY AND DURATION OF SPAWNING OF LOCAL WEAKFISH, *CYNOSCION REGALIS*, BASED ON AGE AND SIZE STRUCTURE OF YOUNG-OF-THE-YEAR FROM THE HUDSON RIVER, NEW YORK

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ABSTRACT

Weakfish, *Cynoscion regalis*, is a key member of the commercially and recreationally important fishes of the Mid-Atlantic Bight that inhabits inland waters during its larval and juvenile life-stages. Most studies on the timing of weakfish reproduction have used gonadal analysis and have focused on populations to the south of the Hudson River. Some studies have inferred the frequency of weakfish spawning from length distributions of young-of-the-year (YOY) juveniles, but this method is imprecise due to the variations in growth rate of YOY. This study utilizes size and otolith-based ages of YOY weakfish to evaluate the frequency and duration of spawning. Young-of-the-year weakfish were collected from the Hudson River by trawling during monthly surveys from April through October of 2001 and 2002 (surveys were not conducted in May or September). Young-of-the-year were collected by 5-min trawl tows at up to 10 stations, from the Battery to Newburgh, New York. Weakfish were abundant in our July, August, and October surveys in both years and each monthly length-frequency distribution was unimodal. In 2002, however, YOY weakfish were collected as early as June. Analysis of the otolith-based hatch-date distribution of YOY weakfish from 2002 suggests some early spawning in April with the median hatch-date in late June. We also estimated hatch-date distributions of YOY for both year-classes based on size-at-collection and estimates of year-specific growth rates. This size-based reconstruction of the hatch-dates also suggested an earlier initiation of spawning in 2002 than in 2001. The interannual variability in the timing of spawning that we observed may be due to variations in environmental factors and/or variation in the demographic composition and condition of the mature females.

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INTRODUCTION

Weakfish, *Cynoscion regalis*, is distributed from Nova Scotia, Canada to Cape Canaveral, Florida and supports an important commercial and recreational fishery in the Mid-Atlantic States (Shepherd and Grimes 1983, Able and Fahay 1998). Weakfish males and females mature and some spawn as early as age 1 (Lowerre-Barbieri et al. 1996b). Weakfish over-winter in continental shelf waters off the coast of North Carolina to Florida (Wilk 1979). In the spring, some weakfish migrate northward and inshore to the waters of the New York Bight, where they spawn in early to mid summer before emigrating offshore and southward in the fall (Wilk 1979, Shepherd and Grimes 1983). Weakfish larvae hatch in ~ 2 d and begin to move up-estuary into brackish waters where they reside until early fall when they also emigrate to over-wintering areas (Thomas 1971, Wilk 1979).

A number of studies have reported on the timing of spawning by weakfish, although the details remain unclear – possibly due to regional and interannual variation in spawning parameters (Thomas 1971, Shepherd and Grimes 1984, Lowerre-Barbieri et al. 1996a, Lowerre-Barbieri et al. 1996b, Nye 2002). Lowerre-Barbieri et al. (1996b) reported that individual female weakfish in Chesapeake Bay released batches of eggs every 2 to 21 d during the period from May to August. Shepherd and Grimes (1984), however, concluded that weakfish in the New York Bight region showed no evidence of multiple batches of eggs per female at this more northerly portion of its regular spawning range. Shepherd and Grimes (1984) also noted that larger females began spawning earlier in the season than did smaller females.

The broad period over which weakfish spawn may lead to similarly broad size and age distributions of YOY in some years, and perhaps to distinct cohorts within a yearclass at some locations (Thomas 1971, Szedlmayer et al. 1990, Paperno et al. 2000). Thomas (1971) concluded that multiple modes in the length-frequency distributions of YOY weakfish in Delaware Bay reflected the time course of local spawning. There are, however, several reasons why length-frequency distributions of YOY may only coarsely portray the temporal distribution of spawning activity that produced these individuals. First, only YOY fish that survive to be captured are represented in the length-frequency distributions of YOY. Thus, any size- (length)-based bias in mortality prior to sampling the population would likely reduce the correspondence between size structure of YOY and its time course of spawning. Second, lengths of YOY at capture will be affected by any variation in their growth rates prior to their time of capture.

Estimates of the ages of captured YOY are likely to provide a more true reflection of the hatch-date distributions than that provided by lengths at capture. Although this age-based method for determining hatch-date may also be affected by differential mortality of YOY prior to their capture, it should otherwise provide an accurate reflection of the timing of spawning if one can assume that ages are determined correctly. Szedlmayer et al. (1990) used daily increments on scales of YOY weakfish to infer the time course of weakfish spawning in waters of the York River estuary in Chesapeake Bay. They identified three clear age cohorts of YOY weakfish in 1983 and two cohorts in 1984, and concluded that these cohorts reflected the pattern of spawning earlier that year.

This study assesses the frequency and duration of spawning by weakfish in 2001 and 2002 in the waters associated with the Hudson River, a site near the northern margin of regular weakfish spawning. Our objective was to estimate the initiation, termination, and frequency of spawning – including any evidence of multi-modality in the spawning distribution – from the size and age structures of YOY. In both years, the sizes of YOY weakfish in combination with estimated growth rates were used to infer the hatch-dates of survivors and, hence, the timing of weakfish spawning. In 2002, an otolith-based aging method was also used to estimate hatch-dates of YOY.

METHODS

Samples of YOY weakfish were obtained from the Hudson River during 2001 and 2002 as part of monthly surveys from April to October of each year (surveys were not conducted in May or September). The sampling stations were located from 5 to 17 km apart, beginning offshore of the Battery on lower Manhattan Island, New York and extending upstream to the Newburgh Bridge (Table 1, Figure 1). A channel tow and a shoal tow to each side of the channel were conducted at each station in 2001. In 2002, a channel tow and one shoal tow were conducted. All tows were of 5-min duration and towed into the current using a 4.9-m otter trawl with 3.5-cm stretch mesh walls and fitted with 4.75-mm stretch mesh liner in the cod end. GPS/Loran C was used to determine locations of each station.

YOY weakfish were separated from the other tow contents and treated in one of four ways. In 2001, the first subset of weakfish (N = 44) was measured (SL) fresh and the fish were individually preserved in 95% ETOH. These fish were measured again after 1 wk and the two lengths were used to derive an estimate of fish shrinkage while in ETOH. Weakfish in the second subset of 2001 (N = 33) were also measured prior to preservation and again 1 wk later, but these were individually preserved in 10% formalin (this subset was also used for a concurrent project). Again, the two lengths were used to derive an estimate of fish shrinkage while in formalin. Our intent was to provide shrinkage corrections for both preservatives for the entire size range of YOY weakfish expected to be collected in our surveys. Our *a priori* expectation for the range of sizes likely to be encountered was based on 9 yr of length-at-capture data for YOY weakfish (1990 – 1998) collected in the Hudson River by the Hudson River Estuary Monitoring Program under the auspices of Central Hudson Gas & Electric Corporation (J. Young, ASA Associates, *unpublished data*). The third and major subset of YOY weakfish collected in 2001 was immediately preserved in 95% ETOH by tow group for later processing in the laboratory. The shrinkage of this third group due to ETOH preservation was estimated based on the analysis conducted on fish in the first subset. The regression equations relating fresh and preserved lengths for ETOH and formalin are $SL_{fresh} = 0.85 + 1.02 * SL_{ETOH}$ ($r^2 = 0.99$, range = 11.3 to 119.0 mm SL_{fresh}, n = 44) and $SL_{fresh} = 1.06 + 1.01 * SL_{formalin}$ ($r^2 = 0.99$, range = 12.5 to 88.7 mm SL_{fresh}, n = 30). All sizes of YOY weakfish collected in 2001 are reported here as fresh SL. The fourth subset contained YOY weakfish collected in the 2002 surveys. These were bagged according to tow group and immediately frozen at -20 °C on board for later processing. All YOY weakfish collected in 2002 are reported as thawed SL.

We used the length-at-capture data in two ways. First, these were examined for seasonal and interannual variations in lengths at capture, as well as for evidence of multiple modes as might be suggestive of multiple peaks of spawning. Second, we also used estimates of length at capture to estimate monthly and overall growth rates (mm d^{-1}). Estimates of monthly growth rates were calculated from the changes in the mean length at capture of YOY weakfish collected in two sequential surveys in a year. For each year, an estimate of an overall growth rate of YOY prior to their capture was calculated from the grand mean of the estimated monthly mean growth rates for that year. These monthly and overall growth rates for each yearclass were analyzed for seasonal and interannual variation, respectively.

We estimated the hatch-dates for the collected YOY weakfish in two ways. First, we used a size-based method to estimate hatch-dates. In this method, the year-specific overall growth rates were applied to the lengths-at-capture data in order to derive estimates of age at the start of growth. Assuming that weakfish hatch 2 d after they were spawned at 1.75 mm TL (Harmic 1958), these ages at the start of growth were used as estimates of hatch-dates of YOY weakfish. This size-based method also assumes that growth rates during all early life-stages of weakfish are constant. We analyzed the size-based hatch-dates for interannual variation in the timing of several parameters of weakfish spawning: initiation, termination, and median (50^{th} percentile) hatch-dates. In the second method, we estimated ages of YOY at the time of capture by enumerating increments of the right-side sagittal otoliths for a subset of YOY weakfish collected from each survey in 2002. This age-based method assumes that the periodicity of otolith increment deposition is daily and that the timing of first increment formation relative to spawning is known. Paperno et al. (1997), in a validation study of increment formation of otoliths of YOY weakfish from the Delaware River, reported that increments are deposited daily. We also assumed that the first increment corresponds to the first day after hatching. In addition to the age-based method providing us means of estimating hatch-dates for the 2002 yearclass independent of the size-based method, we were also interested in the correspondence between estimates of hatch-dates derived from these two methods.

The subset used for the age-based method in 2002 consisted of up to 20 randomly selected fish from every other station for each survey. From the 1,622 YOY weakfish collected in 2002, 216 were assigned to otolith-based ageing. Of these, otoliths from 139 YOY weakfish were successfully prepared and their increments were enumerated. The size of fish for which otoliths were prepared approximated the size range of all weakfish collected from each survey during 2002 (range = 12.4 to 130.4 mm SL).

Otolith preparation was done with procedures modified from Secor et al. (1984). The right-side otoliths were individually embedded in resin (Spurr 1969). A low-speed Isomet® saw was used to cut a transverse section through the resin-embedded otolith. The exposed face was then ground toward the primordial center of the otolith. The rough face of the block of resin containing the otolith was ground by hand on 400 – 2000 grit carborundum paper and polished with 0.3-µm alumina paste. The side opposite of the polished face was then cut with the Isomet® saw, the polished face was attached to a glass slide with thermoplastic glue, and the rough face was then ground toward the center and polished. Enumeration of daily increments was made on the transverse section along transects from the nucleus to the margin of the otolith at 400 – 1000 × magnification using a Leica compound microscope. A second count of increments was conducted on a randomly selected subset of these otoliths in order to evaluate the repeatability of our increment counts. Our technique of enumerating daily increments of otoliths was highly repeatable (between the two readings $r^2 = 0.96$, N = 64).

RESULTS

Over 1,000 YOY weakfish were collected in 2001 with a peak in abundance in July (Table 2). Abundances of captured YOY decreased as the season progressed. Numbers declined by 75 % between July and August and by 73 % between August and October 2001 (Table 2). The number of YOY weakfish collected in 2002 was approximately 1.5 × higher than that of 2001 (Table 2). Unlike the pattern reported for 2001, some YOY weakfish were collected during June in 2002 (N = 3). Maximum abundance again occurred in July and decreased with progression of the season. Numbers decreased by 26 % between July and August and by 78 % between August and October (Table 2).

The abundances of YOY weakfish captured in this study suggest both seasonal and interannual variations in the magnitude and timing of weakfish recruitment to the benthic habitat (Table 2). The collection of YOY weakfish in early June 2002 also