

Reproduction of Black Drum, *Pogonias cromis*, from the Chesapeake Bay Region.

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ABSTRACT

Ovaries of black drum, *Pogonias cromis*, collected from the Chesapeake Bay region in 1992, were used to describe reproductive strategy and fecundity. Histological examination showed that black drum spawn in the Chesapeake Bay region from April through early June. Distributions of oocyte diameter showed distinct oocyte-developmental groups indicating that Chesapeake Bay black drum are group-synchronous batch spawners. Female black drum are extremely fecund ranging from 414,000 to 3,736,000 hydrated oocytes (mean = 1,389,000) per batch with a spawning periodicity of 3.8 days. Estimates of spawning strategy, spawning periodicity, and batch fecundity for black drum from the Chesapeake Bay region were similar to reported estimates from the Gulf of Mexico.

INTRODUCTION

In U.S. waters, where the primary range for black drum, *Pogonias cromis*, in the Northwest Atlantic is from the Delaware Bay south to Florida and through the Gulf of Mexico (Welsh and Breder, 1923; Hildebrand and Schroeder, 1928; Silverman, 1979), there are at least two known populations: one along the U.S. East Coast and one or more in the Gulf of Mexico (Gold *et al.* 1995; Jones and Wells 1998). Many essential elements of the reproductive life history are well understood for stocks in the Gulf of Mexico (Fitzhugh *et al.*, 1993; Nieland and Wilson, 1993; Saucier and Baltz, 1993; Fitzhugh and Beckman, 1987). Specifically, black drum from the Gulf of Mexico mature at five years, are group-synchronous spawners, with a batch fecundity of 1.4 to 1.6 million hydrated oocytes, and have a spawning periodicity of 3 - 4 days (Fitzhugh *et al.*, 1993; Nieland and Wilson, 1993).

In contrast to the Gulf of Mexico black drum, little is known about the reproductive biology of black drum along the U.S. East Coast. Studies of adult black drum in Eastern Florida and in the Chesapeake Bay have been limited to estimating the age at maturity and spawning season. Murphy and Taylor (1989) showed that the age at first maturity is five to six years and the spawning season along Northeast Florida is from January to May with peak spawning in March and April, while Alshuth and Gilmore (1995) found a more protracted spawning season from October to late March. In Virginia waters Bobko (1991) observed a spawning season of April through May, and noted that all fish were mature by age six. Although the length of the spawning season and age of maturity have been documented, spawning strategy has not been described nor batch fecundity estimated for black drum from along the U.S. East Coast.

Estimates of batch fecundity are essential to understanding life-time reproductive output. However, this information is difficult to obtain because an age-specific migration pattern exists for this population. Although black drum of all ages are present

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along Eastern Florida, with the majority of fish being very young, predominately old fish are found in the Chesapeake Bay and individuals younger than 10 are rare. This pattern is a result of size- and age-specific migrations, wherein larger, older fish expand their spawning range (Jones and Wells, 1998). Black drum in the Gulf of Mexico are not known to take the long-range spawning migrations that occur along the East Coast. Given this marked difference in behavior, other differences may also exist in reproduction between these populations.

We estimate the spawning strategy and batch fecundity of black drum within the Chesapeake Bay region, and compare our results to those for black drum of the Gulf Coast.

MATERIALS AND METHODS

The persistence of black drum populations is determined by their lifetime reproductive output (Stearns, 1992). Reproductive output is, in turn, determined by survival, the average age of reproduction, and the annual, age-specific fecundity. The fundamental steps in estimating fecundity are to determine spawning type (total versus batch spawner) and annual fecundity (West, 1990). For a batch spawner, batch fecundity and spawning periodicity must also be estimated. Further, as reproductive output can differ between populations of the same species, estimates must be obtained specifically for spawning strategy, annual fecundity, and average reproductive lifespan from each separate population (West, 1990). For example, populations of American shad (*Alosa sapidissima*) exhibit profoundly different reproductive characteristics along the U.S. East Coast: they are semelparous in the south and iteroparous in the north (Scott and Scott, 1988). Although such dramatic differences are rare, they underscore the importance of determining the reproductive patterns of a fish species throughout its range.

We collected ovarian samples from freshly caught black drum from early April through early June 1992 from the Virginia commercial and recreational fisheries on the bayside and seaside of the eastern shore of the Chesapeake Bay. Additional ovarian samples were obtained opportunistically from the recreational fishery in the Maryland portion of the Chesapeake Bay during 9-16 June 1992.

Commercially-caught fish were taken with anchored, monofilament gill nets of 33 cm bar mesh on the seaside of the eastern shore of Virginia in channels between barrier islands and on the bayside in waters just off Cape Charles. Both locations are sites of black drum spawning (Daniel, 1995). Fishers set their nets in early evening and fish overnight during expected periods of peak spawning (Mok and Gilmore, 1983; Fitzhugh *et al.*, 1993; Nieland and Wilson, 1993; Saucier and Baltz, 1993; Daniel, 1995) and also use multiple nets that they simultaneously drift over drumming aggregations of black drum. From the recreational fishery, we sampled hook and line caught fish, throughout the day from locations mostly off Cape Charles where 90% of the recreational catches are typically landed (Jones and Wells, 1998).

Spawning season for males was described by examining gonadosomatic indices (total gonad weight \times 100/ total body weight). We determined spawning season and fecundity for females by directly examining their ovaries. Unfixed ovarian sections were sieved to release oocytes from tissue following methods presented in Lowerre-Barbieri and Barbieri (1993). Once oocytes were freed from sections, they were preserved in 5% formalin. Smaller ovarian samples (1-2 cm³) were preserved in 10% buffered formalin for histological examination. All ovarian samples were taken from

the medial region of the fresh ovary and included a cross section of tissue from tunica to lumen. The medial region was sampled as our preliminary studies, and those of Nieland and Wilson (1993) and Fitzhugh *et al.* (1993), showed no statistical differences in development or estimates of fecundity among ovarian lobes or among ovarian regions for black drum.

Maturity stages were determined by direct histological examination of fixed ovary sections. Preserved ovarian samples were dehydrated, embedded in paraffin, sectioned to 5 microns, and stained with hematoxylin and eosin Y following Luna (1968). These sections, were used to identify four developmental stages following descriptions in Overstreet (1983), Murphy and Taylor (1989), and Morrison (1990) based on the most advanced oocyte stage and ovarian condition (stages of interest included yolked oocytes, hydrated oocytes, redeveloping ovaries showing postovulatory follicles, and spent).

Spawning strategy was determined from size-frequency distributions of oocytes and histological examination (Clark, 1934; Wallace and Selman, 1981; West, 1990). We placed aliquots of suspended oocytes in a gridded settling dish (0.5 cm² grids) and measured oocyte diameters from randomly selected grids until a minimum of 1000 oocytes had been measured from each ovary. We compared resulting distributions of whole-oocyte diameters to those of oocytes in different developmental stages that we observed in histological sections. This allowed us to associate size modes to oocyte maturation stage (Clark, 1934; Wallace and Selman, 1981; West, 1990).

Batch fecundity was estimated gravimetrically from hydrated oocytes (Hunter *et al.*, 1985). We used only fish that had no postovulatory follicles, which would have indicated a loss of oocytes before the gonads were excised, and estimated a mean fecundity from two subsamples from each fish (one fish had a single subsample). The number of hydrated oocytes estimated for each sample of known weight (0.2 - 3.5g, mean = 1.4g, $N = 13$) was expanded to the entire ovary.

Spawning periodicity was estimated from the fraction of fish with postovulatory follicles to all fish with healthy vitellogenic oocytes (Hunter and Goldberg, 1980). We assumed that all of the postovulatory follicles were approximately the same age based on estimates that postovulatory follicle duration is limited to 24 to 48 hours following ovulation (Fitzhugh *et al.* 1993).

RESULTS

In total, we obtained only 351 black drum despite our almost daily sampling over two and one-half months when the fish were most abundant. Of these, 71 were females and only 54 were considered fresh enough for ovarian examination. Of the 54 fresh ovarian samples, we obtained 37 from the commercial fishery and 17 from the recreational fishery. Also, because we were limited to using only hydrated females caught on the day of sampling, our sample size for batch fecundity estimates was small ($N = 7$). Early in the season, relatively few black drum were captured either by the commercial or recreational fishery. Large catches occurred in the last three weeks of May but were predominately males. Complete reproductive data was taken from only 83 males to accommodate fishers who dressed their catch while we sampled.

Histological examination showed that the black drum spawn in the Chesapeake Bay region from April through early June (Fig. 1). Fish entering the Chesapeake Bay region in April already had yolked oocytes (Fig. 1) and some were redeveloping, indicated by

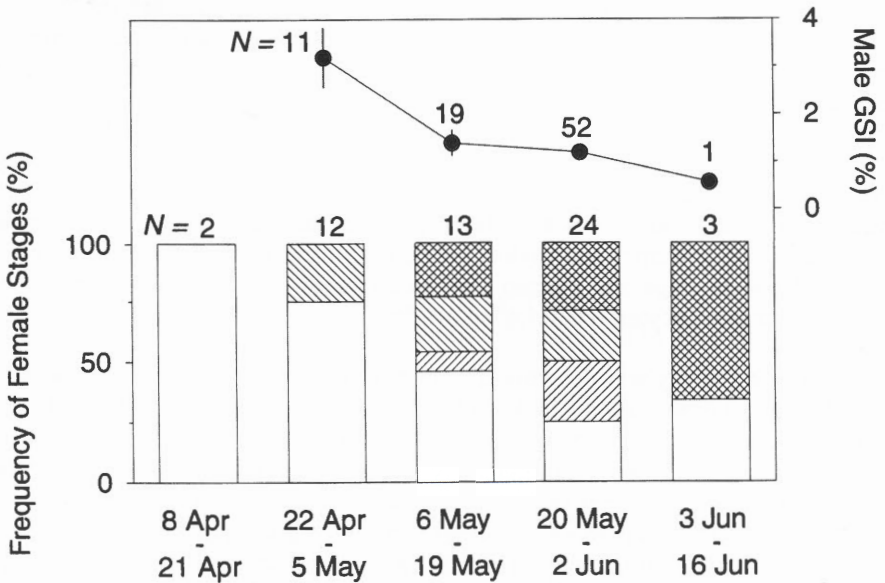


FIGURE 1. Proportions of maturity stages identified in the Chesapeake Bay region sampled 8 April - 16 June 1992. Maturity stages represented are yolked (clear), hydrated (forward diagonal), redeveloping (back diagonal), and spent (cross hatch). Virginia waters were sampled daily from 8 April - 2 June 1992 and Maryland waters were sampled 9 - 16 June 1992. Bars represent the sampled ovaries grouped biweekly. Also shown are the average gonadosomatic indices (GSI, 95% confidence intervals shown by bars) for males during the same time periods represented for females. Notice that decline in GSI values occurs as the proportion of spent ovaries increases supporting the argument that the spawning season is ending by early or mid June. Sample sizes (N) are shown above each bar and average GSI.

the presence of fresh postovulatory follicles. By early June the proportion of spent ovaries increased and that of hydrated, developing, and redeveloping ovaries decreased indicating that the black drum spawning season in the Chesapeake Bay region was April through early June. Male gonadosomatic indices decreased steadily from ~4% in April to ~0.5% by early June ($N = 83$, Fig. 1). The end date of the spawning season could not be confirmed because fishing stopped in early June, although we observed few maturing fish by this time.

Distributions of oocyte diameter ($N = 32$) showed distinct oocyte-developmental groups indicating that Chesapeake Bay black drum are group-synchronous batch spawners as defined by Wallace and Selman (1981). As an example, Figure 2 illustrates a series of size-frequency plots representing different stages of a spawning cycle. The distributions consistently showed these distinct peaks for all females. We identified postovulatory follicles in 11 ovaries out of 42 with healthy vitellogenic oocytes from direct histological examination, from this we estimated spawning periodicity was 3.8 days.

Black drum in the Chesapeake Bay region are extremely fecund ranging from 414,000 to 3,736,000 hydrated oocytes (mean = 1,389,000, $N = 7$) (Table 1). Using the estimated spawning periodicity of 3.8 days and a spawning season of 45 days (mid

TABLE 1. Estimates of batch fecundity and standard errors (SE) obtained from hydrated ovaries. The gravimetric method was used to calculate the mean number of hydrated oocytes from two subsamples from each ovary.

Capture date	Total length (cm)	Total weight (kg)	Age (yr)	Batch fecundity (SE)
18 May	98	15.88	18	897,43 (66,847)
20 May	109	18.14	27	1,423,888 (155,985)
21 May	104	17.69	31	414,307 (104,103)
23 May	111	---	23	459,407 (27,644)
23 May	120	---	30	2,190,169 (one subsample)
23 May	109	---	22	601,198 (75,092)
30 May	109	---	29	3,736,196 (143,583)
Mean	108	17.24	25	1,388,943

April to early June) the total fecundity of an individual black drum in the Chesapeake Bay region could be 16.4 million hydrated oocytes. Although fecundity is often related to size, regressions of length, total weight, and age on batch fecundity estimates were not significant ($P > 0.05$).

DISCUSSION

Until now, there has been a lack of fundamental knowledge of reproduction in black drum, a requisite to manage this population along its entire U.S. range. Although Fitzhugh *et al.* (1993) and Nieland and Wilson (1993) have determined spawning strategy, spawning periodicity, and have estimated the batch fecundity of black drum in the Gulf of Mexico, none of this was known for black drum from the East Coast population. This first examination indicates that reproductive strategy and spawning periodicity of black drum of the Chesapeake Bay region is similar to that from other areas of the U.S. geographic range of the species. Black drum from the East Coast are group-synchronous spawners similar to those in the Gulf of Mexico as reported by Fitzhugh *et al.* (1993) and Nieland and Wilson (1993). Individuals may spawn starting as early as October (Alshuth and Gilmore, 1992) or January (Murphy and Taylor, 1989) and until at least early June in the Chesapeake and Delaware Bays (these results; Thomas and Smith, 1973). This long spawning season on the East Coast is similar to Gulf of Mexico black drum where their spawning season is approximately five months (Fitzhugh *et al.*, 1993; Nieland and Wilson, 1993). Our estimate of spawning periodicity (3.8 days) is also similar to estimates of 3-4 days for Gulf of Mexico black drum (Fitzhugh *et al.*, 1993; Nieland and Wilson, 1993).

Batch fecundity of Chesapeake Bay black drum (1.4 million hydrated oocytes) is similar to fecundities estimated for the Gulf of Mexico reported by Fitzhugh *et al.* (1993) and Nieland and Wilson (1993). Typically, larger, older fish of a species are more fecund (West, 1990). Chesapeake Bay black drum are older and larger on average (109.5 cm) than those in the Gulf of Mexico (76 cm; Fitzhugh *et al.*, 1993); however, they are not more fecund (1.4 to 1.6 million hydrated oocytes; Fitzhugh *et al.*, 1993; Nieland and Wilson, 1993). We suggest three hypotheses to account for this. First, older fish from the Chesapeake Bay region undertake long-range spawning migrations that Gulf of Mexico fish do not. Energy spent in undergoing this migration may reduce their reproductive output. Second, because black drum reach asymptotic growth early (10 - 20 years) relative to their life-span of sixty years, the size range of mature fish is

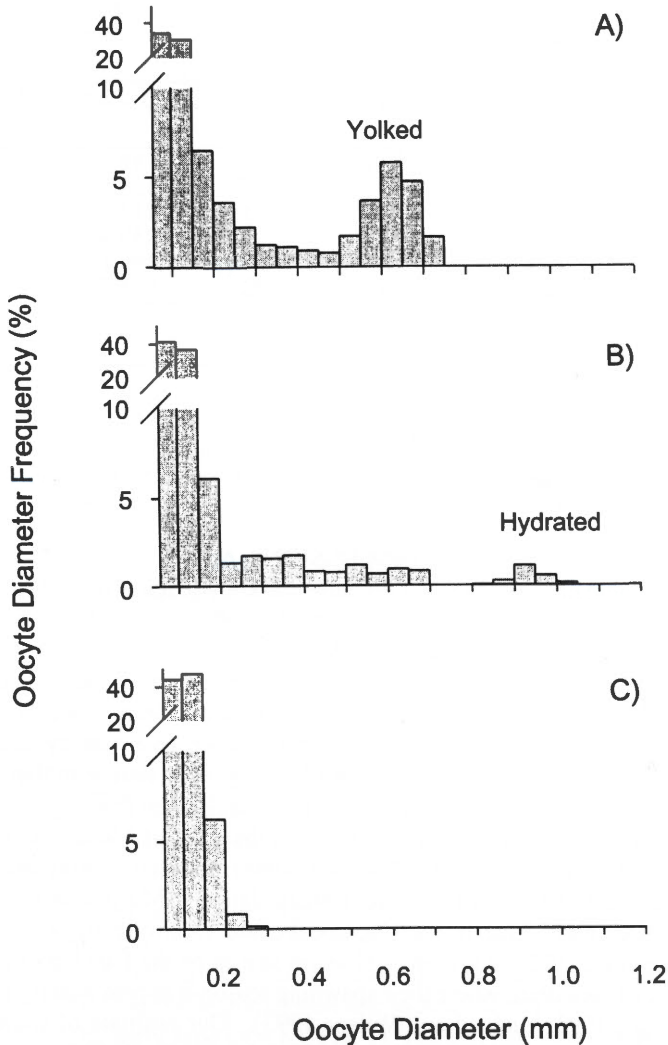


FIGURE 2. Distributions of whole-oocyte diameter for the four stages of maturity identified in adult black drum within the Chesapeake Bay region. Maturity stages represented are a) yolked or redeveloping, b) hydrated, and c) spent. Notice the stages are defined by the most advanced stage of oocyte development and the occurrence of postovulatory follicles as identified using histology. Also note that within an ovary classified as yolked, hydrated, or redeveloping are multiple stages of oocyte development indicating continued spawning once the most advanced stage oocytes hydrate and release. Further, as the oocyte diameter modes are distinct black drum is determined to be a group-synchronous spawner releasing clutches of eggs periodically.

limited so that relationships of fecundity to size and age are poor (Nieland and Wilson, 1993) or insignificant (Fitzhugh *et al.*, 1993). Finally, it may be that East Coast black drum are less fecund at reproductive age.

From our estimates of mean batch fecundity and spawning periodicity, East Coast black drum are capable of producing approximately 56 to 98 million hydrated oocytes in 40 to 70 batches per female during a five to nine month spawning season. As black

drum mature between five and six years, and have a mean maximum age of almost 60 years, these fish have the potential for over fifty years of reproduction. This is similar to the reproductive effort of fish with three times the natural mortality of black drum (Gunderson and Dygert, 1988). Yet, the prodigious reproductive potential of black drum has not resulted in large populations.

We propose that this reproductive strategy is an adaptation to great environmental variability along a geographic gradient characterized by large intra- and interannual temperature and salinity variation. The Chesapeake Bay has sporadic recruitment success as indicated by occasional large numbers of young-of-the-year black drum exiting the bay during the fall. Joseph *et al.* (1964) suggested aperiodic recruitment success is a result of intolerable abiotic factors because the Chesapeake Bay is at the northern extension of the fish's spawning range. For example, winter temperatures in the Chesapeake and Delaware Bays drop below 4°C, the lower thermal lethal limit for other sciaenids (Lankford and Targett, 2001). Moreover, Cowan *et al.* (1992) and Daniel (1995) concluded that poor and episodic recruitment from the Chesapeake Bay is due to a short spawning season which overlaps times when the density of jellyfish predators is great. Such high egg and early-life mortalities are common for a highly fecund fish that has adapted to environmental variability. It follows that during years of favorable environmental conditions and low predator abundances, theoretically, recruitment from the Chesapeake Bay will be high. Therefore, we hypothesize black drum have a reproductive strategy adapted to biotic and abiotic variability such that the contribution of recruits from the Chesapeake Bay to the whole East Coast population will be variable.

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