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# SPAWNING OF THE STRIPED BASS (MORONE SAXATILIS) IN THE ANNAPOLIS RIVER, NOVA SCOTIA

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Plankton net collections of striped bass *(Morone saxatilis)* eggs in the Annapolis River, N.S., indicated that spawning occurred in early June 1983, in freshwater (< 0.1‰ salinity) along a 19 km section of river. Spawning was closely related to water temperatures on the spawning grounds. Most spawning occurred at temperatures ≥ 18°C while rapid temperature drops to 15-16°C resulted in temporary cessation of spawning. Peak spawning was from 7-10 June (65% of all egg collections) when water temperatures were 19.0-24.4 C. Spawning behaviour is described.

Des récoltes d'oeufs de la perche commune *(Morone saxatilis)* ont été effectuées dans la rivière Annapolis, N.S., à l'aide d'un filet planctonique. Ces collections indiquent que le frai s'est produit au début du mois de juin 1983, en eau douce (salinite < 0.1‰) le long d'une section de 19 km de cette revière. Le frai était fortement relié à la température de l'eau des frayères. La plus grande partie du frai ent lieu à des températures ≥ 18°C; des baisses subites de température à 15-16°C résultèrent en un arrêt temporaire du frai. Le maximum de reproduction fut enregistré du 7 au 10 juin (65% de tous les ouefs récoltés) lorsque les temperatures de l'eau étaient de 19.0°C-24.4°C. Le comportement pendent le frai est aussi décrit.

## Introduction

The striped bass, *Morone saxatilis* (Walbaum), is an anadromous coastal species distributed along the Atlantic coast of North America from the St. Lawrence River (49°N) to the St. Johns River in northern Florida (29°N) and along the Gulf of Mexico in fresh and brackish tributaries of western Florida, Alabama, Mississippi, and Louisiana (Scott & Crossman 1973). Introduced to the Pacific coast in 1879 and 1882 it now ranges from Barkley Sound at 49°N on Vancouver Island (Forrester et al. 1972) to just south of the Mexican border at 32°N (Radovich 1961).

In the United States, the striped bass is an important commercial and sport fish that has been extensively studied on both coasts (see Rogers & Westin 1975; Horseman & Kernehan 1976). Canadian populations, however, have not been studied as intensively and scientific literature is limited. This is probably a result of its restricted distribution, and fluctuating abundance.

The present study was initiated to provide basic information on striped bass inhabiting the Annapolis River, Nova Scotia. The population supports a valuable and popular sport fishery, although in recent years the minimum age of bass caught by angling has been increasing, indicating a failure of recruitment (Jessop & Doubleday 1976; Jessop 1980). This paper presents information on spawning time and location in 1976, and observations on spawning behaviour.

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## Study Area

The Annapolis River flows for about 142 km through the Annapolis Valley in southwestern Nova Scotia before discharging into the Annapolis Basin (and ultimately the Bay of Fundy) through the Annapolis River Tidal Dam at Annapolis Royal. This dam (constructed in 1960) converted upstream conditions from a vertically homogenous estuary with 10-m tides into a highly stratified salt wedge estuary with 2-m tides; outflowing freshwater (< 2 ‰ salinity) overlies salt water of 16-24 ‰ and a very narrow halocline and thermocline exists (Daborn et al. 1979b). The upper edge of the salt wedge oscillates between km20 and km30 above the dam as a result of tidal flow, manipulation of headpond and river levels, and varying river discharge (Daborn et al. 1979b).

## Methods

Striped bass eggs are semibuoyant and float downstream from freshwater spawning areas (Raney 1952; Mansueti 1958; Albrecht 1964; Talbot 1966; Scott & Crossman 1973). Therefore, egg and larvae collections by drift and tow nets were used to determine the spawning area and period. Samples were collected with nylon monofilament plankton nets having apertures of 1.0 m and 0.6 m diameter and pore sizes of 0.5 and 1.0 mm, respectively. The smaller nets were used at stations where current flow was too strong to hold or pull a 1.0-m diameter net.

Drift-net collections were made from 7 May to 7 July at 8 stations located at regular distances along the Annapolis River, beginning just downstream from the limit of saline waters in early May (km20 above Annapolis River Tidal Dam, see Daborn *et al.* 1979b) to approximately 26 km upstream. Nets were set in mid-channel, just below the surface, for an average of 12-13 hours at about 3-day intervals at any one location. Tow net collections were made from 14 May to 27 June at about 3-day intervals over the same area and alternated with drift net collection periods. Each tow was of 10 min duration and was made in mid-channel with the boat moving upstream. Both drift and tow-net collection periods were staggered in order to cover the diel cycle.

Egg and larval collections were refrigerated when returned to the laboratory, sorted within 1-3 hours and preserved in 8% neutral formalin. Striped bass eggs and larvae were identified and distinguished from those of other fishes using descriptions and diagrams in Pearson (1938), Mansueti (1958, 1964), Mansueti and Hardy (1967), and unpublished data from J. Brown and W. Hasler (addresses in Acknowledgements). Bass eggs are distinguished from those of the American shad *(Alosa sapidissima)* and the alewife *(Alosa pseudoharengus)* by the presence of an oil globule in striped bass eggs and its absence in the latter two species. White perch *(Morone americana)* eggs possess an oil globule also, but are distinctly smaller than striped bass eggs and possess an attachment disc. In addition, bass eggs collected when spawning was observed were directly compared to shad eggs; shad eggs collected on 8 May were kept in an aquarium, hatched on 11 May, the larvae living until 14 May.

A binocular microscope fitted with an ocular micrometer was used to examine the eggs and measure diameters. Developmental stages of eggs were determined by reference to diagrams and descriptions provided by Pearson (1938), Mansueti (1958), and J. Brown and W. Hassler (pers. comm.). Staging was facilitated by staining eggs with alizarin red, which was selectively taken up by the yolk mass, turning it rusty red while leaving the protoplasm white. Eggs were aged by reference to a nomograph (provided by J. Brown & W. Hassler) relating developmental stage to incubation temperature in order to estimate the age in hours.

The origin of each egg was then calculated by multiplying its estimated age by the mean river velocity upstream from the collection site, determined from current velocity readings taken on the same day. For example, a 2-hour-old egg collected below a stretch of river with a 0.5 m/sec mean current velocity would have been spawned about 3.6 km upstream from the collection site (7200 sec x 0.5 m/sec).

Surface-to-bottom water temperatures and salinities were recorded in the field with a YSI model S-C-T meter prior to each plankton net tow and prior to and after each drift net collection. A Peabody-Ryan D-30 thermograph anchored near the shore in about 1 m of water continuously monitored water temperatures on the spawning grounds during the striped bass spawning period.

## Results

*Spawning Period*

The first striped bass eggs were collected on 1 June and the last on 19 June. A total of 3463 eggs and 3 larvae was netted during this interval (Tables I & II). Drift nets collected 2629 eggs and 2 larvae between June 8 and 19 (Table I) while two nets caught 834 eggs and 1 larva between 1 and 13 June (Table II).

Bass spawning was closely related to water temperatures on the spawning grounds (Fig 1.). Increasing temperatures corresponded with collection of eggs while sudden temperature drops coincided with a temporary cessation of spawning. Water temperatures during the spawning period ranged from 15.0-24.4°C. Prior to the initial egg collection (at 18.4°C) on 1 June a rapid rise in water temperature occurred: temperatures increased from 10.5°C, on 26 May, to 19.2°C, on 31 May. A temperature drop to 16.0°C on 2 June (a result of decreasing air temperature) coincided with a temporary cessation of spawning after 1 June, with spawning resuming on 7 June as water temperatures increased. Most eggs and larvae (64.6%) were collected from 7 to 10 June when water temperatures ranged from 19.0-24.4°C (average daily temperature = 20.6°C). A sharp temperature drop after 10 June coincided with a spawning decline and only 2 eggs and 1 larva were netted from 11-15 June. Spawning resumed on June 16 when temperatures increased, with the final egg collection being made on 19 June.

*Spawning Observations*

Striped bass spawning was observed in fresh water (specific conductance = 55 μmhos/cm, water temperature = 22.°C) approximately 7 km upstream from saline water on 9 June between 2130 and 2215 hours. The river in this region is about 30 m wide, of uniform depth (1.5-2.0 m) with a bottom composed mainly of sand interspersed between basalt and granite rocks and boulders.

Spawning behaviour was similar to that described in Woodhull (1947), Raney (1952), and Miller and McKechnie (1968). Groups of bass were observed spawning in all sections of the river. Each group consisted of one large female and more than 5 males, each considerably smaller than the female. The female quivered and rolled at the surface, vigorously splashing water with her tail while the males remained close, periodically striking her side with their snouts. This action occurred for several minutes, ceased for a few minutes during which time the fish milled around in the general area, and then resumed. A 0.6-m diameter plankton net held stationary just below the surface in the vicinity of spawning bass collected 5075 recently fertilized eggs in 10 min. Although anglers were fishing in the area no bass were caught by them, supporting the contention that striped bass do not feed during spawning (Trent & Hassler 1966), although they may feed within a few hours before and after.

**Table I** Striped bass egg and larvae collections made with drift nets, 1-19 June 1976. Numbers in parentheses indicate river distances above the Annapolis River Tidal Dam in km. (see Fig 2).

| Date (June) | Drift net station no. | Time of day (hrs) | No. eggs collected | No. larvae collected | No. per hour | % of total |
|---|---|---|---|---|---|---|
| 8- 9 | 2(25) | 2140-1050 | 0 | 2 | 0.2 | 0.1 |
| | 3(29) | 2220-1030 | 1419 | 0 | 116.6 | 53.9 |
| 13-14 | 3 | 2220-1050 | 1 | 0 | 0.1 | 0.0 |
| 16 | 5(35) | 1129-2220 | 842 | 0 | 77.6 | 32.0 |
| | 6(38) | 1229-2315 | 50 | 0 | 4.6 | 1.9 |
| 18-19 | 7(42) | 1950-0922 | 317 | 0 | 23.4 | 12.1 |
| Totals | | | 2629 | 2 | 36.1 | 100.0 |

**Table II** Striped bass egg and larvae collections made with towed nets, 1-19 June 1976. Tow net station locations are given in Williams (1978). Numbers in parentheses indicate river distances above the Annapolis River Tidal Dam in km.

| Date (June) | Tow net station no. | Time of day (hrs) | No. eggs collected | No. larvae collected | No. per minute | % of total |
|---|---|---|---|---|---|---|
| 1 | 6(28) | 0911-0921 | 9 | 0 | 0.9 | 1.1 |
| | 7(29) | 0940-0950 | 6 | 0 | 0.6 | 0.7 |
| 7- 8 | 8(30) | 2243-2253 | 410 | 0 | 41.0 | 49.1 |
| | 9(32) | 2319-2329 | 36 | 0 | 3.6 | 4.3 |
| | 10(33) | 0008-0013 | 5 | 0 | 1.0 | 0.6 |
| | 11(35) | 0057-0107 | 4 | 0 | 0.4 | 0.5 |
| 10 | 5(25) | 0815-0825 | 74 | 0 | 7.4 | 8.9 |
| | 6(28) | 0920 | 145 | 0 | 14.5 | 17.4 |
| | 7(29) | 1005-1015 | 135 | 0 | 13.5 | 16.2 |
| | 9(32) | 1132-1142 | 1 | 0 | 0.1 | 0.1 |
| | 12(36) | 1350-1400 | 8 | 0 | 0.8 | 1.0 |
| 12-13 | 5(25) | 2010-2020 | 0 | 1 | 0.1 | 0.1 |
| | 10(33) | 0000-0010 | 1 | 0 | 0.1 | 0.1 |
| Totals | | | 834 | 1 | 6.7 | 100.1 |

**Table III** Developmental stage, size, age, and estimated origin of striped bass eggs collected on 9 June 1976 while spawning was observed (see text).

| Developmental stage | Mean dia. (mm) | Age (hours) | % of total[a] | Estimated origin[b] |
|---|---|---|---|---|
| pre-cleavage | 2.59 | 1.1 | 29.8 | 0.0-2.2 |
| 2-16 cells | 3.53 | 1.1-2.0 | 46.2 | 2.2-4.4 |
| 17-32 cells | 3.74 | 2.1-3.0 | 19.0 | 4.4-4.6 |
| 32 cells | 3.75 | 3.1-4.3 | 5.0 | 6.6-8.8 |

[a]Total = 1139 eggs (22% of 5075 eggs collected)
[b]in km. upstream from collection site

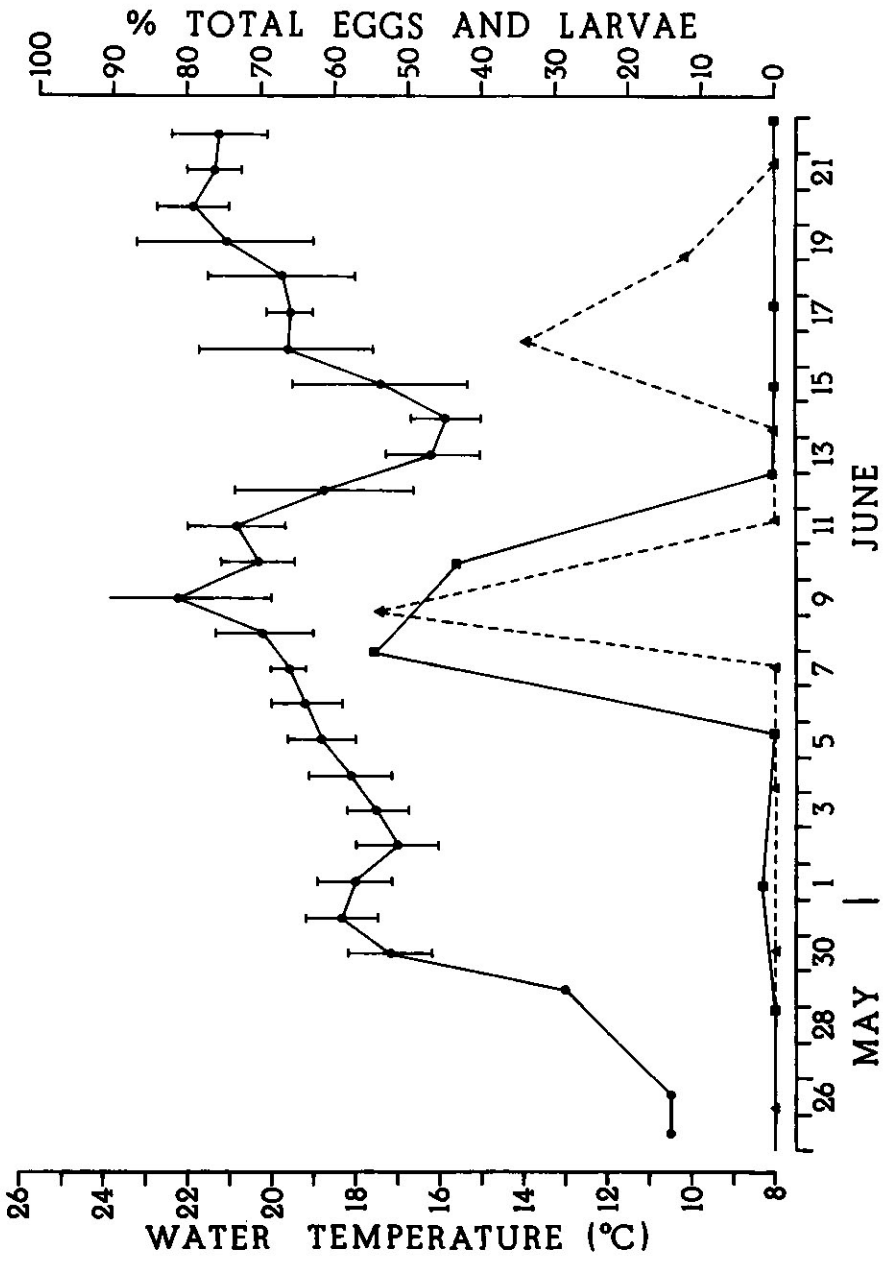


Fig 1. Relationships between water temperatures on the spawning grounds and the % of the total striped bass eggs and larvae collected in tow nets (■) and drift nets (▲) from the Annapolis River, 1976. Vertical bars indicate daily temperature ranges around means (•). Water temperatures prior to May 30 are single readings, taken with a telethermometer.

*Spawning Area*

All eggs were collected within the first 15 km above the head of the salt wedge (which fluctuated between km 20 and 27 during the spawning period) and with two minor exceptions the most downstream collections were made 4-5 km upstream from saline water.

According to drift and tow-net collections of eggs and larvae, striped bass spawned only in fresh water (< 0.1‰ salinity) along a 19 km stretch of river. A 9 km stretch from km 29 to 38 was apparently the most productive portion of the spawning grounds (Williams 1978). An estimate of how far upstream spawning had occurred on 9 June was made using the eggs collected during the spawning observations. Five subsamples of about 225 eggs each (22% of 5075) were aged and each egg was extrapolated to its spawning origin using water velocities upstream from the collection site. Eggs ranged in age from 1.1-4.3 hours; 76% were ≤ 2.0 hours old (Table III). Spawning on 9 June occurred primarily along a 9 km section between the collection site at km 32 and km 41 with the majority (76%) occurring within the lower 4 km section from km 32 to km 36 (Fig 2.).

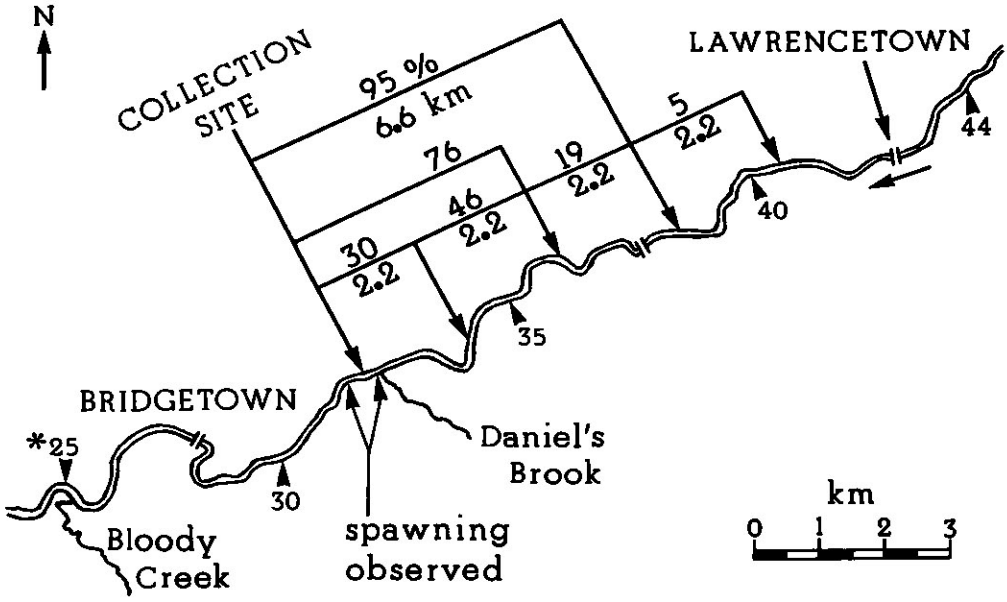


Fig 2. Map of the Annapolis River showing the estimated spawning area on 9 June 1976, determined by examination of eggs collected while spawning was observed (see text). The % eggs originating within each specific area is indicated. River distances (km) above the Annapolis River Causeway are indicated (beginning with *25).

## Discussion

According to egg collections and spawning observations, striped bass spawned intermittently in the Annapolis River from 1-19 June in 1976. Striped bass in

Canadian waters usually spawn in June (Bigelow & Schroeder 1953; Scott & Crossman 1973) although Dadswell (1976) noted spawning from 13-19 May, 1975 in Belleisle Creek, a small tributary of the Saint John River, New Brunwick. He attributed this early spawning to the small size and consequent earlier warming of the creek. Most spawning in the Annapolis River occurred on relatively few days: 4 consecutive days (7-10 June) accounted for 64.6% of all egg and larvae collections (Table I). Similar restricted spawning periods have been noted elsewhere (Calhoun et al. 1950; May & Fuller 1962; Humphries 1966; Johnson 1973: Calif. Dep. Fish and Game et al. 1974).

Bass spawning in the Annapolis River was closely related to water temperatures on the spawning grounds (Fig 1). Apparently a rapid temperature increase above a minimum of approximately 18°C will initiate spawning. In 1976, temperatures rose >8°C between 26 May and 31 May, and the first eggs were collected on 1 June at 18.4°C. In American rivers other investigators have made initial collections at lower temperatures; usually 14.4-16.1°C (Calhoun et al. 1950; Scruggs 1957; McCoy 1959; May & Fuller 1962; Farley 1966).

Although water temperatures during the 1976 spawning period ranged from 15.0-24.4°C, most spawning occurred at temperatures $\geq$18°C with peak collections being made between 19.0°C and 24.4°C. Similarly, Humphries (1966) and McCoy (1959) found peak spawning occurred at 18-22°C and 18-20°C in the Tar and Roanoke Rivers, respectively. Spawning did not occur at <15°C in the Tar River or <14°C in the Roanoke River. In contrast, spawning in the Sacramento, San Joaquin, and Hudson Rivers has occurred over much wider temperature ranges and peak collections made at lower temperatures (Farley 1966; Jensen 1969). Rapid temperature decreases (to 15-16°C) during the spawning period resulted in a temporary cessation of spawning in the Annapolis River. Apparently this is a common phenomenon (Calhoun et al. 1950; Farley 1966; Calif. Dep. Fish and Game et al 1974).

Although striped bass have been shown to spawn in the Annapolis River, recruitment into the population seems to be very low or nil. No larvae or juvenile bass were collected after the 1976 spawning season even though all areas of the river were sampled from June to August using a variety of techniques (towed plankton nets, bag seines, otter trawl) at all times of the day (Williams 1978). Renewed sampling in 1977 indicated (Williams, unpublished data) that more spawning occurred in 1977 than in 1976, although results may be biased because angling was banned on the spawning grounds in 1977. Sampling in the post-spawning period of 1977 (June-October) also produced no larval or juvenile bass (Daborn et al 1979a; Williams, unpublished data). The age-structure of angled bass in the Annapolis River has also changed radically since 1972 with ages 3-5 making up 54% of the catch in 1972, compared with 32% in 1975, 9% in 1976, and 2% in 1978 (Jessop 1980). This trend is probably primarily due to the failure to recruit young fish into the population. The reasons for this apparently poor recruitment are unknown. Earlier suggestions that it was due to high levels of DDT or PCB's (Jessop and Doubleday 1976) or to relatively low pH (6.0-7.0) during spawning (Williams 1978, Jessop 1980) appear to be unfounded (Dr. M. Wiles, Saint Mary's Univ., Halifax, pers. comm.). Nevertheless, angler catches of adult bass in the Annapolis River are still high (Jessop & Doubleday 1976; Jessop 1980), perhaps because part of the Annapolis River bass population is actually derived from others (see Jessop & Doubleday 1976), similar to that of the American shad *(Alosa sapidissima)* in the Bay of Fundy (Dr. M. Dadswell, St. Andrews Biol. Sta., New Brunswick, pers. comm.). If true, this migratory population may continue to provide a sport fishery indefinitely.

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