An examination of the population characteristics, movement patterns, and recreational fishing of striped bass (*Morone saxatilis*) in Minas Basin, N.S. during summer 2008

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Contributors:
Jeremy E. Broome, Anna M. Redden, Michael J. Dadswell, Don Stewart and Karen Vaudry
Acadia Center for Estuarine Research
Acadia University
Wolfville, NS
B4P 2R6

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ACADIA ESTUARINE CENTRE FOR RESEARCH

Executive Summary

This striped bass study was initiated because of the known presence of both Shubenacadie River origin and migrant USA striped bass in the Minas Basin, the "threatened" species COSEWIC designation, the existence of a strong recreational fishery, and the potential for impacts on the population due to the operation of in-stream tidal energy technology in the area.

Striped bass were sampled from Minas Basin through angling creel census during summer 2008. In total, 574 striped bass were sampled for length, weight, scales, and tissue. In addition, 529 were tagged with individually numbered spaghetti tags. Striped bass ranged in length from 20.7-90.6cm FL, with a mean fork length of 40.5cm. Data from FL(cm) and Wt(Kg) measurements determined a weight-length relationship: LOG(Wt) = 3.30LOG(FL)-5.58. Age frequency showed a range from 1-11 years. The mean age was 4.3 years, with 75% of bass sampled being within the Age 2-4 year class. Total mortality (Z) was estimated to be 0.60. Angling effort totalling 1732 rod hours was recorded from June to October, 2008, with an average 7 anglers fishing per tide. Catch per unit effort (Fish/Rod Hour) was determined to be 0.35, with peak landing periods indicating a relationship with the lunar cycle. Recreational anglers were responsible for all tag returns, which resulted in a 25% recapture rate. On average, striped bass recaptures were at large 27 days post tagging. Growth rates were compared across age groups which produced the exponential equation: Growth Rate (mm/day) = $1.71e^{-0.35(Age)}$. Bass movements obtained from tag returns was limited, as 92% of returns were from bass recaptured at the site of initial tagging, indicating a pattern of site fidelity throughout the summer season. Further studies on striped bass movements, using acoustic tracking technology, are planned for 2009.

Genetic analysis using mitochondrial DNA was performed on 60 striped bass tissue samples; 20 fish each from Shubenacadie River, Five Islands, and Southern Bight of the Minas Basin near Wolfville. The analysis showed that 11% of the fish sampled were significantly different from the Shubenacadie captured bass and thus considered to be from other stocks, most likely US migrants. The highest level of differentiation from NS spawned bass was observed in samples collected from Five Islands, NS.

Introduction

Striped bass, *Morone saxatilis,* is an anadromous species commonly found along the eastern seaboard of the United States and Canada where it has long been prized for both commercial and recreational fishing (Merriman 1941; Boreman and Lewis 1987; Scott and Scott 1988; Rulifson and Dadswell 1995).

The Bay of Fundy system was once home to three separate native spawning stocks of striped bass, two from the outer Bay of Fundy (Saint John River, NB and Annapolis River, NS) and one from the inner Bay of Fundy / Minas Basin, with spawning in the Shubenacadie River, NS (Rulifson and Dadswell 1995; Douglas et al. 2003; Rulifson et al. 2008). Of these three bass spawning rivers, only the Shubenacadie River is currently considered active. The others are deemed to be reproductively extinct (Douglas et al. 2004).

In addition to the local Shubenacadie population, Minas Basin is known to harbour contingents of migrant USA origin fish which contribute to a summer aggregate stock (Wirgin et al. 1993; Wirgin et al. 1995; Rulifson and Dadswell 1995; Rulifson et al. 2008). The extent to which migrant stocks contribute to this aggregation is generally unknown and is expected to vary from year to year depending upon southern stock densities and food availability. Larger female bass have been shown to migrate longer distances and in greater proportion than males; as such it is possible that many of the migrant bass which enter Minas Basin are female (Westin and Roger 1978; Boreman and Lewis 1987).

The contribution made by migrant bass to the Minas Basin aggregation likely convolutes the notion of local stock abundance, particularly within the recreational angling community. Due to possible reproductive failures in two of three native stocks and the apparent overall decline of striped bass within the Bay of Fundy system, steps have been taken to list the population as "threatened" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2004).

Current interest in testing and development of alternative forms of energy production within Nova Scotia has prompted renewed attention toward harnessing tidal energy from the Bay of Fundy and Minas Basin. A proposed pilot project for testing three in-stream tidal power turbines is expected to commence by 2010 within the Minas Passage west of Black Rock, NS. An understanding of how striped bass move, feed, and behave within the tidal power test area will be critical for understanding any potential impact posed by installation of in-stream tidal power turbines. At present, the potential impacts arising from either direct or indirect contact of fish with in-stream tidal power turbines are unknown. There is also a lack of information on the importance of recreational fishing pressure on striped bass within the Minas Basin.

The current COSEWIC status of striped bass, and its importance to recreational fishers in Minas Basin, has lead to concern regarding potential impacts of in-stream turbine testing on the fishery. As much of the literature in respect to the Shubenacadie River striped bass stock relates to the freshwater portion of their life history, this project is focused on assessing the population of striped bass within the marine environment of the Minas Basin. The project was designed to provide information on critical population characteristics such as length, weight, age, and stock origin of bass captured within the Minas Basin. Tagging and fin clipping were performed to provide information on both local and long-range movement patterns and stock definition.

Study Site Description

The Minas Basin and Cobequid Bay together comprise the inner Bay of Fundy (Figure 1), with Minas Basin being the larger, deeper, and cooler of the two water bodies

(Greenburg 1984; Rulifson et al. 2008). This highly dynamic environment is characterized by extremely high tidal range (12-15m), strong tidal currents (up to 10kts), high suspended sediment loads (up to 1000mg/L), and fully turbulent flow (Amos and Alfoldi 1979; Greenburg 1984; Rulifson et al. 2008). Sites from which striped bass were sampled and tagged were: Five Islands and Bass River on the North Shore, and Gaspereau River, Grand Pre (Guzzle), and the Cornwallis River within the Southern Bight (Figure 1).

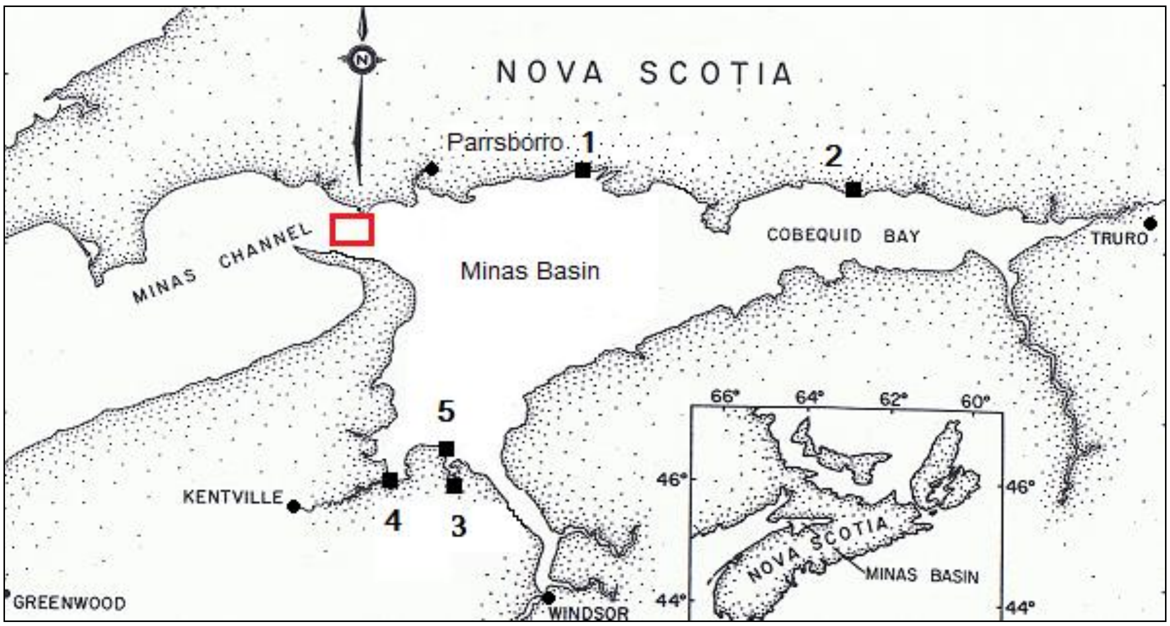

Figure 1. Minas Basin and Cobequid Bay of the inner Bay of Fundy, NS indicating primary sampling locations: 1) Five Islands, 2) Bass River, 3) Gaspereau River, 4) Cornwallis River, and 5) Grande Pré (The Guzzle). The rectangle indicates the proposed general location for the testing of in-stream tidal turbines.

<u>Methodology</u>

Field sampling

Striped bass were captured by rod and reel angling during June – October 2008. Fishing effort generally lasted from 2 hours prior to high tide until a period 2 hours after high tide. Fishing was performed using hi-low style rigs featuring size 1/0-6/0 size circle hooks weighted with 4-6 oz doughnut sinkers, attached to 40 lb-test braided line on 9′ surf rods. The predominant bait used was chunked or filleted mackerel, but other baits such as herring, shad, gaspereau, and squid were also used when in season.

Upon capture, striped bass were measured for fork and total length (FL and TL) to the nearest 0.1cm, and weight to the nearest 0.1kg. A scale sample, 6-10 scales, was removed from below the first dorsal fin and above the lateral line and stored in paper envelopes for aging. A fin clipping (1cm^2) was taken from the pectoral fin, and placed in 95% ethanol for mitochondrial-DNA analysis. Before being released, each fish was tagged with an individually numbered T-Bar style dart tag (Floy Tag, Seattle) inserted just below the first dorsal fin. Each tag contained return address information for the Acadia University Biology Department.

A single VR2 acoustic receiver (VEMCO, Halifax, N.S.) was deployed from shore during sampling activities from mid August-October, to detect the presence of striped bass tagged during the downstream migration from Shubenacadie River. Deployment consisted of wading into the water on upcoming tide and throwing the receiver out into the water column. The receiver unit was weighted with a 1kg lead bullet weight, and a small float was used to ensure the receiver sat upright in the current. The unit was tethered to shore using a 30m rope spiked into the mud. The receiver was retrieved as the tide receded.

Analysis

Aging was conducted on scales collected during sampling. Three scales were selected for mounting from each sampled bass. Scales were then cleaned in water and mounted between two standard microscope slides. Using a dissection microscope, annular growth rings were visible and age could then be determined. Each mount of scales was read by two individuals for age validation purposes.

Angling effort (rod hours) were recorded by tracking both the number of anglers and the number of rods being used by each angler during each tide sampled. Exploitation (μ) was calculated by using the equation (Ricker, 1975):

$$\mu = R/M$$

where:
μ = exploitation rate.
R = number of tag returns.
M = number marked in the system.

Estimated total mortality (Z) was determined from the use of a Gulland Method plot which relates the natural log of abundance to year class (Ricker, 1975). The sum-of-squares regression line was evaluated to determine slope, which determined the value of Z.

Length and date information were used to calculate the growth increment (change in length between time of release and time of recapture) and time-at-liberty (time difference between date of release and date of recapture) for individual striped bass (mm/day).

Mitochondrial DNA Analysis

DNA (mt-DNA) analysis of striped bass fin clipping samples was utilized to characterize the origin of Minas Basin striped bass. A subsample of 60 striped bass was selected, of which 20 were collected from the Shubenacadie River, 20 from Five Islands, NS, and 20 from the Grand Pre, NS area. The Shubenacadie River bass sequences acted as a control and were assumed to be the native population of striped bass in Minas Basin (Wirgin et al. 1995) .

From each fin sample a small piece of the preserved pectoral fin was dissected and processed using a DNeasy kit to elute the genetic material. A segment of approximately 500 base pairs (bp) was amplified from the 5' region of the mitochondrial control region using primers utilized in past studies (Wirgin et al. 1993; 1995). The control region was targeted due to the known presence of high variability regions, coupled with regions of high conservation (Ruokonen, 2000). This ensured that primers would recognize the region of the mitochondrial genome. Regions with a high rate of mutation provide clear differentiation between interbreeding stocks.

The Polymerase Chain Reaction (PCR) conditions used to amplify this region consisted of heat treatment at 95°C for 5 min, 35 cycles of 95°C for 1 min, 56°C for 1 min and 72°C for 1 min, with a final extension at 72°C for 7 min. Once amplified, the PCR product was run on a 1% TAE agarose gel using electrophoresis. A 100-bp DNA ladder was used to reference the migration of bass DNA fragments within the agarose gel matrix. The ladder made it possible to estimate the size of the amplified genetic material, and to determine if it was the length of the targeted gene. Those bands which exhibited strongly under UV light were excised and further purified. The purified DNA samples were examined with a spectrometer to ensure adequate purity. At least a 5% concentration of mtDNA was present per sample. The samples were then packaged and sent to McGill University, Montreal for sequencing.

Upon receiving sequence data, the program Bioedit was used to align forward and backward sequences of each sample, and to clean up regions not fully sequenced. The forward and backward sequences were then compared using the Bioedit application known as "Clustal Alignment". Clustal alignment combined both forwards and backwards sequences, determining the overall sequence for each sample. Overall sequences were then compared to individual bass from the Shubenacadie River (assumed to have no variation because they are one inbreeding stock). Any variations between regional samples were recorded. The individual samples from Five Islands and Wolfville region were compared to each other and any variation recorded. Variation in sequences of targeted genes is assumed to indicate a difference in stock origin. The sequences were then put into GenBank, with the program BLAST. BLAST compares extracted sample sequences to sequences already present within the GenBank library. BLAST also provides assurance that the amplified and sequenced gene was the genetic region targeted, and in addition provides a list of related species with similar sequences in their respective genomes.

Determining the relatedness of each striped bass to other individuals was necessary. The application 'Neighbor-Joining' of the program Mega® was used to develop distance matrices. The distance matrices allowed for creation of bootstrap trees, which depict the degree of relatedness between individual bass based upon variations present within each control region.

The final step to determining relatedness of the individual striped bass involved the construction of parsimony trees with the program Mega®. To determine relative relatedness of each individual, a species with a closely related control region sequence was selected from the BLAST results. This species was assumed to be an ancestor species and was used as a relative sequence to root the tree and by which to compare other individuals. The parsimony tree will clearly depict the inter-relationships of Minas Basin striped bass based upon sequence variation.

Results

Population Characteristics

In total, 574 striped bass were captured and sampled during the summer or 2008. Fork length (cm) and weight (Kg) measurements were used to determine the weight-length relationship: log(Wt) = 3.30log(FL)-5.58 (Figure 1). Mean FL (±SD) was 40.5±10.6 cm. A length frequency distribution was developed from FL measurements (Figure 2). From this, using the back calculated length at age equation Age(x) = ((FL)-11.98)/6.62 obtained from Rawley (2008), an approximate age frequency distribution was determined (Figure 3). A strong peak in frequency is apparent which centers around the Age 2-4 year classes. Individuals within this age range accounted for 75% of all bass sampled. The appearance of a second smaller peak, centered on the Age 6-7 year class, was also observed. The total mortality (Z), obtained from a slope of a Gulland plot (Ricker, 1975) was found to be 0.60 (Figure 4).

Angling Effort and Catch Patterns

The numbers of anglers present at all sampling sites was tracked during sampling in order to determine rates of fishing effort and success. Angling activity and subsequent landings were recorded during collection over all sample locations (Table 1). Effort per tide was found to vary greatly. The greatest numbers of anglers were observed when high tides occurred during weekends and late afternoon/early evening situations. A mean of 7.08 anglers were present per tide. In total 1732 rod/hours were recorded from June through October and within this time period a total of 603 landings (with corresponding effort data) were recorded by anglers (recaptures included). Of these, 11 bass were of legal retainable size (≥68cm TL). Catch per unit effort was determined to 0.348 fish/rod hour, and 0.006 retainable size fish/rod hour. Recreational angler reports accounted for 100% of returned tags. The exploitation rate (μ), based on tag returns, was 0.25, with the bulk of tags being returned from locations within the Southern portion of Minas Basin.

Catch per unit effort data (Fish/Rod Hour) indicate trends in fishing success across the sampling period in which several peaking periods were observed (Figure 6).

The data was plotted against lunar cycle stages which occurred during the sampling period, and appears to correlate well with moon stage. Peaks in landings occurred between the first quarter and full moon periods.

Recaptures and Movement

For the period ending May 1, 2009, a total of 134 recaptures, representing 25% of the tagged individuals, had been reported. Recaptures were received from a small geographical area, with 86% of tags recaptured at the site of initial tagging; indicating a pattern of residency during the summer feeding season. On average, tagged fish were at large 27 days (n= 134) prior to recapture, with a range of 1-77 days at large as of October 2, 2008.

Initial experimentation with a VEMCO VR2 acoustic hydrophone produced limited, yet interesting results. Upon uploading the stored data it was found that a single female bass (68.1cm TL – of retainable size) had been observed in the Guzzle area on August 26, 2008. The detected bass had been tagged May 13, 2008 in the Shubenacadie River, near Enfield, NS (Rod Bradford, DFO – Dartmouth, NS, pers. comm.. Jan. 8th, 2009). This work will be extended with a significant effort in acoustic tracking of striped bass during the summer of 2009.

Growth Rates

Growth rates were calculated from those bass re-captured during continuing sampling. Only those bass that were measured using the same equipment, by the same individual, and recaptured more than 4 days after tagging, were included in growth rate determinations. The mean growth rate of all recaptured bass was 0.61±0.28 mm/day, with a mean fork length (±SD) of 36.5±4.6cm at the time of recapture. Growth rates were further compared between year classes, where it was observed that mean growth rate declined with age (Figure 4). This relationship was represented by the exponential decay equation where Growth Rate (mm/day) = $1.713e^{-0.3562(Age)}$.

Mitochondrial DNA Analysis

Results from mt-DNA analysis concluded that it was possible to differentiate between the Shubenacadie River origin striped bass and other originating stocks. However, only 11% of the fish sampled were deemed to be from stocks other than those spawning in the Shubenacadie River. Within this group, it was found that the highest level of differentiation existed in those samples taken at one site, Five Islands, NS. This site was sampled early in the year (May-June) and the fish exhibiting differentiation were found to be significantly smaller than others sampled at that site.

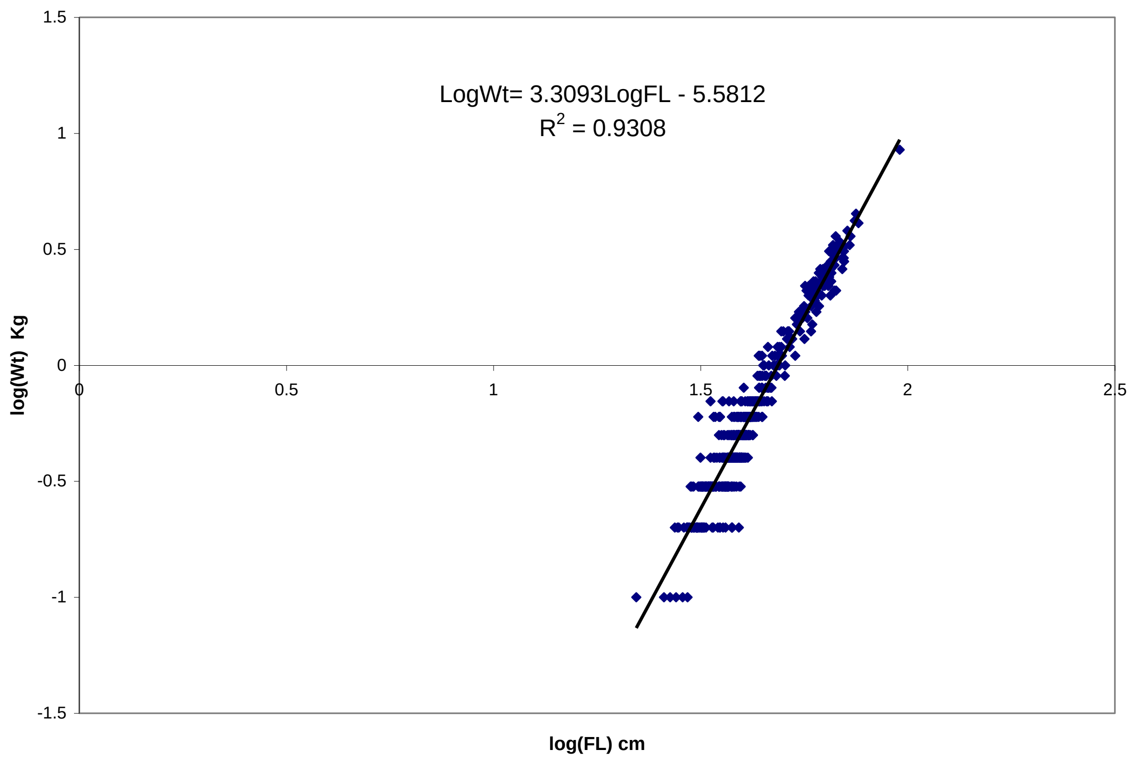

Figure 2. Log transformed weight-length relationship of striped bass sampled during summer 2008 in Minas Basin, NS. The LOG transformed weight-length equation: LOG(Wt) = 3.3093(LOG(FL))-5.5812 (R^2 = 0.9308).

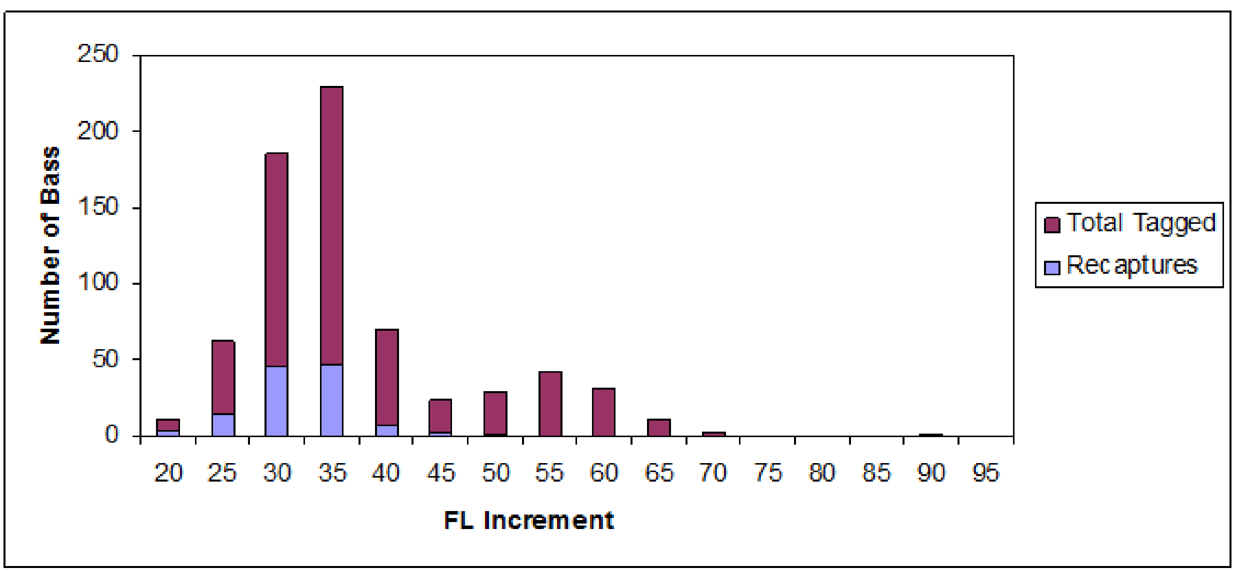

Figure 3. Length frequency distribution of striped bass sampled during summer 2008 in Minas Basin indicated in burgundy, with blue bars indicating the number of corresponding recaptures within each 5cm increment.

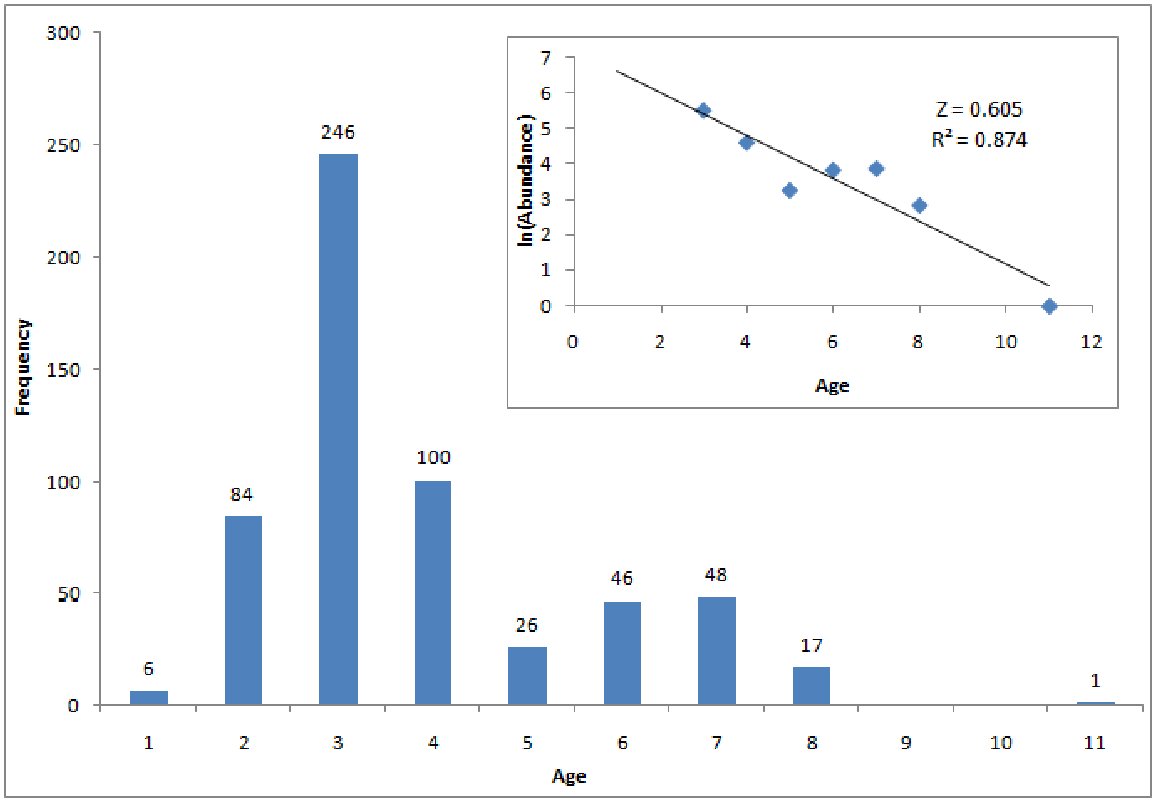

Figure 4. Age frequency distribution of striped bass sampled during summer 2008 in Minas Basin, determined from equation: Age = ((FL)-11.98)/6.62 (Rawley, 2008). Offset is a plot of ln(Abundance) vs Age, used to obtain the rate of total mortality (Z).

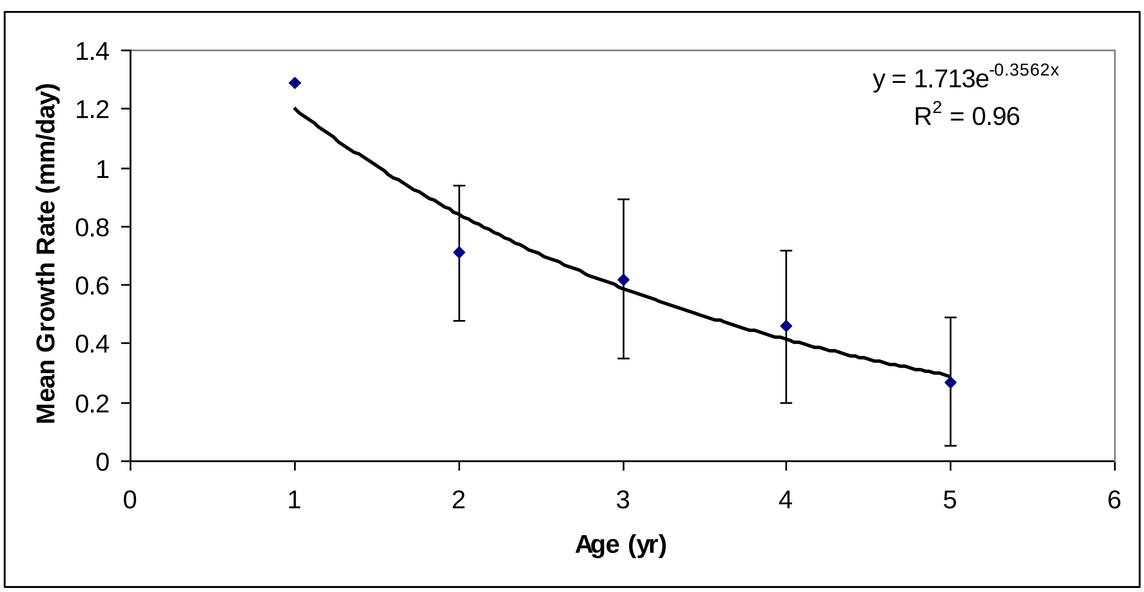

Figure 5. Age versus mean growth rates per year class (mm/day). The exponential regression equation: $y = 1.713e^{-0.3562x}$, $R^2 = 0.96$.

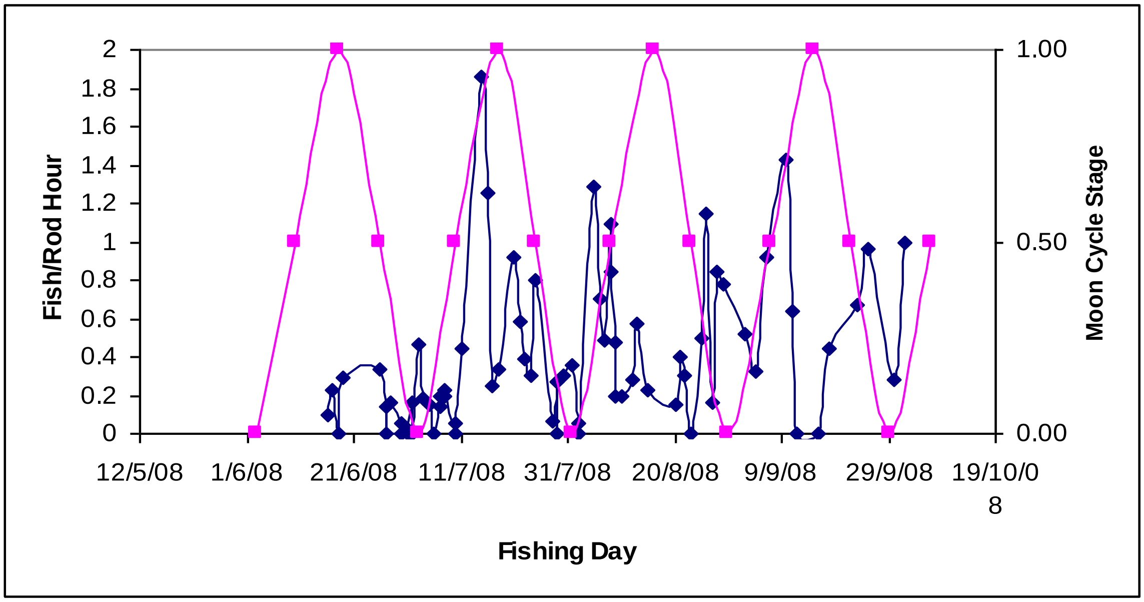

Figure 6. Catch per unit effort (Fish/Rod/Hour) shown in conjunction with the moon stage cycle throughout the course of summer sampling. New moon is 0.00, full moon 1.00.

Discussion

Sampling was undertaken to gather preliminary data concerning population structure and movement of the striped bass assemblage in Minas Basin, NS during summer. Weight-length comparisons indicate that those fish present within the Basin are in good condition as indicated by the condition factor (3.31) determined from the log transformed weight-length equation. The average fork length of angled bass (40.5cm FL) was larger than the average 36.2cm fork length for angled bass found by Rawley (2008) during 2007. This shift in the mean may simply be an indication of one year of growth within the sample population, or may be caused by differences in relative sample size between the two studies. The presence of one particularly large bass during sampling in 2008 contributed largely to the difference in observed means.

Age frequency analysis indicted a dominant peak centered on the 2-4 year class which represented approximately 75% of striped bass sampled. This abundance of younger individuals may be indicative of a recruitment movement from the Shubenacadie River estuary nursery area into Minas Basin for feeding. As bass age, they are known to undergo longer range migrations from their home estuary, and upon reaching sexual maturity, bass will stray increasingly further to sea (Kohlenstein 1981; Rulifson and Dadswell 1995; Secor and Piccoli 1996). As migratory potential is considered to be both a function of maturity and overall size, the presence of these two peaks may also relate to the sexual maturity and therefore increased movement of males (3-4 years) and females (5-6 years). The abundance of bass within the 2-4 yr age class could also be an indication of success in recent management efforts including: elimination or restriction of striped bass as bycatch in commercial fisheries, and an increase in size limit for retention in the recreational fishery (Douglas et al. 2003). The exploitation of older adults by the commercial fisheries prior to 2004 or out migration to the Atlantic coast are possible explanations why larger bass were observed infrequently in this study.

The limited occurrence of larger fish may also be attributed to limitations placed on the angling effort by fishing from shore. Much of the deep water and channels where larger bass were expected to occur could not be reached through shore casting, and as such large bass which may have been present were not exposed to the bait and could not be caught. On the few instances where a boat was accessible for sampling it was possible to catch bass that were on average larger than those caught from shore.

Angling effort was found to vary widely during the study. Peaks in catch per unit effort appear to be closely related to the moon cycle. Peaks were observed just prior to the full moon. This could be related to the fact that Bay of Fundy tides reach their lowest range approximately 3 days before the full moon stage; this 3 day lag may be the reason why an offset from the full moon stage is observed. These data represent fishing effort across all locations sampled during the period and as such the pattern could to be generalized throughout the sites sampled around Minas Basin. The increased catch per unit effort during these periods may be linked to the decreased range with which bass can feed over the tidal flats during high water events (i.e. they are more concentrated in the intertidal region and would come in contact with the bait more often).

Mean growth rates were determined for each age class and we found that growth rates decreased in an exponential fashion as fish aged. From the 57 bass used to determine growth rate, mean growth rate was found to be 0.62±0.28 mm/day, (mean fork length of recaptured bass being 36.5cm). In a similar study Rulifson et al. (2008) reported an average growth rate for bass recaptures during 1985-1986 as 0.37±0.12 mm/day (n= 16). Although these two growth rates do not appear drastically different, it is important to consider that although the average FL of recapture was not reported by Rulifson et al. (2008), it was stated that recaptures were at minimum 1 year old (≥14.1cm FL). The results are therefore rather counter intuitive in that the striped bass sampled by Rulifson et al. (2008), from the known nursery area of Minas Basin, were generally younger than the recaptured bass sampled during this study, which had a mean age of 3.5 years. It would be expected that a younger group would exhibit a significantly faster rate of growth. It may be that the 1985-86 sample was biased by a few large bass. Understanding growth rates within and between stocks of striped bass is valuable in that it allows for prediction of when bass of certain year classes will reach legal length limits. This type of data may be important to future studies on sexual maturation, fecundity, recruitment, and migration.

Mitochondrial DNA results provided some interesting insight into the potential makeup of the Minas Basin summer bass aggregation. The assumption was made that those samples collected from the Shubenacadie system during the spawning run were local origin bass. These 20 bass were of large size and were taken from the spawning grounds during 2008. Although this testing did not provide complete identification as to the origin of the non-local fish (11%), this estimate does align well with previous works which have estimated that migrant bass may comprise 6-20% of the total aggregation (Rulifson and Dadswell 1995; Rulifson et al. 2008). As an interesting comparison it should be noted that to date no tag returns have been recorded from any other distant areas that would corroborate the presence of migratory bass; and further to this only two tag returns have been reported from outside Minas Basin.

A limitation of the study is that sampling effort was not uniform across all locations, since one sampling site (Grand Pre – Guzzle) received greater focus because bass were more abundant at this location. Although angling is considered to be an un-biased sampling technique, a bias may have originated causing few large fish to be caught due to the depth at which bait was presented. Due to the nature of many of the sites sampled, the large deep water channels, which are expected to hold large sized fish, were inaccessible through casting from shore. When sampling occurred by boat from deeper water, larger fish were obtained more readily.

Research Plans for Summer of 2009

An application has recently been approved to conduct testing of VEMCO (Halifax, NS) acoustic telemetry systems within the Minas Passage. The proposed project will form the basis of a MITACS/Accelerate Nova Scotia internship with VEMCO and the Acadia Center for Estuarine Research; with strong underlying connections to the Department of Fisheries and Oceans Canada. The objective of the project is to test the capabilities of acoustic receiver/transmitter technology for potential application in anticipated future fisheries monitoring projects. The capabilities of this equipment will be evaluated by assessing transmission efficiency in response to changes in water depth/tidal height, current speed and direction, wind speed, transmitter power output, and distance of the transmitter form the receiver. Establishing the range and frequency of detection within the megatidal Minas Passage will allow for more efficient and cost effective study designs. The project will serve as an important first step toward the future development and design of environmental monitoring strategies involving both fish and other mobile marine organisms.

In addition to the range test project, a total of six (6) VEMCO acoustic receivers (in-kind from the Department of Fisheries and Oceans) will be placed at strategic points along the shore of Minas Basin to provide information on movements of fish surgically implanted with acoustic transmitters. Local origin bass were tagged in May 2009 during their downstream migration from Shubenacadie Grand Lake and will join the bass from this population tagged during 2008. In order to properly assess and monitor the interaction of local fish species, particularly the highly migratory striped bass, it will be important to gather information on their patterns of movement on both long and short term scales, and the depth at which they travel. Future modelling of striped bass movements in the upper Bay and in the test area will be useful in assessing the potential for fish-turbine interactions.

Assessment of population characteristics and overall abundance of the striped bass population should be continued. It is also important to examine other impacts upon striped bass, including mortality attributed to recreational angling pressure and catch and release practices. By enhancing knowledge in these two areas it will be possible to more accurately gauge the impact, if any, posed by installation and operation of in-stream tidal turbines.

As a final aside it should be mentioned that time spent interacting with recreational anglers during this study was extremely valuable. While some individuals may have had concerns regarding tidal power developments, the response to the assessment work being conducted has been extremely positive. The vast majority of the anglers encountered were very pleased to see that research was being conducted on striped bass, and were enthusiastic and interested in becoming involved.

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