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Science Response 2016/026

REVIEW OF A METHOD FOR IDENTIFYING A WINDOW OF PRINCIPLE STRIPED BASS (*MORONE SAXATILIS*) SPAWNING IN THE SHUBENACADIE RIVER ESTUARY

Context

The Alton Natural Gas storage facility is to consist of an underground hydrocarbon (i.e., natural gas) storage facility near Alton, Nova Scotia (see NSDOE 2007). A water intake facility will draw water from the main stem of the Shubencadie River estuary to create cavern spaces for natural gas storage through dissolution of salt within a subsurface salt deposit. The resulting brine solution will be brought back to the surface and stored in a holding pond for eventual discharge back into the estuary in a manner that aligns with natural salinity fluctuations. Release of the salt brine will be via a diffuser pipe located in a mixing channel that has been constructed along the shore of the estuary.

The Stewiacke River estuary, which joins the tidal main stem of the Shubenacadie River approximately 2 km upstream of the mixing channel, is the primary spawning site for Shubenacadie River Striped Bass. This population is the only one of the three member populations of the Bay of Fundy Striped Bass Designatable Unit (DU) that is known to be reproductively viable (DFO 2014). Accordingly, they are of high conservation significance. The Environmental Registration Document for the Proposed Alton Natural Gas Storage Project acknowledges that Striped Bass eggs and larvae may occur in significant numbers in the vicinity of the mixing channel during May-June spawning events (Jacques Whitford 2007). Annual May-August ichthyoplankton surveys during the years 2008-2015, conducted under the supervision of Dr. J. Duston, Agricultural Campus, Dalhousie University, have confirmed the presence of Striped Bass eggs and larvae in the vicinity of the mixing channel in all years.

In light of uncertainties concerning the potential for brine release infrastructure and effluent to negatively influence Striped Bass productivity (DFO 2007), Alton Natural Gas LP. has proposed to cease brining operations during peak Striped Bass spawning events. However, no definition for “peak spawning events” for Shubenacadie River Striped Bass has been developed (Conestoga-Rovers & Associates 2015). Guidance provided to the proponents on August 11, 2015, following discussions between Fisheries and Oceans Canada (DFO) Science and DFO Fisheries Protection Program (FPP) on August 10, 2015, recommended that any analyses of existing data to identify ’principle’ spawning events should 1) consider use of water temperature as an indicator of onset of spawning; and 2) be conducted within the context of the overall timing and duration of annual spawning activity. Subsequent analysis by the proponent was provided to DFO Science in support of a peer-review of a proposed protocol for ensuring that the period when brining would cease aligned with natural spawning activity by Shubenacadie River Striped Bass, such that eggs and larvae would not be exposed to effluent or be at risk of entrainment during principle spawning events.

This review is to consider whether the portrayal of the timing and duration of spawning activity as outlined in the proponent’s analysis is accurate and whether knowledge gaps remain. The outcomes of the review will be used by the DFO FPP to help guide determination of when the project proponent might suspend brining operations in line with Shubenacadie River principle Striped Bass spawning events.

The objectives of this Science Response Process are to provide peer-reviewed science advice on:

1. a proposed method to define timing and duration of the annual window of principle spawning events for Shubenacadie River Striped Bass; and
2. the accuracy and gaps in the proponent's analysis of timing and duration of Shubenacadie River Striped Bass spawning activity.

This Science Response Report results from the Science Response Process of September 21, 2015, on the Review of a Method to Define the Timing and Duration of Spawning Activity for Shubenacadie River Striped Bass.

Background

Shubenacadie River Striped Bass Spawning, Early Life-History and Recruitment

Striped Bass spawning typically occurs during May-June and primarily within the freshwater tidal portion of the Stewiacke River estuary. Onset of spawning activity is associated with the rise in water temperatures from seasonal lows to a minimum threshold that has been generally defined for northern populations as 15°C (DFO 2014). Extensive ichthyoplankton sampling within the tidal Shubenacadie River by Dalhousie University indicates the onset of spawning activity at average daily water temperatures of 12°C in some years. Spawning activity within the estuary is episodic, and frequently intense, reflecting the interaction between tidal forcing, river discharge, local weather, and the state of sexual maturation of individual fish (Bradford et al. 2015). Spawning occurs at or near the surface, with eggs and milt broadcast simultaneously into the water column. Female Shubenacadie River Striped Bass are fecund with eggs per female estimated to be 41,000 eggs for a 45 cm Fork Length (FL) fish to 2.1 million eggs for a 91.0 cm FL fish (DFO 2014). The density of fertilized eggs in the river following spawning can therefore be high (e.g., >100 eggs/m^3 of water; Bradford et al. 2012) when large numbers of adults participate in a spawning event.

Fertilized eggs float freely and hatch after 2 to 3 days depending upon water temperature and environmental conditions (DFO 2014). Eggs generally tolerate salinities up to 20 parts per thousand (ppt) (Cook et al. 2010). Larvae forage on zooplankton within the estuary following exhaustion of the yolk reserves at about 5 to 10 days post-hatch (DFO 2014). Pre-feeding larvae can tolerate salinities as high as 30 ppt (Cook et al. 2010). Transition to juveniles occurs approximately 35 to 50 days post-hatch (Bradford et al. 2012). A range extension of the juveniles into Minas Basin is apparent by mid-summer in most years (Bradford et al. 2012). Striped Bass populations typically exhibit significant inter-annual variability in recruitment (DFO 2014). Available data indicates that for Shubenacadie River Striped Bass, Age 0_+ year juvenile abundance is not highly-dependent on spawner abundance; high juvenile abundances can be generated at low spawner abundance and low juvenile abundances can be generated at high spawner abundances. Local weather, via its influence on water temperature, water salinity, and estuarial flushing, are considered to exert a significant stochastic influence on the survival of Shubenacadie River Striped Bass eggs and larvae.

Age 0_+ year juvenile Striped Bass belonging to northerly spawning populations have been shown to exhibit body size-dependent mortality during the first winter (Hurst and Conover 1998). Fish ≥10 cm FL have higher starvation endurance when not feeding during winter compared to those <10 cm FL. Hatching date and water temperatures during the first summer and autumn, the duration and severity of winter conditions, and the interplay between these variables, are therefore potentially important determinants of eventual recruitment. Allocating survival potential to Striped Bass eggs and larvae on the basis of the number produced at a specific time in the spawning season is difficult.

Overview of Window of Principle Spawning Start Time and Duration

Intense, relatively brief spawning events appear to be a characteristic of the spawning behavior of Shubenacadie River Striped Bass. Available data indicates that the fertilized eggs produced during these events frequently represent a significant proportion of the total number that are produced during the period of spawning that, at the population level, can persist for more than a month. Definition of principle spawning activity is therefore best considered in the context of overall egg production for a given year of spawning.

Concern of Project on Principle Spawning

Uncertainties remain with respect to the potential for the water intake (impingement) and effluent (toxicity) to negatively influence Striped Bass productivity. The proportion of eggs entering the mixing channel and at risk to impingement cannot be quantified until the facility becomes operational. The toxicity of the brine to Striped Bass eggs cannot be empirically determined until brine and eggs are available at the same time. DFO (2007) suggested that in light of these uncertainties the simplest and safest recourse to maintain spawning viability is not to allow activities associated with the dilution and discharge of brine to take place during the Striped Bass spawning season.

Summary of Proposed Mitigation

Alton Natural Gas LP. has proposed to stop the release of brine into the Shubencadie River estuary for a two week period. The decision on when to stop the release of brine is to be based on the outcome of water temperature monitoring undertaken to anticipate the first large spawning event

Daily monitoring of estuarial water temperatures at the brine release site is proposed to begin May 1 of each year. Degree days above 12°C will be calculated daily, and weather forecasts will be consulted in anticipation of the first spawning event. After May 15 of each year, if the water temperature is above 12°C and the weather forecast calls for warm weather, the rate of brine release into the estuary is to be reduced.

Daily tows with plankton nets in the main channel of the Shubenacadie River estuary at the mixing channel site are proposed to begin May 10 (a fixed date approach). Tows will be completed every ten minutes through the 90 minute flood tide occurring during daylight hours, following established protocols. Samples will be visually examined at the Alton site within 2 hours of collection for presence/absence of Striped Bass eggs. Presence of eggs is to trigger a decision to cease the release of brine into the mixing channel.

Analysis and Response

Sampling and Reporting of Egg Density Data

Egg density data was collected for eight consecutive years beginning in 2008 using plankton nets equipped with flow metres. Onset of sampling varied among years, from as early as May 7th (2010) to as late as May 24th (2015), presumably a reflection of among-year differences in local weather conditions. The number of sampling days per year that occurred once eggs were detected in the river varied between 13 and 25, with eggs captured 80% or more of the time.

Egg densities were reported as daily mean values. The number of plankton tows used to calculate daily mean egg density was not reported and it is not clear whether replicate (paired) samples were acquired for each tow. As such, the data are reported without variance, and all subsequent interpretations of spawning activity and intensity assume the central tendencies of daily spawning activity are accurate and representative of among-day variability in spawning intensity. Water temperatures were reported as daily mean values.

Onset and Duration of Spawning

Once sampling was initiated for the year, it does not appear to have been conducted daily in all years, which lends uncertainty to identification of the specific date of onset of spawning activity. However, zero egg catches were reported for between 1 to 5 sampling events at the onset of spawning in seven of the eight survey years (eggs were collected on the first day of sampling in 2010). The estimates provided of day of onset of annual spawning activity are therefore generally accurate to within several days. The overall portrayal of significant inter-annual variability in the timing of onset of spawning is credible.

Duration of spawning activity was estimated to vary between 31 days (2008) and 56 days (2010) among years. However, eggs were absent in the ichthyoplankton samples acquired on the last day of sampling in only 6 of the 8 years and, of these, zero catches on consecutive days of sampling occurred in only 2 years. The aggregate results indicate that duration of spawning activity can vary by up to 56 days inter-annually.

There are indications within the data set that local weather can influence the length of time between first detection of eggs in the river estuary and the timing of the initial first spawning event. In particular, inclement weather (e.g., rain, freshets and low air temperatures) appears to delay the initiation of large spawning events. However, there does not appear to be a clear association between accumulated degree days >12°C and initiation of a large spawning event; for example, during years with relatively few accumulated degree days >12°C (2011 = 5.6; 2013 = 5.5), the estimated times between first detection of spawning activity and the first large spawning event were 4 (2011) and 17 (2013) days, respectively. During years with relatively large accumulated degree days >12°C (2010=16.2; 2014=17.2), the estimated time between first detection of spawning activity and the first large spawning event were 10 (2011) and 0 (2014) days, respectively.

Identification of Principle Spawning Activity

Presence of eggs was detected as early as May 7th (2010) to as late as May 29th (2015) among years. Time between first detection of spawning activity and first detection of a large spawning event, defined as daily mean egg density >1,000 egg/m^3, varied between 0 (2014) days and 17 (2013) days. First detection of eggs in the river estuary coincided with a large spawning event during 2014 and occurred 1 day prior to a large spawning event during 2015. The number of sampling events with 0 eggs captured prior to detection of spawning activity was 3 and 5 during 2014 and 2015, respectively. No sampling occurred on the day prior to first detection of spawning activity in either year (sampling hiatus of 3 days in 2014 and 1 day in 2015). Thus, it is not possible to discern whether these large spawn events were preceded by spawning activity within the previous 24 hours. Sampling on the day prior to the first detected large spawn appears to have occurred only during 2 (2012 and 2015) of the 8 years, which suggests that uncertainty remains as to whether the reported dates of large spawning events represent the first occurrence of a large spawning event for 6 of the 8 years.

Available data indicates that the annual principle spawning activity among Shubenacadie River Striped Bass occurs during a relatively few large spawning events (Figure 1), with individual events accounting for as much as 50% of the estimated total annual egg production. Up to 90% of the estimated total annual egg production can occur during two or more large spawning events that are completed within about 20 days from the onset of spawning activity (Figure 1).

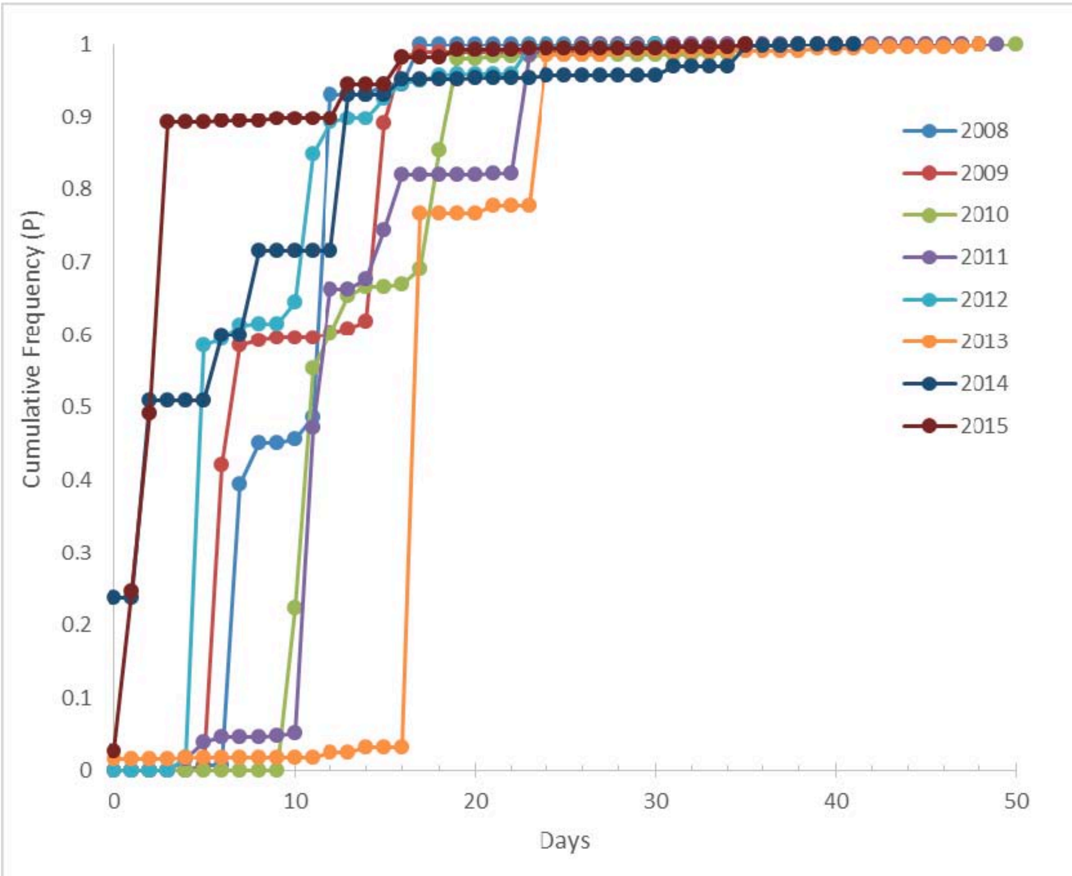

Figure 1. Cumulative proportional frequency distribution of egg production by year (2008-2015). Day 0 represents the first day eggs were detected in a given year (data source: Dr. J. Duston, Agricultural Campus, Dalhousie University, Truro, Nova Scotia).

At least one half (0.5) of the estimated cumulative egg production occurred within 2 weeks of first detection of eggs in 7 of the 8 years of sampling, 75% occurred within 2 weeks during 4 years and 90% occurred within 2 weeks in 3 years (Table 1). Eighty percent of the estimated annual egg production was achieved within 14 days (2 weeks) on average but with high variance among years (Table 1). Ninety-five percent of the estimated annual egg production occurred within 16 to 24 days (or approximately 2.3 to 3.4 weeks) of the first detection of eggs in the river (Mean±1 Standard Deviation = 18.5±3.3; Table 1).

Table 1 The number of days required each year (2008-2015) to attain quantile milestones of the annual egg production (P(Annual Egg Production)) calculated from the day that eggs were first detected in the river (data source: Dr. J. Duston, Agricultural Campus, Dalhousie University, Truro, Nova Scotia).

Year	Days required to Achieve P (Annual Egg Production)							
	0.01	**0.25**	**0.5**	**0.75**	**0.8**	**0.9**	**0.95**	**0.99**
2008	7	7	12	12	12	12	17	17
2009	6	6	7	15	15	16	16	28
2010	10	11	11	18	18	19	19	35
2011	4	11	12	16	16	23	23	24
2012	4	5	5	11	11	15	17	23
2013	1	17	17	17	24	24	24	28
2014	1	1	3	13	13	13	16	35
2015	1	3	4	4	4	13	16	19
Mean	**4.3**	**7.6**	**8.9**	**13.3**	**14.1**	**16.9**	**18.5**	**26.1**
StDev	**3.3**	**5.2**	**4.9**	**4.5**	**5.8**	**4.6**	**3.3**	**6.7**

Conclusions

Available information indicates that while there is a general association of principle spawning activity with water temperatures and local weather, the ability to predict the onset of large spawning events of Shubenacadie River Striped Bass on the basis of environmental conditions alone may be uncertain. Presence of eggs (onset of annual spawning activity) in the river as a trigger to cease the release of brine has potential to be a means to eliminate the risk of both exposure of eggs to brine and entrainment during the period of principle annual spawning activity; large spawning events appear to be preceded by low level, but detectable, spawning activity in most years. Cessation of brine release for a two week (14 day) period could, however, potentially expose significant proportions of the eggs to brine once brining resumes. Available data indicates a time period up to 24 days would protect 95% of eggs produced (Table 1 and Figure 1). Thus, the risk of exposure of eggs to brine would be greatly reduced if brining activities were to cease for 24 days following first detection of eggs.

The proposal to monitor daily water temperatures at the brine release site, beginning May 1st, can help to identify the potential onset of spawning activity and to begin preparations for reducing/ceasing the release of brine.

The results of the daily sampling for eggs with plankton nets in the main channel of the Shubenacadie River estuary at the mixing channel site will provide essential input into a decision to cease brining. However, in light of the existing uncertainties of the precise day that detectable spawning activity occurred during most years of previous sampling, it would not be advisable to base the onset of annual egg monitoring activities on a fixed date, as is presently proposed (10 May). Adoption of this protocol during 2010, for example, would have resulted in the failure to detect the first appearance of eggs, which was estimated to have occurred on May 7th.

Monitoring for eggs during the brief 90-minute flood tide period should be sufficient. However, because the monitoring site is downstream of the spawning site there should be recognition that any eggs collected would be the result of spawning activity that had occurred prior to sampling (i.e., the eggs would have to have drifted downstream in order to be captured on a flood tide). This will introduce a lag between release of eggs and their first detection, which could potentially be significant given that monitoring is proposed only during flood tides that coincide with daylight. This implies that there is some risk that large spawn events may occur while brine is being released under certain circumstances.

The brevity of the non-feeding (yolk-sac) stage, when larvae are most sensitive to salinities in excess of 20 ppt, and their apparent rapid dispersal throughout the estuary, suggests that overall risk to this life history stage would be low when brine releases are managed as to minimize risk to eggs during principle spawning activity.

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