Lake Trout Spawning and Egg Deposition Survey in Kawagama Lake

Prepared For:
Ontario Ministry of Natural Resources
Bracebridge Area Office

Prepared By:
Azimuth Environmental
Consulting Inc.

February 2007

AEC 06-213/214

ACKNOWLEDGEMENTS

Azimuth Environmental would like to graciously thank the following people and organizations for their help in assuring that this project was successful.

The MNR, and in particular Stephen Scholten, deserve considerable recognition for providing the majority of the background information and materials necessary for completing this study. In addition, Steve provided valuable input regarding study design and logistics. Steve Taylor is to be thanked for providing the water level and temperature data over the study period.

We are indebted to Dean Mark (The Scuba Shack) and his associates at 'The Diving Company' for agreeing to spend a couple hours taking turns in ice-cold water counting lake trout eggs.

We would like to extend our thanks to Chuck MacDonald for allowing us to store our boat between survey outings at his home.

TABLE OF CONTENTS

Acknowledgements…… i
Table of Contents……... ii
List of Tables, Figures, Photographs and Appendices……...iii

1.0 INTRODUCTION..... 1
2.0 BACKGROUND 1
3.0 OBJECTIVES 2
4.0 METHODOLOGY 3
4.1 SPAWNING SURVEY 3
4.1.1 Locating Shoals..... 3
4.1.2 Field Surveys..... 3
4.2 EGG DEPOSITION SURVEY..... 4
4.2.1 Study Design 4
4.2.2 Field Survey 5
4.2.3 Analyses 6
5.0 RESULTS 6
5.1 SPAWNING SURVEY 6
5.2 EGG DEPOSITION SURVEY..... 7
6.0 DISCUSSION 10
6.1 SPAWNING SURVEY 10
6.2 EGG DEPOSITION SURVEY..... 12
7.0 CONCLUSION AND RECOMMENDATIONS..... 15
8.0 REFERENCES..... 18

List of Tables

Table 1 – The area (m^2) and number of sites sampled across the four depth strata and two spatial zones……8
Table 2 – Mean egg densities (eggs/quadrat) in each depth strata……9
Table 3 – Mean percent egg survival in each depth stratum……..9
Table 4 – Estimate of the total number of eggs on the shoal……10
Table 5 – Results of a re-examination of the 2003 findings (Acres 2004) using the spatially stratified approach and areas used in this study…… 12

List of Figures

Figure 1 – Regional site map..…… 20
Figure 2 – Previously identified spawning shoals……..…… 21
Figure 3 – Water levels and water temperatures over the survey period…… 22
Figure 4 – Results of 2006 spawning survey……..…… 23
Figure 5 – Categorization of the observed number of eggs/quadrat on Shoal 16……... 24
Figure 6 – Categorization of percentage eggs/quadrat on Shoal 16……25

List of Photographs

Photograph 1 – Western edge of Shoal 16……..27
Photograph 2 – Shoal 5 with the exposed bedrock island and submerged shoal to the north…… 27
Photograph 3 – A diver measuring water depth at an egg collection site……...28
Photograph 4 – Eggs collected from site W22……28
Photograph 5 – A portion of the eggs collected from Site W25……29
Photograph 6 – Eggs collected from site W24……29

List of Appendices

Appendix I – GPS locations of the 27 shoals investigated in this study……..31
Appendix II – Raw data table for observations made on each survey outing……..32
Appendix III – Weather conditions and water levels for each survey outing……..33
Appendix IV – GPS locations of the 25 sites where egg collections were made…… 34
Appendix V – Raw data table from the egg collection survey…… 35
Appendix VI – Confidence intervals for egg densities and total egg estimates…….. 36
Appendix VII – Re-analysis of the 2003 data using the spatially-stratified approach… 37
Appendix VIII – Kawagama Lake "Rule Curves"…….…… 38
Appendix IX – Figure 3.2 from Acres (2004) report ……..….39

1.0 INTRODUCTION

Lake trout (*Salvelinus namaycush*) populations are of considerable importance to the Muskoka River Watershed, providing a highly coveted recreational fishery, and acting as a barometer for environmental degradation. Water level fluctuations, caused by water level regulation by dams, can have a crippling effect on resident lake trout populations in a lake. Relatively small fluctuations (i.e., <0.5m), occurring at critical periods of the year may lead to the potential elimination of optimal spawning habitat and, perhaps of greater concern, the stranding and desiccation of eggs. Lake trout populations in regulated watersheds are particularly vulnerable to chronic fluctuations in water levels as spawning and egg incubation periods often coincide with fall and winter drawdowns, which provide storage capacity for the anticipated high volumes in the spring.

Appreciating the long-term value in managing water levels to promote ecological function, the Muskoka River Water Management Plan (WMP) (Acres 2006) was recently developed to help balance ecological needs with social and economic demands. Acknowledging the importance of lake trout in the area, this plan has taken great strides to reduce the magnitude of the winter drawdown to help reduce the chances of stranding lake trout eggs and fry within the watershed.

The purpose of this study was to evaluate whether or not the recently adopted water management plan was having a positive effect on the lake trout populations, namely continued use of historical spawning shoals and egg deposition depths within Kawagama Lake.

2.0 BACKGROUND

Historically (prior to 1969), water levels in the large reservoir lakes in the watershed were managed to maximize waterpower production, while having little regard for natural features and ecological functions within the watershed. Water levels were kept relatively constant until the early winter when the reservoir lakes were partly drained to make room for spring runoff and high volumes. Under this scenario, lake trout were able to spawn successfully; however, reduced water levels in the winter resulted in the substantial stranding of eggs on those shoals with insufficient water depths.

In 1969, appreciating the complexity of issues and the variety of stakeholders with a vested interest in water management activities, the Province of Ontario and Hydroelectric Power Commission of Ontario (now Ontario Power Generation) made an amendment to their existing agreement (i.e., the Hackner-Holden Agreement) governing water regulation in the province. This new agreement was initiated to manage water levels with consideration for water conservation, navigation, recreational users, flood control and

fisheries resources. Under this agreement, reservoir lakes in the watershed were to impose limits to fall and winter drawdowns. The fall drawdown resulted in the reduction in water levels in the early fall, thus forcing lake trout to spawn in deeper areas. In early November, after spawning had subsided, lake levels were allowed to rise to regular levels. A winter drawdown was implemented in mid-March, in preparation for anticipated high flows in the spring. A series of "rule curves" were developed for each reservoir lake within the watershed, displaying the target water levels throughout the year.

Kawagama Lake is a deep headwater lake in the south-eastern portion of the watershed (Figure 1). Historically, Kawagama Lake was used as the main storage reservoir on the South Branch of the Muskoka River, and drawdown levels were initiated to meet the needs of Ontario Hydro. More recently, draw down levels in the fall were scheduled to reach elevations of 354.8 meters above sea level [herein, expressed simply as meters (m)] on October 15th and a further 0.6m to 354.2m for the winter on March 15th.

In developing the current WMP, the MNR retained Acres International to complete a study to evaluate the impacts of various water management scenarios on lake trout populations in Kawagama Lake. Building upon earlier MNR reports (Rettie and Ellerington 1960, Gillespie 1981, Spray et al. 1999), the Acres study (Acres 2004) provided current spawning locations, detailed descriptions of habitat conditions and egg deposition characteristics (e.g., depths, survival rates) at the main spawning shoals. Results of this study demonstrated that some of the main lake trout spawning shoals in the lake continued to be partly dewatered under the existing rule curve (354.2m). In light of these findings, the new WMP reduced the magnitude of the winter drawdown to an elevation of 354.6m, in hopes of reducing the potential stranding of lake trout eggs.

3.0 OBJECTIVES

The WMP was approved and implemented in 2006. The plan specifies that effectiveness monitoring be completed to assess if the ecological objectives of the plan are being met. In particular, the plan outlines that the 2003 spawning survey is to be repeated on Kawagama Lake in the first year of implementation to evaluate the effectiveness of the new WMP on protecting lake trout spawning habitat and egg survival. Therefore, the purpose of this study was to evaluate the effects of the recently adopted water management strategy and associated rule curve on lake trout populations, namely spawning shoal use and egg deposition depths within Kawagama Lake.

The study was conducted in two separate parts – 1) the spawning survey, and 2) the egg deposition study – each having its own set of objectives.

The objectives of the spawning survey were to:

1) document the occurrence and relative abundance of lake trout at the spawning shoals identified in the Acres (2004) report. There was some concern that chronic dewatering may result in the abandonment of historical spawning shoals, and replaced with shoals that may not have been heavily used in the past.

2) determine the peak spawning window for lake trout populations in the lake. Pin-pointing when the peak spawning window occurred provided an indicator of when to initiate the egg deposition study.

The primary objective of the egg deposition study was to:

3) estimate the proportion of eggs being dewatered under both the old rule curve (354.2m) and the new rule curve (354.6m).

4.0 METHODOLOGY

4.1 Spawning Survey

4.1.1 Locating Shoals

Prior to initiation of the spawning survey, a map of all known historical spawning locations in the lake was obtained from the Acres (2004) report (Figure 2). This map included all known and potential lake trout spawning shoals within the lake; however, GPS coordinates for these shoals were not listed in the original report. Therefore, Azimuth staff performed a reconnaissance survey to locate all previously identified shoals. Shoals were located using their relative location on the map, available photos, descriptions found in Acres (2004), and general observations made on site of suitable habitat in the area. The geographic coordinates for each shoal were recorded (see Appendices) to allow surveyors to quickly relocate shoals during survey outings.

4.1.2 Field Surveys

To ensure that the spawning surveys spanned the peak spawning window, surveys were conduced on five evenings spread over the course of the spawning period (October 16 – October 31, 2006). It is well documented that lake trout in this region of the province begin to spawn around the second week of October and continue until the beginning of November (Rettie and Ellerington 1960, Spray et al. 1999, Acres 2004). Surveys were generally conducted between ½ hour after sunset (generally around 1900 hours) and midnight. This time period coincides with peak activity for spawning lake trout (Scott

and Crossman 1973). A handheld GPS unit was used to help navigate the survey crew to the appropriate shoals in the dark. Once at a shoal, surveyors slowly passed over the area of suitable habitat and used two high intensity spotlights (i.e., 2.5 – 10 million candle watts) to spot any lake trout on the shoal. Gunn et al. (1996) found this to be an effective technique for enumerating lake trout on spawning shoals. Surveyors recorded the estimated number of lake trout observed at each locations and any pertinent behavioural information (i.e., spawning, courtship behavior). Surveyors remained on each shoal for approximately 10-15 min, making successive passes, if required.

In an attempt to ensure that the most heavily utilized shoals were visited during the peak spawning window, those sites that were found to have fish in the 2003 survey (i.e., Shoals 5, 7, 8, 11, 16, 17, and 18; Figure 2) were surveyed on each survey outing (five times). In contrast, all remaining shoals, with the exception of Shoal 3, were surveyed a minimum of twice; spread randomly throughout the duration of the survey period. Due to its remoteness, poor summer habitat conditions in Minden Bay (maximum depth <8m), and relatively poor spawning habitat (i.e., limited fetch, small substrate, sediment), Site 3 was only sampled once.

Earlier studies (Spray et al. 1999, Acres 2004) revealed that Shoal 16 was the most heavily utilized spawning shoal in the lake. Therefore, observations made on this shoal were to be used as an indication of when the peak spawning period occurred throughout the lake.

Daily water temperatures in the lake over the duration of the spawning period were obtained from the Bracebridge Area MNR office. Dissolved oxygen levels were measured at Shoals 5 and 16 on each survey outing to provide an idea of conditions at opposite ends of the lake. Weather conditions, including cloud cover, presence of rain, wind speed and general wind direction were estimated on site for each survey outing. In addition, the amount of rain falling and the mean and max air temperatures over the previous 24 hours, were recorded for each survey night and obtained from the weather network's website (www.theweathernetwork.com) for Dorset, Ontario.

4.2 Egg Deposition Survey

4.2.1 Study Design

Shoal 16 is believed to be the primary spawning shoal for lake trout in Kawagama Lake and was used in this study to evaluate egg deposition characteristics. Shoal 16 was described and surveyed in detail by Acres (2004) and, consequently, Azimuth used the surveyed drawing in their report (Figure 3.2 in their report, see Appendices) as a template for the work in this study. In addition, to ensure that results of this study were

comparable to those in 2003, we followed a similar methodology as that used in the initial study (Acres 2004).

The primary objective of this survey was to estimate the proportion of eggs subject to winter drawdown desiccation under different drawdown scenarios. To address this, mean egg densities were obtained at four different depth strata (0.0-0.3m, 0.31-0.6m, 0.61-1.3m, >1.3m), which roughly correspond to the strata used in the 2003 study. All depths are expressed relative to the fall drawdown elevation of 354.8m, as most fish were forced to spawn below this elevation.

The first depth stratum (0-0.3m) represents an approximation of the area that would be subject to winter desiccation under the new rule curve (bottom of normal operating zone as per Acres 2006). The second stratum (0.31-0.6m), when combined with the shallower depth stratum, represents the total area that would be dewatered under the old rule curve (i.e, 354.8m-354.2m). Contrary to the 2003 study, this study divided the area that was not threatened by dewatering (>0.6m) into two separate strata (i.e., 0.61-1.3m and >1.3m), in an attempt to make estimates more precise.

Results of the 2003 (Acres 2004) survey suggested that the western portion of the shoal received considerably greater use that the eastern half. As a result, this study divided the shoal into two spatial zones (i.e., east and west of the exposed bedrock). The rationale for this was that it would permit a more precise estimate of the total number of eggs on the shoal, accounting for differential use of the shoal.

4.2.2 Field Survey

A sub-meter accuracy, WAAS enabled Trimble GPS receiver was used to help guide surveyors to sampling points used in 2003. A survey rod was used to position sampling points in the assigned depth strata. All sampling sites were located within the area of habitat identified as “most suitable” for spawning as outlined in Acres (2004), as it is believed that this is where the majority of the spawning occurs. In addition, we attempted to sample a minimum of three points in each depth stratum within both spatial zones (with the exception of the deepest stratum).

At each sampling location a 25 cm x 25 cm grid was placed on the lake bed. A certified commercial diver was tasked with collecting all the eggs found within the grid. Eggs were transferred from the substrate to a plastic container with the aid of a suction device (i.e., a turkey baster). Upon removing all visible eggs from the quadrat, the diver removed the cobble and rock substrate, as much as possible, attempting to collect any additional eggs found within the grid. The maximum depth at which eggs were collected was recorded. All eggs were brought to the surface where an Azimuth biologist

separated and enumerated those eggs that were dead (e.g., white, opaque, fungus) from those that were alive (e.g., orange). All eggs were then returned to the substrate.

4.2.3 Analyses

The area of each depth stratum in each of the two spatial zones was determined using the surveyed depths found in the Acres report (2004; see Appendices). This figure was scanned and imported in AutoCad, where all depth contours were manually delineated and specific areas could be calculated. Only depths found within the area considered the "most suitable" spawning habitat, as defined by Acres (2004), were included in the calculations.

The mean number of eggs in each of the eight strata (4 depth strata x 2 spatial zones) were converted to the number of eggs/m^2 and then multiplied by the respective area to obtain the estimated number of eggs in each stratum. The number of estimated eggs in a stratum divided by the total estimated eggs provided the proportion of the total eggs found at the specified depth, and consequently the proportion subject to the various drawdown scenarios.

5.0 RESULTS

5.1 Spawning Survey

In total, 28 of the 29 previously identified spawning shoals were found; the only exception being Shoal #6, which appears to have been plotted incorrectly on the original map. Therefore, a 100m stretch of shoreline closest to the coordinates provided by MNR was considered to be Shoal #6, and surveyed as outlined in Section 4.1.2.

Surveys were conducted on the following five nights; October 16, 20, 23, 26, 31, 2006. Water levels remained relatively constant over this time, displaying only an 8 cm fluctuation over the two weeks (354.82-354.90m) (Figure 3). Weather conditions varied considerably over the two week period (see Appendices). As expected, water temperatures declined dramatically and ranged from 10.2ºC to 4.4ºC over the two weeks (Figure 3). Dissolved oxygen levels remained relatively constant throughout the sampling period, averaging 10.6 mg/L (range = 10.2-10.9) (see Appendices).

Lake trout were observed on 9 of the 29 shoals (Figure 4; see Appendices for raw data). Shoals 16, 5 and 26 were found to be the most heavily utilized and were the only shoals to have lake trout observed on three or more survey outings. The six other shoals with fish appeared to receive very limited use. Three fish were observed on Shoal 17-1 on the first survey outing; however, failed to produce any fish on the four remaining survey attempts. Fish were observed at Shoal 15 on two separate survey outings, although only

a single fish was observed each night. The additional four shoals with fish (Shoals 1, 14, 22, 23) were found to contain a single fish on a single survey outing.

As documented in previous reports (e.g., Spray et al. 1999, Acres 2004), Shoal 16 (Photograph 1) was found to contain the highest numbers of spawning Lake Trout, totaling 99 fish. Peak spawning activity was observed on October 20th with an estimate of 70 fish being observed on the shoal. Surprisingly, not a single fish was observed on the shoal on the next survey outing (October 23rd); however some activity was observed again on October 26th. A large percentage of the spawning appeared to occur within a 2m band on the east and the west side of the bedrock outcropping.

Shoal 5 (Photograph 2) was found to be the second most heavily utilized shoal in the lake, with an estimated 87 fish being observed over the five outings. Fish abundance on this spawning shoal appeared to increase gradually and peaked on October 26th with an estimated 50 fish observed. Only two fish were observed on the following (final) survey outing. Almost all of the fish observed on Shoal 5 were located on the shallow open water patch of cobble approximately 50 m to the north of the exposed bedrock.

Shoal 26, off Echo Island, was the only other shoal to have fish observed on three separate outings. The most notable observations at this shoal occurred on October 23rd, in which surveyors estimated 15 fish in the vicinity of the shoal. Most of the fish were observed in deeper water (>2m) compared to the other two shoals. Small groups containing 3-4 fish were evident with fish swimming around each other, characteristic of spawning behaviour. Only one or two fish were observed on the other two nights (20th and 26th).

Given the variation in peak spawning activity at the three main shoals, it was difficult to provide a precise estimate of the peak spawning window for the lake. Based upon the large numbers of fish observed on October 20th (Shoal 16) and October 26th (Shoal 5), it is reasonable to consider that the peak spawning window for Kawagama Lake spanned from October 20th to October 27th. However, it was apparent that, for any given shoal, the peak window may have lasted only 1-2 nights.

5.2 Egg Deposition Survey

The egg deposition survey was conducted at Shoal 16 on November 15, 2006. Complications in scheduling divers forced the egg deposition survey to occur later in the season than initially planned (Photograph 3). Water levels at the time of the survey were 354.97m; however, all depths were expressed relative to the fall drawdown level of 354.80m. Heavy winds at the time of the survey made it difficult to replicate the exact locations used in the 2003 study, therefore, samples were chosen in the same general

areas as in 2003, taking care to ensure that the site remained within the "most suitable" habitat. For the most part, all samples were located at sites having similar substrate conditions – large cobble and small rocks, with some gravel.

In total, 25 sites were sampled; 13 in the eastern and 12 in the western zones (Figure 5). Sampling was divided somewhat evenly between the three shallower depth strata, with 7 samples in the 0-0.3m stratum, and 8 samples in each of the 0.31-0.6m and 0.61-1.3m depth strata (Table 1). Only two sites were sampled in the deepest stratum, both being within the western portion of the shoal. Very few eggs were found resting on the surface of the substrate, but rather located an average of 15 cm below the top of the substrate, clustered on the lake bottom.

Table 1. The area (m^2) and number of sites sampled across the four depth strata and two spatial zones. Note that all areas are for the "most suitable" habitat sections only.

Spatial Zone	Depth Strata (m)	Area (m^2)	Samples
East	0.0-0.3	35.3	4
East	0.31-0.6	139.7	5
East	0.61-1.3	228.1	4
East	>1.3	37.5	0
West	0.0-0.3	31.2	3
West	0.31-0.6	16.8	3
West	0.61-1.3	55.7	4
West	>1.3	51.2	2
Totals	-----	*595.4*	*25*

In total, 559 eggs were observed at the 25 sites. The number of eggs found in each quadrat varied considerably (Photographs 4-6), with 65 eggs/quadrat (site W22; Photographs 4) being the maximum observed and only four sites having no eggs; three of which were located in the eastern zone (see Appendices for raw data).

Despite the western zone comprising roughly 26% of the total optimal spawning habitat on the shoal (154.8m^2 in the west compared to 440.6m^2 in the east), this area contained roughly 65% of all eggs found (363 eggs in the west compared to 196 eggs in the east) (Figure 5, see Appendices for raw data).

The 0.31-0.6m depth stratum contained the highest egg densities in both zones, averaging 37.5 eggs/quadrat, although mean densities were much higher in the west (48.7 eggs/quadrat) compared to the east (26.4 eggs/quadrat) (Table 2). The shallow stratum (0.0-0.3m) was found to contain the next highest density of eggs (mean = 24.6

eggs/quadrat) with the west having more than double the densities found in the east (35.0 and 14.3, respectively).

Table 2. Mean egg densities (eggs/quadrat) in each depth strata.

Strata	East	West	Combined
0.0-0.3	14.3	35.0	24.6
0.31-0.6	26.4	48.7	37.5
0.61-1.3	1.8	23.3	12.5
>1.3	-----	9.5	9.5

When egg densities in the two zones were combined, the 0.6-1.3m depth stratum appeared to have the next highest density (mean = 12.5 eggs/quadrat), although there were substantial differences between the west and eastern zones (means = 23.3 and 1.8 eggs/quadrat, respectively). The two deep water samples in the western zone produced an average of 9.5 eggs/quadrat (range 4-15 eggs/quadrat).

The mean egg survival was 73.8% (consistent with the 76% observed in 2003) and increased gradually from 63% in the shallowest depths to 91% in the 0.6-1.3m depth strata (Table 3, Figure 6). Survival rates dropped off to 68% in depths greater than 1.3m. Overall, the eastern zone appeared to have higher survival rates than in the western portion of the shoal (79% and 68%, respectively), although the large variance in survivorship across the shoal (ranging from 40% to 100%) suggests the two areas are not statistically different. However, it is interesting to note that in the 0.31-0.6m depth stratum, the survival rates in both spatial zones were almost identical (76% in the east compared to 77% in the west).

Table 3. Mean percent egg survival in each depth stratum.

Strata	East	West	Combined
0.0-0.3	78.2	48.3	63.3
0.31-0.6	75.9	77.2	76.6
0.61-1.3	100.0	82.1	91.0
>1.3	-----	67.5	67.5

When the mean egg densities were extrapolated to provide an estimate of the total number of eggs in each stratum and zone, it was determined that roughly 133,500 eggs were on the shoal. This calculation is based on the >1.3m depth having the same mean egg density as the 0.6-1.3m strata (east only). The majority (54.0%) of all eggs were estimated to be within the 0.31-0.6m depth strata (Table 4).

Table 4. Estimate of the total number of eggs on the shoal ("most suitable" habitat only). Refer to Appendices for confidence intervals.

Zone	Depth	Area (m^2)	Stations in strata	Mean # eggs/quadrat	Mean eggs/m^2	Est. Total eggs[1]	Proportion of Total
East	0.0-0.3	35.3	4	14.3	228.0	8046	6.0
East	0.3-0.6	139.7	5	26.4	422.4	58997	44.2
East	0.6-1.3	228.1	4	1.8	28.0	6387	4.8
East	>1.3	37.5	0	1.8*	28.0*	1050*	0.8*
West	0.0-0.3	31.2	3	35.0	560.0	17472	13.1
West	0.3-0.6	16.8	3	48.7	778.7	13059	9.8
West	0.6-1.3	55.7	4	23.3	372.0	20702	15.5
West	>1.3	51.2	2	9.5	152.0	7782	5.8
Totals	**----**	**595.4**	**25**	**----**	**----**	**133 495**	**100**

[1] Estimates are rounded to whole number.

* Based on egg densities in 0.6-1.3m depth stratum (east only).

In contrast, only 19.1% were found within the 0-0.3m depths. In addition, the deeper strata (i.e., 0.6-1.3m and >1.3m) were estimated to contain 20.3% and 6.4% of all eggs, respectively. Therefore, under the current winter drawdown level an estimated 19.1% of the eggs would be subject to desiccation. However, if the winter drawdown levels had not changed, maintaining levels 0.6m below the fall drawdown, it is estimated that 73.1% of the eggs would have been stranded.

6.0 DISCUSSION

6.1 Spawning Survey

This study confirms the conclusions made by earlier reports (Rettie and Ellerington 1960, Gillespie 1981, Spray et al. 1999, Acres 2004) that Shoal 16 is the most heavily utilized spawning shoal for lake trout in Kawagama Lake. In 1959, Rettie and Ellerington (1960) estimated approximately 300 lake trout off Barnum's Point (i.e., Shoal 16). Similarly, Spray et al. (1999) performed a comprehensive survey of 27 shoals in the lake during the final week of October, and found most fish were observed at Shoal 16; however, the maximum number of fish estimated at the shoal was 35. More recently, Acres (2004) estimated more than 100 fish on the spawning shoal on three separate evenings between October 24 and 29, 2003.

This study demonstrated that Shoal 5 appears to be an extremely important spawning location for lake trout in the area, supporting earlier findings by Acres (2004). Up until the Acres (2004) report, Shoal 5 was not known to be a major spawning shoal for lake

trout in the lake. Spray et al. (1999) observed only a single fish over the course of three evenings. With the exception on Shoal 16, Acres (2004) found Shoal 5 to be the most prolific shoal on the lake with a total of 40 fish observed over 4 nights. Detailed habitat mapping by Acres (2004), indicates that all optimal spawning habitat on this shoal is located at depths greater than 354.2m and, therefore, it is suspected that most eggs deposited on this shoal are not at risk of being dewatered.

Somewhat surprising was the number of fish that Azimuth documented on Shoal 26. The two previous studies that investigated this shoal (Spray et al. 1999, Acres 2004) did not observe a single fish at this location. In contrast, this study was unable to confirm the observations of earlier studies (Spray et al. 1999, Acres 2004), which documented substantial numbers of fish (>10) on Shoals 17 and 18.

Although there is evidence to suggest that lake trout return to their natal shoals to spawn (Martin 1957), there is growing evidence to support the notion that some straying occurs and that lake trout will abandon historical shoals in search of alternate locations if conditions degrade over time (Gunn and Sein 1996). As a result, there was some concern that chronic dewatering of key spawning shoals in Kawagama Lake would result in the abandonment of these historical shoals. Although this study was able to document some new shoals that were previously not found with fish, and vice-versa, it is suspected that these differences are not a response to long-term dewatering of spawning shoals but rather attributed to a variety of other causes, including difficulty in observing fish in deep and windy locations, and survey dates falling outside of the peak spawning nights.

It is apparent that on the lesser-used shoals that spawning may last only 1-2 nights, and unless the survey happens to land on that night, substantial spawning activity will go unnoticed. This may partly explain why this study, and to a lesser extent Spray et al. (1999), did not observe ay fish on Shoal 18, while Acres (2004) found 30 on a single night. Detailed shoal mapping done by Acres (2004) indicates that the entire "most suitable" habitat for spawning is below the winter drawdown levels (354.2m); therefore, drastic differences among years are not likely a response to chronic dewatering. In addition, observers may have a difficult time to spot fish in high winds and rain, especially at spawning shoals located in deeper water (<2m). It is suspected that the greater water depths at Shoal 26, combined with the long fetch and accompanying rough water, likely contributed to the fact that previous studies failed to observe fish on this shoal.

We caution that studies, such as this, that rely on observations to make rough estimates of abundance may be somewhat misleading in terms of trends through time, as it is difficult to estimate large numbers of fish in a small area. Therefore, little emphasis should be

placed on changes in numbers over time but rather on those shoals that are consistently found to have fish. Similarly, little attention should be given to those sites where only 1-2 fish were observed, as these fish may have been cruising along the shoreline and not necessarily looking for spawning areas.

6.2 Egg Deposition Survey

The results of the egg deposition investigation reveal that spawning lake trout target the western portion of Shoal 16. Observations made during the spawning survey confirm this, as most of the spawning fish were seen just off the western tip of the exposed bedrock island. The Acres (2004) report provides similar results, empirically demonstrating that roughly 80% of all eggs found on Shoal 16 were within the western half of the shoal (see Appendices).

Results of this study clearly show that the 0.3-0.6m depth stratum was the most populous in terms of eggs, with almost 50% of all eggs collected. This appears to be consistent with the results provided by Acres (2004), which documented approximately 46% of all eggs collected were from the 0.3-0.6m depth stratum. However, there was some disagreement between the other depth strata. This study found that the shallow depth stratum (0-0.3m) contained higher egg densities than did either of the other two strata (Table 2). In contrast, the results from 2003 (Acres 2004) found that the 0.6-1.3m depth stratum had extremely high egg densities; slightly more than 4 times that of the 0-0.3m depth (Table 5). It is believed that the 2003 estimates were somewhat skewed by extremely high egg counts found at two samples in this depth stratum in the western portion of the shoal.

Table 5. Results of a re-examination of the 2003 findings (Acres 2004) using the spatially stratified approach and areas used in this study.

Depth	Mean Eggs		Est. Total Eggs*		% of Total Eggs	
Strata (m)	2003	2006	2003	2006	2003	2006
0.0-0.30	18.6	24.6	27,000	25,500	6.3	19.1
0.31-0.6	97.6	37.5	102,500	72,000	16.8	54.0
0.61-1.3	86.3	12.5	235,000	27,100	73.1	20.3
>1.3	12.7	9.5	13,100	8,800	4.0	6.6

*numbers rounded to nearest 100.

It seems prudent to reiterate that it may not be appropriate to make inter-annual comparisons for the total number of eggs collected and densities, but rather emphasis should be placed on where the majority of eggs were found in each year. There was considerable discrepancy between this survey and the 2003 survey with respect to the

amount of time between the peak spawning and the collection of eggs from the substrate (roughly a 3.5 week difference). The additional time between peak spawning and egg collections is believed to be largely responsible for the large difference in total eggs collected. Within this time period, eggs may have washed away or been eaten by a variety of egg predators known to occur in Kawagama Lake including crayfish, sculpins (*Cottus* sp.), lake whitefish (*Coregonus cluepaformis*), brown bullhead (*Ameiurus nebulosus*), white sucker (*Catostomus commersoni*) and burbot (*Lota lota*) (Martin 1957, Scott and Crossman 1973, Chotkowski and Marsden 1999, Fitzsimons et al. 2002). In fact, on November 1, 1959, Rettie and Ellerington (1960) collected 3 whitefish, 15 suckers and 2 bullheads from two gill nets set in 3m of water immediately adjacent Shoal 16. We can infer from these catches that these fish were in the area eating recently deposited lake trout eggs.

Egg survival appeared to increase with depth up to the 0.6-1.3m stratum, but fell slightly in the deeper stratum. Despite the difference in time between the peak spawning and the egg collections, our findings mirror those observations made in 2003 (Acres 2004; although their study combined the 2 deeper strata). Our study found considerable differences in survival rates between the two spatial zones in the 0.0-0.3m depth stratum (Table 3). It is unclear if this discrepancy is related to some mechanistic process occurring between the two areas of the shoal, or simply an artifact of differences in the egg densities in the two areas (i.e., sites with more eggs are likely to contain more dead eggs).

The primary objective of this study was to assess the proportion of eggs that would be stranded under various water management strategies. Using a stratified-random approach, this study was able to successfully demonstrate that recent changes to the water management plan (i.e., reduction in magnitude of winter drawdown rates) will result in the stranding on approximately 19% of all eggs on Shoal 16. However, had the new drawdown rates not been implemented in 2006, it is anticipated that close to 73% of all eggs would have become stranded and succumbed to desiccation. In addition, our calculations suggest that, had this study not spatially stratified the areas of the shoal, we would have underestimated the total amount stranded (13.5% and 61.4% for the new and old rule curve, respectively). This underestimate would have stemmed from the fact that most eggs were deposited in western portion of the shoal, which represents only 26% of the total shoal area.

Our results suggest that under the old rule curve, egg survival on Shoal 16 was substantially constrained by low-water levels in the winter. Analyses conducted in this study imply that the new rule curve will prevent 54% of the eggs on Shoal 16 from becoming stranded. Therefore, prior to 2006, egg survival on Shoal 16 may have been

suppressed by 73%. Given that this is the primary spawning shoal on the lake, this would have had the potential to decimate particular year classes and cripple the overall population in the lake. Clearly, recent changes to the WMP will have a positive effect on lake trout egg survival at Shoal 16 and the overall population; however, these changes still appear to be suppressing potential for fry emergence (e.g., 19%) on the shoal in certain years.

These numbers are considerably higher than what was initially anticipated given the results of the 2003 study. The Acres report (2004) indicates that the estimated egg loss would be approximately 6% under the new rule curve and 30% under the old rule curve, underestimating our results by 13% and 43% respectively. This discrepancy was initially believed to be a result of the added precision that arises from spatially stratifying the data. However, upon re-analysis of the Acres (2004) data, stratifying based on four depth strata and two spatial zones, as was done in this study (Table 5; see Appendices), 2003 estimates appeared to change very little (i.e., 6.3% and 23.1% for the new and old rule curve, respectively). Therefore, discrepancies between years should not be blamed upon differences in analytical approaches.

We anticipate that differences in the proportion of eggs stranded under the two rule curves between this study and the 2003 study (Acres 2004) can be attributed to substantial inter-annual variability in the locations that lake trout choose to deposit their eggs. Although it is difficult to compare densities between years, it does appear that the shallower stratum (i.e., 0-0.3m) received much greater attention in 2006. It would seem likely that the extended period between peak spawning and egg collection observed in this study would have resulted in fewer eggs observed in this stratum, when in fact this is not the case. It is unclear why lake trout eggs were more numerous in the shallower depths in this study, although we speculate that slightly higher water levels on the peak spawning night (354.86m in 2006 compared to354.81m in 2003) allowed fish to spawn in shallower water.

In addition, we suspect that some of the variation in the estimates may originate from increased egg predation in the deeper (>0.6m) areas in the 2006 study. The extended time between peak spawning and egg collections provided egg predators (as outlined above) more time to find and consume hidden eggs. Although this is only speculative, it seems likely that the turbulent, shallow conditions found in the nearshore habitats would confine egg predators to the deeper areas. Acknowledging the differences between years, it seems advantageous to assess egg deposition well after the peak spawning, as it provides a more realistic estimate of the number of eggs available and at risk of being dewatered in late winter.

It is likely that our estimate of the total eggs subject to drawdown desiccation may be slightly inflated as our analyses were based on depths to the substrate and not the maximum depth at which eggs were collected. In many cases eggs were found between 10-20cm below the top of the substrate. As a result, eggs identified as being near the periphery of the 0-0.3m stratum may in fact be resting 0.4m below the fall drawdown and consequently not at risk. We chose the former of the two to maintain consistency with the depth contours provided by Acres (2004). Post-hoc attempts to categorize and analyse data based on maximum depth also proved problematic as the number of samples in each depth category would have been highly skewed towards the deeper areas. For example in the eastern zone the 0.6-1.3m stratum would have seven samples represented whereas the 0-0.3m stratum would have had none. This unbalanced design would have compromised any attempts to derive realistic estimates of the total eggs on the shoal.

In addition, the total area of "most suitable spawning habitat" was determined to be slightly larger than the area presented in the 2003 study (595 m^2 compared to 578m^2, respectively). This difference represents less than a 3% increase in area and, as a result, had a negligible effect on overall estimates. The reason for the discrepancy among areas remains unclear, but it is suspected that some distortion may have resulted through the digitizing process.

It is important to emphasize that these results apply only to Shoal 16 and do not translate to the elimination of 19% of the lake wide production. Although Shoal 16 is the primary spawning shoal, there exist other substantial spawning locations throughout the lake (e.g., Shoal 5). The two other shoals found in this study to have significant numbers of fish (Shoals 5 and 26) are completely below the 354.2m elevation and are not in jeopardy of being dewatered. In addition, some spawning may occur on shoals that are deeper than 2m; too deep to observe fish and confirm their location. Studies of inland lake trout populations have shown that it is not uncommon for lake trout to spawn at depths greater than 2m (Tarandus 1988, Flavelle et al. 1999). This may be more evident in lakes that have been dammed, such as Kawagama Lake, where historical spawning shoals may now be located at considerable depths. It has been suggested that, although likely too deep to be affected by wind action, deeper offshore areas (4-6m) with sufficient slope and exposure to internal currents may provide suitable spawning habitat (Flavelle et al. 1999).

7.0 CONCLUSION AND RECOMMENDATIONS

Water drawdowns in the fall and winter have the potential to dewater spawning shoals and strand developing lake trout eggs and larvae. Chronic dewatering of these critical habitats may result in lake trout abandoning historical spawning shoals in search of deeper, less suitable, spawning areas. Observations made during our lake-wide spawning survey confirmed that lake trout in Kawagama Lake continued to use the two primary

shoals identified in the 2003 study (i.e., Shoal 16 and 5). Despite previous reports considering it inactive, substantial spawning activity was observed at one shoal (Shoal 26), which was found in deeper water (>2m). However, it is unclear if this is a newly colonized spawning shoal, in response to dewatering at other shoals, or simply missed in previous reports due to the difficulty in observing fish in deep, rough water. In contrast, some shoals, previously found to contain substantial numbers of spawning fish, were found to have few, if any, lake trout. We stress that the continuation of periodic spawning surveys is needed to ensure that water management strategies are not adversely affecting lake trout spawning behaviour and population size.

One of the objectives of the newly implemented Muskoka River Water Management Plan was to enhance spawning success of lake trout by reducing the magnitude of winter drawdown levels. Relying on the findings of a pilot study on Kawagama Lake (Acres 2004), the WMP calls for winter drawdown levels to be raised to 354.6m from354.2m. The Acres (2004) study demonstrated that a reduction in the magnitude of winter drawdown by 30cm (354.2m to 354.5m) would result in the stranding of only 6% of all eggs on the primary spawning shoal. Using a similar approach to that used in the Acres (2004) study, this study estimates that a winter drawdown elevation of 354.5m would result in the stranding of roughly 19% of all the eggs on Shoal 16. However, our results suggest that considerable egg loss would have resulted at Shoal 16 (73%) had the WMP not adopted the new rule curve. These findings imply that, in some years, the old rule curve severely suppressed egg survival and potentially fry emergence on Shoal 16 and, potentially, in the entire lake.

It seems apparent that there is considerable inter-annual variation in the proportion of eggs found in the various depth strata. The effectiveness of the WMP in promoting lake trout production in the lake, relies upon a better understanding of how much of this variation is attributed to the size of the spawning population, the time elapsed from peak spawning and the water levels during the spawning period. We emphasize that future management goals of balancing the conflicting needs of lake trout populations and water management demands would benefit greatly from an improved understanding of the relative contribution of the main shoals to the overall production (i.e., recruitment to adult population) in the lake.

The large variation in egg deposition rates within the 0-0.3m stratum suggest that attempts to keep egg mortality to below 6% may not be realistic on an annual basis under the current scenario. Ideally, the fall drawdown levels would match the winter drawdown levels. Future work may wish to assess the trade-offs on egg survival and fry emergence between lowering the fall drawdown an extra 20cm to match winter drawdown and the potential loss under current drawdown scenarios (i.e., 6-19%).

We stress that future egg deposition studies maintain a spatially stratified approach and ideally conduct egg collections at 4-5 locations in each stratum and spatial zone (32-40 samples in total). This would help provide more precise estimates and allow a better assessment of inter-annual variability. Given that this study was able to collect considerable numbers of eggs three weeks after the peak spawning had occurred, we recommend that future egg collections occur at similar times. The extended time between peak spawning and egg collection would provide a more realistic estimate of the eggs that may be subject to over-winter mortality.

Finally, this study underscores the benefits of balancing water management needs and ecological processes. It is evident that the recently imposed Muskoka River Water Management Plan is having a positive impact on lake trout egg survival; however, this study convincingly demonstrates that current drawdowns may still be constraining lake trout populations in Kawagama Lake.

8.0 REFERENCES

Acres International Limited. 2004. Kawagama Lake – Lake Trout Spawning Studies. Prepared for the Ontario Ministry of Natural Resources, Bracebridge, Ontario.

Acres International Limited. 2006. Muskoka River Water Management Plan – Final Plan Report. Prepared for the Ontario Ministry of Natural Resources, Bracebridge, Ontario.

Chotkowski, M.A., and J.E. Marsden. 1999. Round goby and mottled sculpin predation on lake trout eggs and fry: field predictions from laboratory experiments. J. Great Lakes Res. 25(1):26-35.

Fitzsimons, J.D., D.L. Perkins, and C.C. Krueger. 2002. Sculpins and crayfish in lake trout spawning areas in Lake Ontario: estimates of abundance and egg predation on lake trout eggs. J. Great Lakes Res. 28(3):421-436.

Gillespie, G. 1981. Kawagama Lake - Trout Spawning Beds. Unpublished Data. Ontario Minsitry of Natural Resources, Bracebridge, Ontario.

Gunn, J.M., M. Conlon, R.J. Kirk, and S.C. McAughey. 1996. Can trained observers accurately identify lake trout spawning habitat? Can. J. Fish. Aquat. Sci. 53: 327-331.

Gunn, J.M, and R. Sein. 1996. Effects of forestry roads on reproductive habitat and exploitation of lake trout (*Salvelinus namaycush*) in three experimental lakes. Can. J. Fish. Aquat. Sci. (Supp. 2): 97-104.

Martin, N.V. 1957. Reproduction of Lake Trout in Algonquin Park, Ontario. Trans. of the Am. Fish. Soc. 86:231-244.

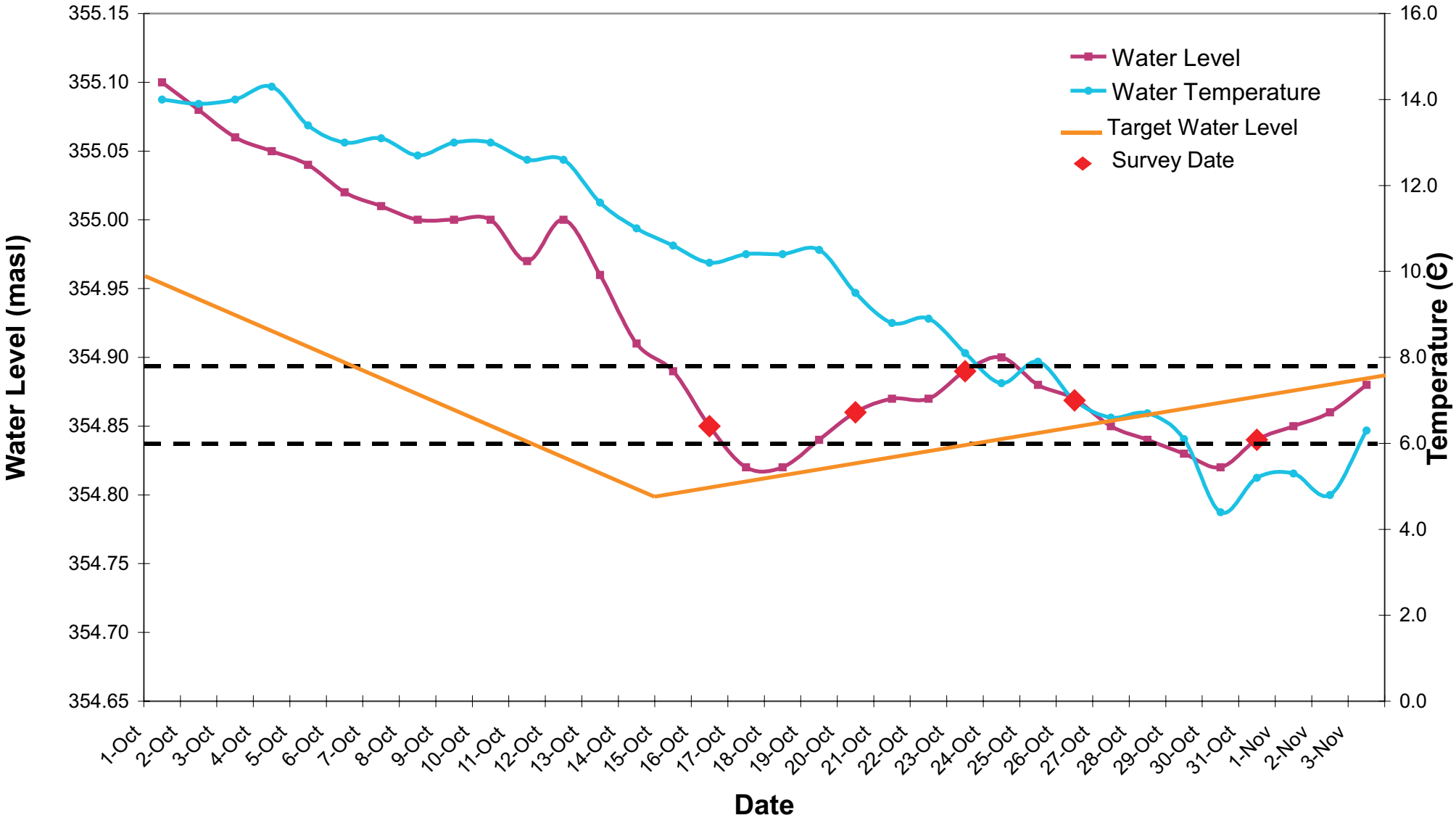
Rettie, C.A., and W.C. Ellerington. 1960. Lake Trout Spawning Survey – Hollow Lake – 1960. Ontario Ministry of Natural Resources, Bracebridge, Ontario.

Scott, W.B., and E.J. Crossman. 1973. Freshwater Fishes of Canada. Bulletin 184. Fisheries Research Board of Canada. Ottawa, Ontario.

Spray, G., K. Morrison, and B. Stewart. 1999. Fall Lake Trout Spawning Observations and Shoal Mapping, Camp Lake and Kawagama Lake. Prepared for the Ontario Ministry of Natural Resources, Bracebridge, Ontario.

Tarandus Associates Limited. 1988. An Evaluation of Selected Lake Trout Spawning Shoals in Lake of Bays. Prepared for the Ontario Ministry of Natural Resources, Bracebridge, Ontario.

FIGURES



Note: dashed horizontal lines represent range in water levels over the survey period

AZIMUTH ENVIRONMENTAL CONSULTING, INC.

Water levels and water temperatures over the survey period

Date Issued:	February 2007
Created By:	S.F.G.
Project No.	06-213
File Name:	Fig3.DWG

Kawagama Lake Spawning Survey

Figure No. **3**

APPENDICES

Appendix I – GPS locations of the 27 shoals investigated in this study. All points are in Universal Transverse Mercator (UTM) Zone 17, NAD 83. Points with asterisk (*) were derived using digital maps and not a GPS unit. Shoal 6 co-ordinates were provided by MNR.

Shoal	X – Easting	Y- Northing
1*	673810	5019940
2*	673947	5020412
2a*	674066	5020611
3*	672396	5014310
4	675062	5016433
5a	675654	5017017
5b	675676	5017072
6	677304	5017531
7	677697	5018265
8	675801	5018123
9*	675377	5018639
10	677185	5019084
11	677654	5020807
12	676699	5020945
13	677662	5019893
14	678512	5020346
15	679961	5020872
16	679764	5020533
17-1	679096	5019544
17-2	678774	5019086
18	678162	5018901
19	675784	5019364
20	677125	5020214
21*	674808	5018266
22	681659	5019310
23	681437	5019272
24	680822	5019172
25	680757	5018732
26	678149	5020761
27	676464	5020945

Appendix II – Raw data table for observations made on each survey outing. Yellow rows denote active shoals in 2003 and those shoals surveyed each night in this survey.

Shoal	October 16		October 20		October 23		October 26		October 31	
	Time	# LT	Time	# LT	Time	# LT	Time	# LT	Time*	# LT
1			9:30	0			7:30	**1**		
2			9:40	0			7:40	0		
2a			9:45	0			7:45	0		
3					7:45	0				
4	8:50	0			8:10	0			6:25	0
5	9:15	0	8:30	**15**	8:20	**20**	10:25	**50**	6:40	**2**
6					8:35	0	10:15	0		
7	9:30	0	11:30	0	8:45	0	10:05	0	8:55	0
8	12:05	0	8:55	0	11:45	0	10:45	0	6:50	0
9			9:10	0					7:10	0
10			11:35	0	11:35	0	11:00	0		
11	11:15	0	10:05	0	11:10	0	8:35	0	7:35	0
12	11:20	0					8:20	0		
13					11:25	0			7:25	0
14	10:55	**1**			10:45	0			8:00	0
15	10:40	**1**					9:30	**1**		
16	10:20	**15**	10:30	**70**	10:30	0	9:20	**13**	8:10	**1**
17-1	10:00	**3**	10:45	0	9:25	0	9:30	0	8:20	0
17-2	9:50	0	11:05	0	9:10	0	9:40	0	8:30	0
18	9:40	0	11:15	0	9:00	0	9:55	0	8:45	0
19	11:55	0					8:05	0		
20			11:45	0			9:00	0		
21			9:05	0					7:00	0
22					10:05	0	11:30	**1**		
23					9:55	0	11:45	**1**		
24					9:40	0	11:15	0		
25					9:45	0	11:50	0		
26	11:05	**1**			11:00	**15**	8:45	**2**	7:45	0
27	11:30	0					8:15	0		

* time is an hour earlier due to switch back from daylight savings time on October 29.

Appendix III – Weather conditions and water levels for each spawning survey date.

	Oct. 16	Oct. 20	Oct. 23	Oct. 26	Oct. 31	Source
Water Level (m)	354.85	354.86	354.89	354.87	354.84	MNR Gauge Station
% Cloud Cover	100	100	100-0	0	0-40	Observation
Wind Speed (km/h)	0-5	10-15	10-15	0-5	20-25	The Weather Network
Predominant Wind Direction	SE-SW	NW	NW	E	NW-W	Observation
Rain at Time of Survey	No	No	Yes	No	No	Observation
Daily Precipitation (mm)	0	0	0.7	0.8	0	The Weather Network
Mean Daily Air Temp (ºC)	4.9	2.6	3.3	-1.1	6	The Weather Network
Max Daily Air Temperature (ºC)	14.3	4.7	4.9	4.0	14.2	The Weather Network
Water Temperature (ºC)	10.2	9.5	8.1	7.0	5.2	MNR Gauge Station
Mean Dissolved Oxygen (mg/l)	10.3	10.8	10.7	10.8	10.9	Observation – YSI meter

Appendix IV – GPS locations of the 25 sites where egg collections were made. All points are in Universal Transverse Mercator (UTM) Zone 17, NAD 83. Site code prefixes (E,W) denote the eastern or western portion of the shoal. All co-ordinates obtained using sub-meter accuracy WAAS-Enabled Trimble GPS receiver.

Site	X – Easting	Y- Northing
E1	679772	5020559
E2	679780	5020553
E3	679788	5020557
E4	679799	5020559
E5	679803	5020568
E6	679786	5020565
E7	679779	5020565
E8	679783	5020562
E9	679777	5020549
E10	679773	5020554
E11	679775	5020548
E12	679772	5020555
E13	679791	5020555
W14	679764	5020545
W15	679763	5020540
W16	679765	5020534
W17	679758	5020539
W18	679755	5020552
W19	679745	5020549
W20	679762	5020540
W21	679762	5020535
W22	679765	5020548
W23	679762	5020544
W24	679762	5020537
W25	679762	5020550

Appendix V – Raw data from the egg collection survey. All depths are relative to the fall drawdown depth (354.8m).

Site	Water Depth (m)	Max Depth (m) Eggs Collected	# Eggs Collected	# Eggs Alive	# Eggs Dead	% Eggs Alive
E1	1.0	1.2	0	0	0	---
E2	0.6	0.8	30	27	3	90.0
E3	0.6	0.7	19	8	11	42.1
E4	0.3	0.4	6	6	0	100
E5	1.0	1.1	0	0	0	---
E6	0.9	1.2	7	7	0	100
E7	0.9	1.2	0	0	0	---
E8	0.6	0.8	20	20	0	100
E9	0.3	0.5	22	13	9	59.1
E10	0.3	0.5	23	20	3	87.0
E11	0.3	0.4	6	4	2	66.6
E12	0.5	0.6	16	12	4	75.0
E13	0.5	0.6	47	34	13	72.3
W14	0.2	0.3	28	16	12	57.1
W15	0.3	0.4	17	7	10	41.2
W16	0.2	0.3	60	28	32	46.7
W17	1.3	1.6	11	9	2	81.8
W18	2.1	2.3	4	3	1	75.0
W19	2.3	2.6	15	9	6	60.0
W20	0.5	0.6	22	19	3	86.4
W21	0.9	1.1	0	0	0	---
W22	0.5	0.7	65	46	19	70.7
W23	0.55	0.7	59	44	15	74.6
W24	0.7	0.9	26	20	6	76.9
W25	1.2	1.4	56	49	7	87.5

Appendix VI – Confidence intervals for egg densities and total egg estimates[1].

Zone	Depth	Stations in strata	Mean # eggs/quad	Lower Limit[2]	Upper Limit	Mean eggs/m^2	Lower Limit	Upper Limit	Est. Total eggs	Lower Limit	Upper Limit
East	0.0-0.3	4	14.3	4.9	23.6	228.0	78.5	377.5	8 046	2 770	13 322
East	0.3-0.6	5	26.4	15.3	37.5	422.4	244.8	600.0	58 997	34 197	83 797
East	0.6-1.3	4	1.8	0	5.2	28.0	0	82.9	6 387	0	18 905
East[3]	>1.3	0	*1.8**	---	---	*28.0**	---	---	*1 050*[*]	*0*	*3 108*
West	0.0-0.3	3	35.0	9.7	60.3	560.0	155.6	964.4	17 472	4 853	30 091
West	0.3-0.6	3	48.7	22.3	75.0	778.7	357.0	1 200.3	13 059	5 987	20 129
West	0.6-1.3	4	23.3	0	47.1	372.0	0	752.9	20 702	0	41 901
West	>1.3	2	9.5	0	20.3	152.0	0	324.5	7 782	0	16 613
Totals	**----**	**25**	**----**			**----**			**133 495**	**47 807**	**227 865**

[1] based on 95% confidence
[2] lower limits having a negative value were recorded as zero.
[3] confidence intervals could not be determined as no samples were collected in this stratum.
* based on values from East 0.6-1.3 (to provide estimates of total eggs)

Appendix VII – Re-analysis of the 2003 data using the spatially-stratified approach[1].

Zone	Depth	Area (m^2)	Sites	Total Eggs	Mean # eggs/quadrat	Mean eggs/m^2	Est. Total Eggs*	Proportion of Total
East	0.0-0.3	35.3	4	83	20.75	332	11,716	3.6
East	0.3-0.6	139.7	2	10	5	80	11,174	3.5
East	0.6-1.3	228.1	6	27	4.5	72	16,423	5.1
East	>1.3	37.5	0	0	*4.5*	*72*	*2,700*	*0.8*
West	0.0-0.3	31.2	3	47	15.67	251	7,822	2.4
West	0.3-0.6	16.8	3	478	159.3	2549	42,743	13.3
West	0.6-1.3	55.7	2	491	245.5	3928	218,593	68.0
West	>1.3	51.2	3	38	12.67	203	10,379	3.2
Totals	**----**	**595.4**	**23**	**1174**	**----**	**----**	**321,551**	**100**

*Totals are rounded to the nearest whole number.

[1] Site 'S16-5' was included in the analysis as it was considered on the border of the "most suitable" spawning habitat. Site 'S16-23' was NOT included in the analysis as it was in the "unacceptable" spawning habitat. Site "S16-25' was included in the 'western' zone calculations. No samples were taken in the >1.3m depth stratum in the East and, therefore, estimated eggs were based on densities in the 0.6-1.3m depth strata.

Appendix VIII – Kawagama Lake "Rule Curves"; old rule curve (above) and recently adopted (2006) rule curve (below). Modified from Acres (2006).

