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Kawagama Lake - Lake Trout Spawning Studies

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Acres International
Niagara Falls, Ontario

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1 Introduction

The Planning Team for the Muskoka River Water Management Plan (WMP) identified the need for a study to evaluate the impact of water level management on the spawning success of lake trout (*Salvelinus namaycush*) in Kawagama Lake. Kawagama Lake is located on the South Branch of the Muskoka River (Figure 1.1), and has historically been operated to provide flow for water power generation during the winter months. The winter drawdown also serves to provide storage capacity for the spring freshet, and protect shoreline recreational properties from spring flooding damage. As a result, the lake typically undergoes a water level change (winter drawdown) of 0.62 m between October 15 and March 15. The study was approved by the Muskoka River Water Management Plan Steering Committee to assist with the option development and evaluation process for this lake. Muskoka Heritage Foundation funded the study.

1.1 Background

Lake trout are one of the most sought after game fish species in the Muskoka River system. Healthy lake trout populations represent an important long-term investment for government agencies and area stakeholders, and significantly add to the economic and recreational resources of the area. Water management activities, such as the late fall and winter drawdown undertaken on many of the large Muskoka River system lakes, including Kawagama Lake, have the potential to affect lake trout populations.

Lake Trout Biology

Mature lake trout seek out and congregate near windswept shores and shoals with rock rubble substrates in late September in preparation for spawning. Generally these substrates are 10 to 20 cm in diameter, and free of sediment, attached algae or periphyton. While individual fish may not return to the exact location year after year, there is evidence of homing to the general area. Lake trout will use artificial substrate if natural substrate is not available, or if it is not in the correct size range. In addition, research (McAughey and Gunn, 1995) has shown that lake trout will select and spawn on alternate substrates if their preferred substrate is not available.

In small inland lakes (as opposed to the Great Lakes), spawning sites tend to be located in shallow water, often within water depths of 1 m or less. The timing of

spawning is variable between lakes, and is highly dependant on water temperature and photoperiod, but often begins near mid-October in the Muskoka area. Peak spawning takes place at night over a 2- or 3-day period. Lake trout do not make actual nests, but rather 'sweep' bottom areas clean by swimming activity in preparation for spawning over those sites. Eggs, which are 5 to 6 mm in diameter, are scattered among the rocks and rubble and sink into the intervening spaces between them. No parental care is provided after spawning. The number of eggs produced by an individual female lake trout may vary from 880 to 2640 per kg of body mass (Scott and Crossman, 1973). Embryonic development of the fertilized eggs occurs over winter, and the eggs normally hatch between mid-February and mid-March [15 to 21 weeks in Algonquin Park lakes, depending on water temperature (Scott and Crossman, 1973)]. The developing fry (alevins) are essentially immobile, and stay in the interstices of the rock rubble until the yolk-sac is absorbed – usually until early May. Once the yolk-sac is absorbed, the young fry leave their rock rubble beds and begin actively feeding.

As this entire process takes place in shallow water (often 1 m or less), the developing lake trout eggs and fry are vulnerable to water level manipulation during the incubation, hatching and early fry development periods. Dewatering, freezing or exposure to ice scour would all have adverse impacts on egg/fry survival. This could potentially result in decreased reproductive success and, if recruitment continues to be impaired over an extended period of time, could lead to a decline in lake trout populations.

Potential Drawdown Effects

The Hackner-Holden Agreement (HHA), which governs the manipulation of water levels in the major reservoir lakes in the watershed, including Kawagama Lake, was developed to balance the needs of hydropower production with the needs of other users (initially navigation and 'conservation of water'). One of the specific water management activities undertaken on Kawagama Lake (and many other Muskoka Lakes) as part of the Agreement is the fall drawdown. Prior to the HHA (i.e., pre-1940), Kawagama Lake was utilized as the main storage reservoir on the South Branch, and was drawn down over the fall and winter (at will) to meet the needs of Ontario Hydro's (now OPG) generating stations. With the 1969 Amendment to the Agreement, specific target levels were established for the fall and winter drawdown levels (354.8 m and 354.18 m, respectively) in Kawagama Lake.

The two stage (i.e., fall/winter) drawdown was initiated under the HHA to minimize the impact on lake trout stocks, while maintaining the maximum amount of water available for power generation. It was known at the time that lake trout spawn on shallow shoals/shoreline areas, and that their eggs would be dewatered if the winter drawdown extended past the lowest extent of their spawning areas. The fall drawdown was therefore initiated to force lake trout to spawn deeper, so that more water level change could be achieved. After the fall drawdown was completed, and lake trout had spawned, lakes were allowed to rise to or near their end of summer level in preparation for the upcoming winter drawdown.

While it may have been coincidental during the development of HHA rule curves, the fall drawdown elevation is about the same as the early February drawdown elevation in most lake trout lakes, and corresponds to the time that lake trout eggs hatch. We do not know whether HHA developers were aware of/used this relationship in the development of their curves, but suspect they were, and this correlation between fall and early February water level was done intentionally. Thus, eggs would hatch, larva would disperse, and no additional harm would be incurred by additional drawdown past the fall drawdown elevation. However, what was not known at the time, is that lake trout fry (yolk-sac larva) are essentially immobile after hatching, and remain within the spawning bed gravel for an additional 2 to 3 months after hatching (before swim-up and dispersal to open water). Given this information, the successive winter drawdown (0.6 m below the fall drawdown level for Kawagama Lake) may be significantly, but inadvertently, impacting these larvae.

Kawagama Lake Operating Levels

The operating curve for Kawagama Lake identifies an end of August lake level of 355.40 m. From this point, the lake is lowered to 354.8 m by October 15 prior to the initiation of the lake trout spawning. After spawning is complete, the lake is allowed to rise naturally (due to fall rains), with the rule curve identifying an ideal level of 355.10 m. The winter drawdown is then initiated on January 15, with the lake lowered to 354.18 m by March 15. Thus, any lake trout eggs or larvae that are located between elevation 354.80 and 354.18, corresponding to the 0.62-m winter drawdown, could be negatively impacted by the winter drawdown.

Previous Studies

MNR sponsored several previous lake trout spawning studies on Kawagama Lake (Spray et al., 1999; Gillespie, 1981; Rettie and Ellerington, 1960). The surveys identified a total of 25 potential lake trout spawning areas (Figure 1.2). One or more lake trout was observed on 11 of these 27 shoals during the spawning period. One of the shoals (Shoal 16), which has been identified as the 'primary' shoal, has a portion of the shoal lying in water shallower than 1 m, and is therefore potentially subject to drawdown. Rettie and Ellerington (1960) found that lake trout eggs were generally deposited in Kawagama Lake at depths ranging from 15 cm to nearly 2 m. Spray et al. (1999) concluded that there is an abundance of good potential spawning sites on Kawagama Lake, and that the majority of the shoals are deep enough to minimize the impact of the winter drawdown on lake trout reproductive capability.

However, these previous studies were not definitive in their ability to fully ascertain the impacts of water level management on the reproductive success of lake trout in Kawagama Lake. Specifically, unknown variables include the overall proportion of lake trout eggs deposited within the drawdown zone and the susceptibility of eggs within this zone to desiccation or ice-induced mortality (i.e., do eggs/larvae in the interstitial substrate spaces become dewatered). One of the goals of the Muskoka River water management plan is to improve habitat conditions for lake trout by improving water level conditions. Hence, additional information on the potential impacts of water level management on lake trout spawning and incubation is required as input to the selection of a preferred water management strategy for Kawagama Lake.

1.2 Objectives

The objectives of the study were to

- characterize the physical habitat and shoal depth ranges and establish depth distribution to determine vulnerability of shoals to dewatering
- investigate and document spawning activity, and verify egg deposition locations
- assess the effect of winter drawdown on eggs and/or yolk-sac fry within spawning substrate prior to dispersal.

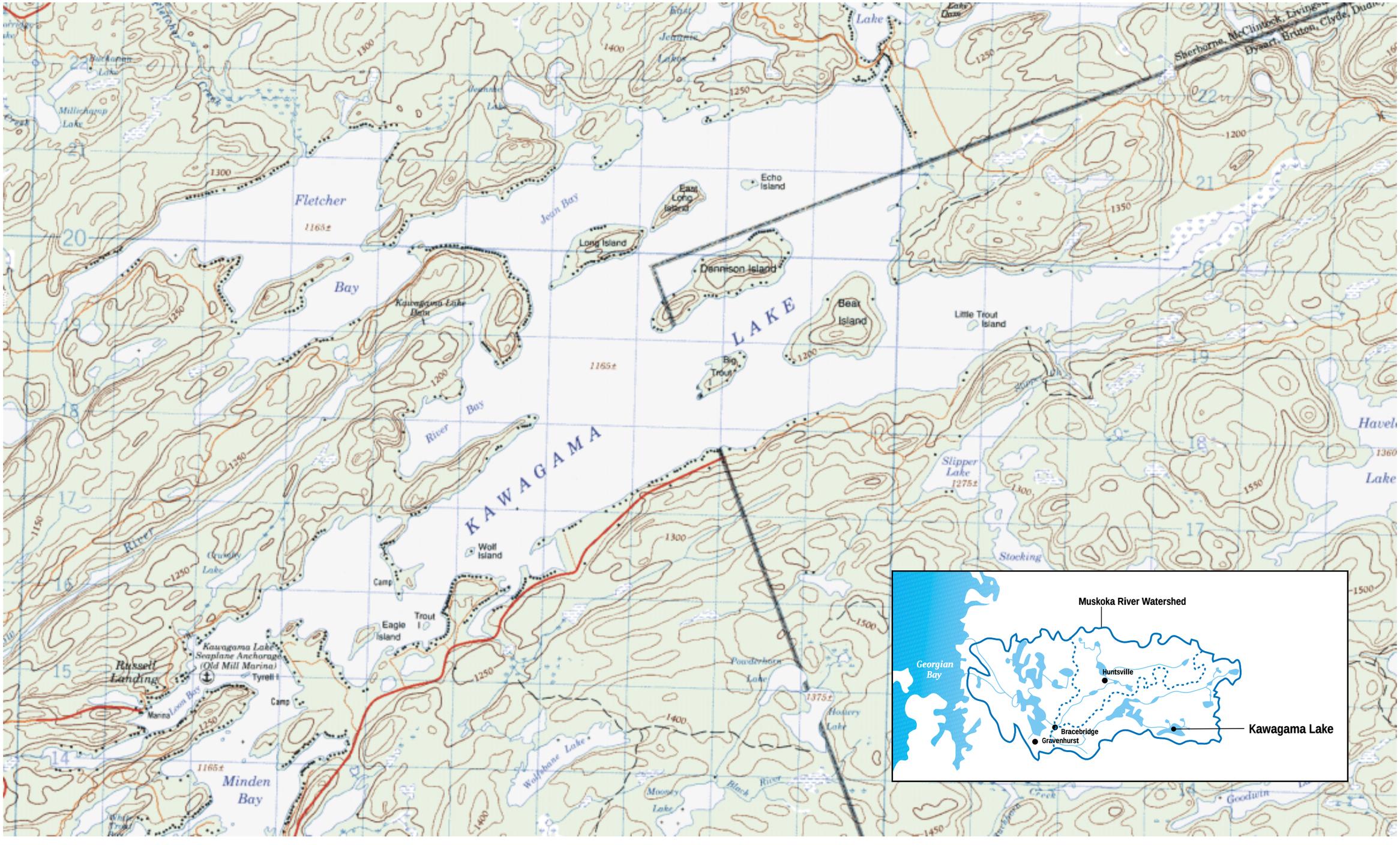
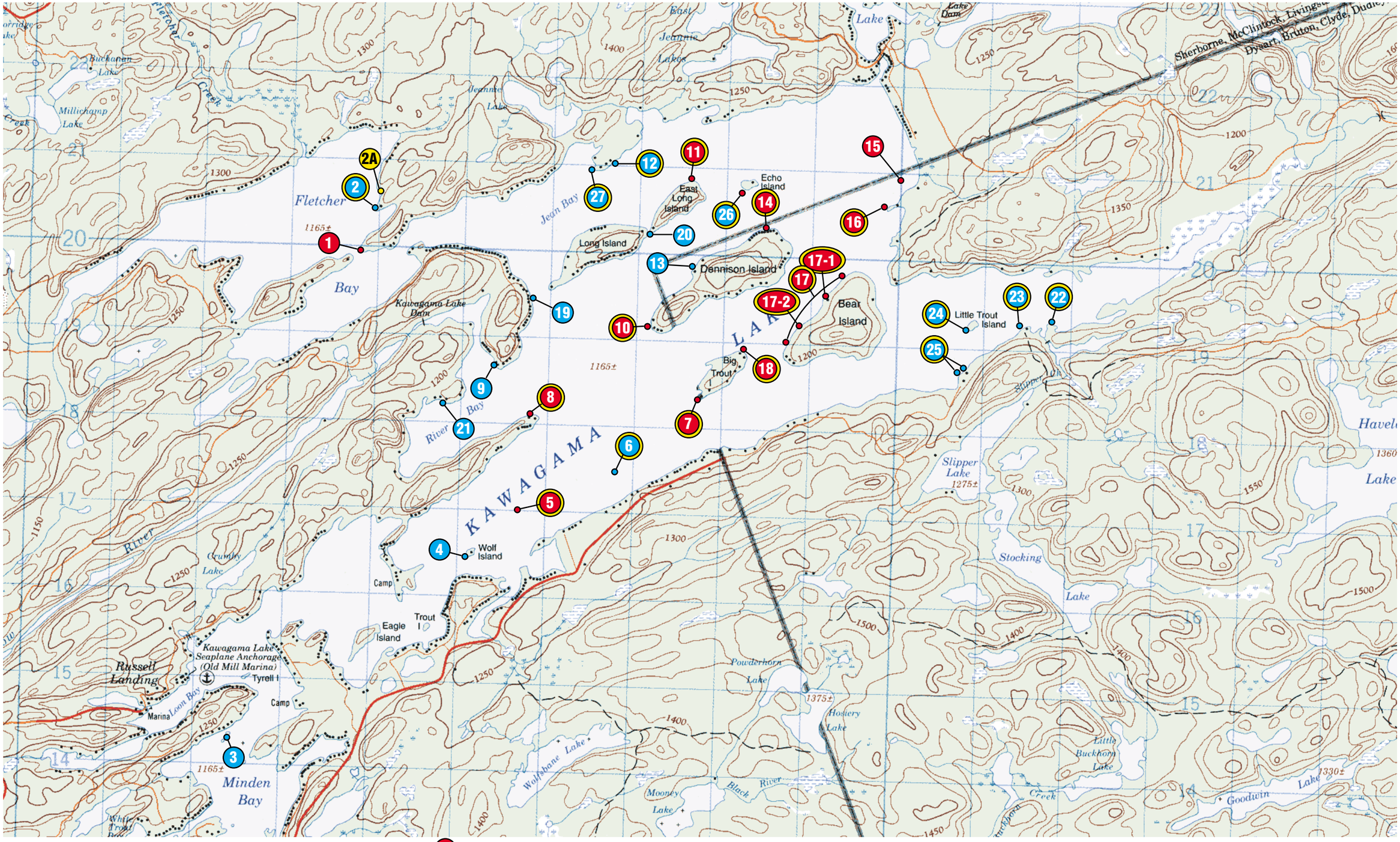


Figure 1.1
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Study Area Location

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Active Lake Trout Spawning Shoals (from previous investigations)

Potential Lake Trout Spawing Shoals (from previous investigations)

Shoals investigated during current study

Figure 1.2
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Spawning Shoal Locations

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2 Methodology

The following documents the methodologies employed during the various phases of the study. Tasks undertaken include habitat mapping, spawning surveys, egg collection, and winter egg/larvae observations.

2.1 Habitat Mapping

Previous spawning studies, including Spray et al. (1999), Gillespie (1981), and Rettie and Ellerington (1960), were consulted to determine the shoals that historically exhibited lake trout presence during the spawning period. Those with the most activity previously were selected as the priority shoals for this study, and included shoal 16 (the primary shoal in the lake), 17, 18, 11 and 7 (Figure 1.2). Shoals 5 and 8 were also mapped due to the presence of lake trout on these shoals during MNR spawning surveys conducted as part of this study.

Mapping of Shoal 16, 17, 18, 11, 7 and 8 was undertaken by visual observation and particle size measurements on October 22 and 23, 2003. Previous mapping (from Spray et al., 1999) was utilized as the starting point and reference for habitat mapping at each shoal. Utilizing these figures, a number of transects were established perpendicular to the shore, with transect spacing dependant on the overall size of the shoal. Along each transect, water depth and substrate composition were recorded at points spaced 2 m apart, or at obvious changes in substrate or depth. Observations were taken by wading in shallow water (less than 1 m), from a boat in deeper areas, and were enhanced with the use of a viewing box. Water depths were recorded using a 4-m long survey rod. A 25-cm x 25-cm square metal quadrat, with graduated markings, was used to assist with the determination of particle size. Substrate cleanliness (i.e., presence of silt, attached algae or periphyton) was also recorded.

The following substrate particle size classification system was used for determining substrate composition:

- Boulder >256 mm
- Cobble 64 to 256 mm
- Gravel 2 to 64 mm
- Sand 0.062 to 2 mm.

In addition, detailed mapping of Shoal 16 was undertaken on November 4, 2003, using a Trimble GeoXT, sub-meter accuracy, Wide Area Augmentation System (WAAS) differential Global Positioning System (GPS) receiver in preparation for the egg sampling task. Shoal characteristics included the water's edge, location of exposed rocks or stumps and the 0.30, 0.60 and 0.90 m depth contours. Additional substrate and water depth observations were also recorded at Shoal 16 during the egg collection activities on November 6, 2003, including detailed substrate characteristics at each of the 25 egg-sampling sites.

Shoal 5 was mapped during the egg collection activities on November 7, 2003. Detailed substrate particle size compositions and water depth were recorded at four egg-sampling sites on the shoal, and additional mapping was undertaken using the GPS and visual recording techniques (viewing box and 0.25 x 0.25-m graduated grid).

All water depths recorded during the various survey periods were corrected to actual Kawagama Lake water levels as determined by the MNR operated gauging station at Russell Landing.

2.2 Spawning Surveys

Observations of lake trout spawning activity on Kawagama Lake were undertaken by MNR biologists/staff on the evenings of October 16, 20, 22, 26, and November 3, 2003. Surveys were generally conducted between 8:00 and 12:00 p.m. when spawning lake trout are active. Shoals were slowly cruised by boat with a high intensity underwater spotlight to illuminate shoal areas and observe fish. The number of fish at each shoal, and all observations of courtship behavior and/or spawning activity (e.g., location, depth, substrate characteristics, intensity of use, etc) were recorded. Brightly colored rocks (yellow) were placed on shoal areas where spawning activity and/or large congregations of lake trout were observed in order to facilitate relocation of high potential spawning sites during habitat surveys or egg collection activities. Water temperatures on each evening of the survey and Kawagama Lake water levels throughout the month of October and early November were also recorded.

2.3 Egg Collection Surveys

Divers were utilized to undertake a survey for lake trout eggs at select shoals on November 6 and 7, 2003. Egg collection surveys were undertaken to

- determine the spatial extent of egg deposition
- verify that egg deposition had occurred in areas where lake trout were observed during the spawning survey
- provide an estimate of the density of deposited eggs throughout the shoal area, with particular emphasis on the depth strata that would be susceptible to the winter drawdown.

Egg collections were conducted on Shoals 16 and 5 only. Collections on other shoal areas were not undertaken due to adverse weather conditions, equipment malfunctions and other considerations.

Galcon Marine Ltd. was retained to conduct the underwater portion of the egg collection activities. The diver was equipped with a 25-cm x 25-cm (0.0625-m^2) sampling quadrat, constructed of approximately 1-cm diameter steel bar. Sampling locations at each of the shoals were selected by MNR/Acres biologists based on visual observations of suitable spawning substrates (i.e., well-washed cobble/rubble), and previous records of lake trout congregation or spawning activity (as observed during the aforementioned spawning surveys). Sampling was undertaken at a variety of depth strata, with particular emphasis on the 0.0 to 0.30 m, 0.30 to 0.60 m and >0.60 m depths, relative to the fall drawdown level (354.80 m).

At each sampling site, the 0.25-m x 0.25-m metal quadrat was used to delineate the sampling area. Substrate composition and the number of eggs on the surface of the substrate were determined and recorded. Water depth to the top of the substrate was also recorded. The location of each sampling site was determined using a Trimble GeoXT, sub-metre accuracy, WAAS differential GPS receiver. Individual rocks were then slowly removed by the diver until he could proceed no further into the underlying substrate (i.e., bedrock, sand/silt, or large rocks). Eggs within the sampling grid area were collected (with a manually operated suction device - i.e. a turkey baster) and placed in a sampling jar by the diver. The depth of excavated substrate (i.e., maximum depth at which eggs were found) by the

diver was recorded. Photographs of substrate conditions (as possible) were taken at several of the sampling sites.

Eggs from each sampling location were then transferred to the surface for processing. Eggs were emptied into a black enamel sorting pan and separated from foreign material (i.e., organic matter, sediment). The total number of eggs, as well as the number of live and dead eggs (as evidenced by opaque to white egg interiors or the presence of an outer covering of algae or fungus) was recorded. Several of the egg samples were photographed. All eggs were then released back to the approximate sampling location.

2.4 Winter Egg Observation

Shoal 16 was visited by MNR and Acres biologists on March 22, 2004 to determine the impact of the winter draw down on eggs and/or newly hatched fry within the draw down zone. Water level at the time of the survey was 354.25 m, which is 7 cm above the rule curve draw down target.

Ice thickness in the area was established by augering a hole in the vicinity of sampling location S16-17. Subsequently, an ice auger and chain saw were used to section and remove a slab of ice approximately 1.75 m in length by 0.75 m in width from the west side of Shoal 16 to expose the underlying spawning shoal substrate. The ice slab removed extended up-slope from the water level on the day of the survey (354.25 m) to approximately 354.6 m, which is near the upper limit of spawning activity (as determined during the November 6 and 7, 2003 sampling). Ice and snow that had fallen into the opening was carefully removed to expose the underlying substrate. A 500,000-candle power spotlight was used to illuminate the study area.

The substrate surface was then visually checked for the presence of eggs or larvae. Surficial substrates, primarily cobble slabs and gravels were then slowly removed by hand. Any eggs and larvae observed were recorded, along with their condition (e.g., alive/dead, frozen/moist) and position in the substrate in relation to water level (i.e., submerged within the gravel or above the water level). Several live and dead yolk-sac larvae were retained for further analysis (e.g., length measurement, age determination).

2.5 Data Analysis and Reporting

An AutoCAD map of each shoal was prepared, and all habitat information collected during the field activities (e.g., substrate composition, topography, suitability for spawning) was transferred to this map. GPS coordinates and other information collected at Shoals 16 and 5 was utilized to produce a more accurate map for those sites. Overall shoal area, total suitable spawning area and the proportion of most suitable spawning areas located within the potential drawdown zone were calculated for these shoals.

All egg-sampling locations on Shoals 16 and 5, as recorded with the GPS, were then transcribed onto the habitat map for each shoal. The egg density (i.e., number of eggs per m^2) for each sampling quadrat was then calculated. The overall area of suitable spawning substrates was then divided into distinct sections, based on the location of egg sampling sites and depth strata, in order to estimate the number of eggs deposited on the shoal. Each of the separated areas contained one or two egg sampling locations. If one egg sampling location was conducted within the blocked area, the entire area was assumed to have the egg density of the single sampling location. If several sampling locations were located within a blocked area, the average number of eggs from each of the sampling locations was taken as representative of egg density for the overall area. The total area for each block was then calculated using AutoCAD, and the total number of eggs was estimated [egg density (eggs/m^2) x area (m^2)]. The estimated number of eggs within the 0 to 0.30 m, 0.30 to 0.60 m and >0.60 m depth strata was then determined.

The winter egg collection site was also prepared in figure format, illustrating the location that eggs and larva were noted during the survey.

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3 Results

The following section documents the results of habitat mapping, spawning surveys, and egg collections undertaken during the fall of 2003, and egg observations undertaken during the late winter/early spring of 2004.

Kawagama Lake water levels throughout the month of October as well as during field activities in early November were provided by MNR water control staff. A tabular depiction of water levels is provided in Table 3.1, while Figure 3.1 graphically depicts actual water levels plotted against the Kawagama Lake rule curve.

3.1 Habitat Mapping

Detailed habitat maps were produced for Shoals 16, 5, 18, 17, 11, 7 and 8. Shoal maps are provided in Appendix A. Descriptions of each of the mapped shoals are provided in the following text.

Shoal 16

Shoal 16, located at Barnum's Point, is on the eastern shoreline of Kawagama Lake (see Figure 1.2). The shoreline in this area extends to a point which projects into the lake over a distance of approximately 50 m. An exposed bedrock island (approximately 7 m x 12 m) is located near the eastern tip of the shoal. The western and southwestern portions of the shoal appear to be well cleansed by wave and current action, as they exhibit few signs of siltation or biofouling (i.e., algae or periphyton growth). This is likely due to the long fetch for incoming winds from the west/southwest.

The habitat map and several photographs of Shoal 16 are presented in Appendix A, Figure A1. The map depicts substrate composition and topographic conditions over the entire shoal. An assessment of spawning suitability for the shoal areas is also provided based on substrate size, water depth, and cleanliness (i.e., degree of biofouling or sedimentation).

The entire shoal occupies an area of approximately 1800 m^2, while the areas "most suitable for spawning" on the shoal total approximately 578 m^2, or 32% of the entire shoal. These areas consist of predominantly 10 to 15 cm diameter cobble, mixed with scattered larger boulders, ranging in size from

Table 3.1 Kawagama Lake Water Levels – October/November 2003		
Date	**Actual Water Level (m)**	**Rule Curve Water Level (m)**
Oct. 1	355.16	355.00
Oct. 2	355.14	354.99
Oct. 3	355.10	354.97
Oct. 4	355.09	354.96
Oct. 5	355.08	354.94
Oct. 6	355.05	354.93
Oct. 7	355.03	354.91
Oct. 8	355.01	354.90
Oct. 9	354.99	354.89
Oct. 10	354.97	354.87
Oct. 11	354.95	354.86
Oct. 12	354.92	354.84
Oct. 13	354.91	354.83
Oct. 14	354.90	354.81
Oct. 15	354.91	354.80
Oct. 16	354.92	354.81
Oct. 17	354.92	354.81
Oct. 18	354.91	354.82
Oct. 19	354.90	354.82
Oct. 20	354.88	354.83
Oct. 21	354.87	354.84
Oct. 22	354.85	354.84
Oct. 23	354.82	354.85
Oct. 24	354.81	354.85
Oct. 25	354.81	354.86
Oct. 26	354.82	354.86
Oct. 27	354.82	354.87
Oct. 28	354.83	354.88
Oct. 29	354.84	354.88
Oct. 30	354.85	354.89
Oct. 31	354.85	354.89
Nov. 1	354.86	354.90
Nov. 2	354.87	354.91
Nov. 3	354.87	354.91
Nov. 4	354.89	354.92
Nov. 5		354.92
Nov. 6	354.94	354.93
Nov. 7	354.97	354.94

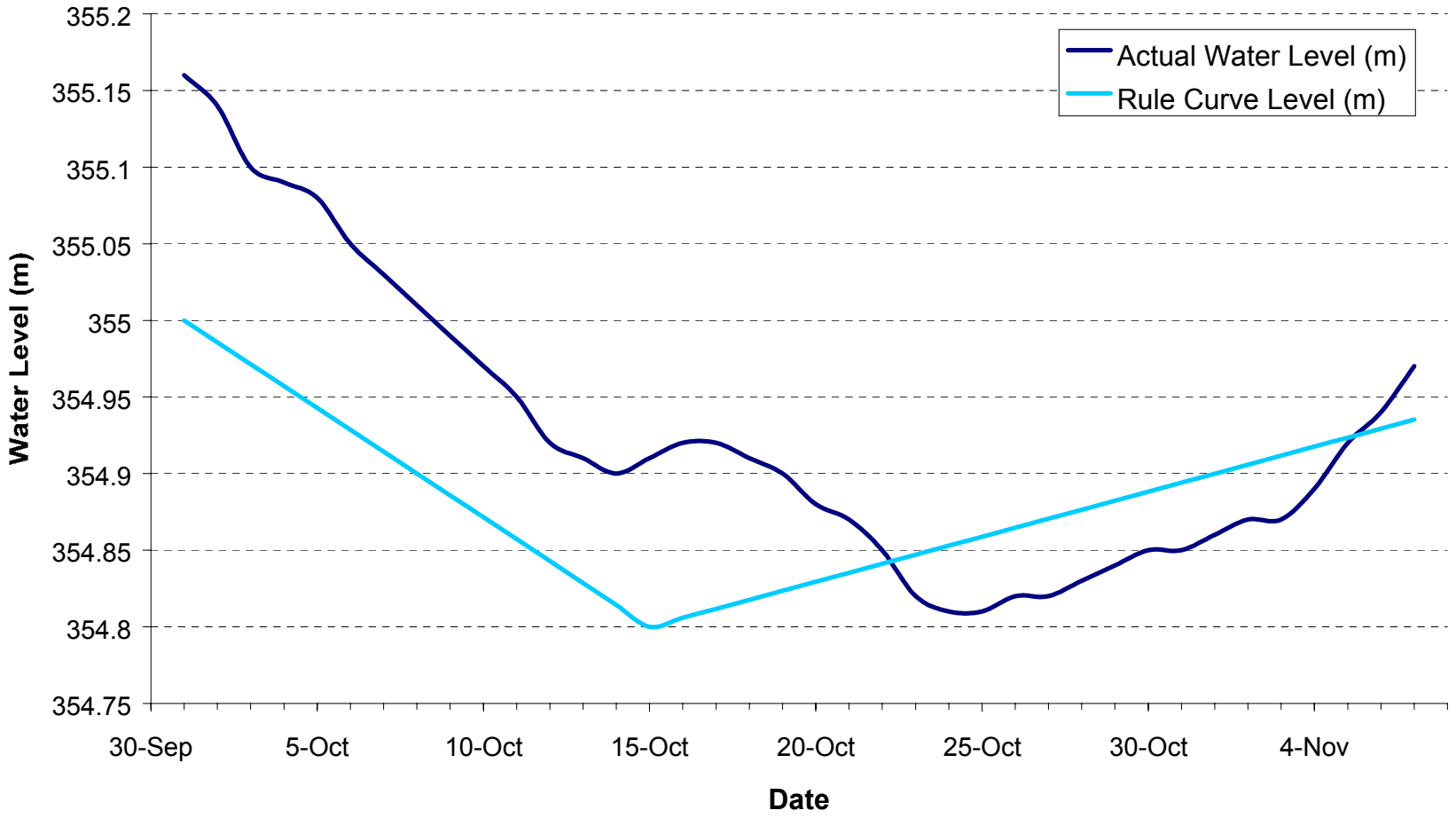


Figure 3.1
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Kawagama Lake Water Levels

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25 cm to >1 m in diameter. The majority of most suitable spawning habitat ranges in depth (relative to the fall drawdown level of 354.80 m) from 0.0 m to approximately 1.5 m, although a maximum depth of approximately 2.3 m is found off the western point of the shoal.

An additional 990 m^2 of the shoal (55%) is identified as "acceptable but less suitable" spawning habitat, based on the fact that substrate size appears to be appropriate (i.e., 10 to 15 cm diameter cobble mixed with scattered boulders, similar to other areas of the shoal) but biofouling (i.e., presence of attached algae, periphyton) and siltation is broadly evident. No lake trout eggs were observed in these less suitable areas. The other areas of the shoal, identified as unacceptable spawning habitat, are dominated by either very large boulders (~60+ cm diameter) or exposed bedrock, substrates not utilized by spawning lake trout. Boulders occupy a 2- to 4-m wide row around the periphery of the shoal, before dropping off to the lakebed, which consists of sand, silt and organic substrates with scattered single layers of boulder and cobble.

Shoal 5

Shoal 5 is a mid-water shoal located in the southern section of Kawagama Lake, northeast of Wolfe Island (see Figure 1.2). The shoal consists of the sloping shoreline around an approximately 30-m x 10-m exposed bedrock island, and a second elevated area extending northward from the island. The habitat map of the shoal is provided in Figure A3.

The northward extension falls to approximately 2 m off the shoreline of the island, and then progressively rises to a depth of approximately 0.60 m on top of a ridge located approximately 40 m from the island. This ridge is dominated by exposed bedrock and scattered larger boulders. Thirty square meters of this area would be dewatered at the maximum winter drawdown limit, although it does not represent suitable spawning habitat. The ridge is surrounded by a relatively narrow band of predominantly large boulders with scattered patches of cobble ("acceptable but less suitable" habitat). A larger (27 m^2) 'patch' of fractured cobble ("most suitable"), with particles ranging in size from 10 to 15 cm diameter is found at the western edge of this part of the shoal. During egg collection activities in this area, it was found that the 'patch' consists of a surface layer of the aforementioned cobble, underlain by smaller cobble and gravel. This area, which has an average depth of approximately 1.5 m, is identified as the "most suitable" spawning habitat in

this portion of Shoal 5. None of this area would be dewatered at the maximum winter draw down level. The 'patch' is surrounded by larger boulders and scattered cobble, approximately 530 m^2 in area, which may offer "acceptable but less suitable" spawning habitat. No eggs were found in this habitat type during egg collection activities.

The area surrounding the exposed island at the southern end of the shoal is dominated by a steep bedrock slope to the north and a shallower bedrock slope to the south and southwest. The southwest projection of the slope extends into the lake approximately 20 m and is dominated by boulders with scattered accumulations of smaller cobble. The boulders also extend in a narrow band around the exposed bedrock island. These boulder-dominated areas may represent some "acceptable but less suitable" spawning habitat, although no eggs were found among the boulders during egg collection activities. One small patch of relatively clean 10 to 13 cm diameter, fractured cobble was found in deeper water (1.3 m) on the western end of the island, and represents the "most suitable" spawning habitat in this portion of the shoal.

At the winter drawdown limit, only a small portion of exposed bedrock around the island and at the northern crest would be dewatered. It is not anticipated that any suitable spawning substrate would be affected by the winter drawdown.

Shoal 18

This shoal is located along the northeast corner of Big Trout Island (see Figure 1.2). Spray et al. (1999) indicated that the shoal has a total length of approximately 225 m, with a maximum extension into the lake of over 45 m, wrapping around the northeast corner of the island. Our reconnaissance survey of the shoal found that the majority of the substrate, including nearly all of the area to the east of the island, consisted of one or two layers of suitably sized material, heavily impacted by sediment accumulation or algae/periphyton growth. Two areas (Area 1 and Area 2 below), one shallower (approximately 1 m deep) and one deeper (approximately 1.8 to 2.5 m deep), were deemed to be more suitable for spawning. Substrates in these areas were dominated by cobble, with scattered boulders and were relatively free of debris (i.e., silt, organic debris, algae or periphyton). These areas and their immediate surroundings were mapped during the current study.

The habitat map and several photographs are provided in Appendix A, Figure A4. The shoal is fairly low gradient, with immediate shoreline areas consisting of fairly extensive shallows. The total area of "most suitable" spawning substrate is approximately 165 m^2, being comprised of two separate areas (see Figure A4) that are outside the potential drawdown zone.

Area 1 is approximately 25 m^2 in size and consists of approximately 70% cobble and 30% larger boulders and exhibits a relatively clean surface, free of sediment and biofouling. The area is located approximately 22 m offshore and is surrounded by large boulders to the north (deeper water) and boulders and scattered cobble over sand to the south (shallow water). All substrates along the shoreline generally exhibit a high degree of impact due to siltation, and represent marginal or unsuitable spawning areas.

Area 2 is located at the northwest corner of the shoal and occupies a total area of approximately 140 m^2. The area consists of approximately 80% cobble (10 to 15 cm diameter) and 20% boulders. It is surrounded by a row of large boulders to the north before grading into the mucky lake bottom. The southern edge of this area is bordered by a mixture of cobble and boulder exhibiting a moderate to high degree of siltation/biofouling. Thirty lake trout were observed circling each other in this area during the spawning surveys, but no spawning activity was noted.

Shoal 17

Spray et al. (1999) identified Shoal 17 as encompassing almost the entire north shore of Bear Island (see Figure 1.2). They indicated that the shoal generally followed the shoreline and was relatively narrow (3 to 4 m wide). However, the one area of this shoal in which they observed lake trout during spawning surveys was located in the vicinity of a dock (25 m long) near the mid-point of the shoreline. For the current study, the entire shoreline was surveyed at a reconnaissance level to identify the areas with the highest potential as spawning sites. A total of four areas were identified, two of which were deemed to have moderate to high potential. One of the areas was in the vicinity of the dock (Shoal 17-1) (shown in Figure 1.2), while the other was further west (Shoal 17-2).

Shoal area 17-1 (see Figure 1.2) is found on the western side of a long pole dock, which extends approximately 25 m into the lake. The habitat map and

photographs of this shoal are presented in Appendix A, Figure A5-1. The shoreline appears as a small bay extending southwest from the dock area. The bay is very shallow (i.e., generally <30 cm), and dominated by gravel, sand and scattered large emergent boulders. Rocky substrates (cobble and boulders) are found in deeper areas. Suitable spawning sites exist in an irregularly shaped area centered approximately 40 m west of the dock before the shoal grades into a sand and boulder dominated flat. Boulders dominate the substrate to the east of the dock. Boulders also dominate the majority of the mapped shoal area, although a band of more suitable spawning substrate (approximately 6 m wide and 20 m long) is found in the center of the area. One small area, approximately 56 m^2, was dominated by approximately 70% cobble and was fairly clean (i.e., relatively free of sediment and algal growth). This area was assessed as being the "most suitable" spawning habitat on the shoal. Water depth over this area (relative to the fall drawdown water level of 354.80 m) ranged from approximately 0.65 m to 1.05 m. An additional area of approximately 375 m^2 was comprised of approximately 50 to 60% boulder and 40 to 50% cobble. This area was deemed to have "acceptable but less suitable" spawning potential due to the predominance of larger boulders and a greater degree of biofouling. At the theoretical winter drawdown limit, approximately 700 m^2 of the mapped area would be dewatered, although this area is dominated by the shallow gravel and sand inshore flats, and does not comprise any suitable spawning habitat.

Shoal 17-2 (Figure 1.2) is located approximately 200 m east of the northeast corner of Bear Island. This area comprises more of a rocky shoreline than a typical shoal, with the source of the abundance of rock appearing to be a steep bedrock cliff located adjacent to the shoreline. The rocky section runs approximately 57 m along the shoreline, and occupies a total area of approximately 850 m^2. The habitat map and several photographs of this shoal are presented in Appendix A, Figure A5-2. The shoreline is relatively steep, with a narrow band approximately 4 m wide representing the "most suitable" spawning substrate (approximately 225 m^2). Water depth at 4 m offshore is approximately 1.2 m. Substrates in this band are dominated by angular cobble (50%), boulder (45%) and smaller gravel sized material (5%). The substrate in this area appears to be very well washed. Approximately 47% of this area (106 m^2) would be dewatered at the maximum winter drawdown limit.

From 4 to 10 m offshore, substrates are dominated by large boulders (90%) with smaller patches of rubble scattered throughout. Some degree of biofouling is evident in this area, although some "acceptable but less suitable" rubble patches are present. Water depths range from 1.2 to 2.8 m. Further offshore, substrate are finer (50% rubble), and more of biofouling is evident. This fine material extends out to approximately 15 m offshore at a depth of nearly 5 m. Large boulders (0.60 to 1.5 m diameter) were observed farther out from this area. Given the fine sediments and large boulders, it is unlikely that spawning occurs in these deeper areas.

Shoal 11

Shoal 11 is located on the northeast side of East Long Island (see Figure 1.2). Spray et al. (1999) noted that the shoal area, which is essentially a shallow rocky shoreline projecting into the lake, occupies a total area of approximately 1500 m^2 (125 m long with an average width of 12 m). The western side of the shoal is bordered by a steep shoreline, while the eastern side is shallow. The east side exhibits more sand accumulation due to its protected nature and poor exposure to prevailing winds (Spray et al., 1999).

The habitat map and several photographs of Shoal 11 are presented in Appendix A, Figure A6. Spray et al. (1999) noted that the most suitable spawning habitat on the shoal appeared to be the westernmost 30 m. Reconnaissance surveys over the entire shoal area conducted during the current mapping activities confirmed this conclusion. Based on these observations, a total area of 460 m^2 on this portion of the shoal was mapped in detail. Parts of the western half of the shoal are comprised of suitable lake trout spawning substrates (i.e., approximately 50% dominated by 10 to 25 cm diameter cobble, and 50% dominated by boulders). However, only the first 12 m of the cobble area is relatively clean, whereas the remaining portion exhibits siltation and biofouling. The total amount of "most suitable" spawning habitat was estimated to be approximately 48 m^2, with approximately 25 m^2 (52%) of this area dewatered at the winter drawdown level. The total area of "acceptable but less suitable" spawning habitat is estimated at 310 m^2, and exhibits some degree of biofouling.

The remaining shoal areas are dominated by large boulders (i.e., >60 cm diameter), mixed with smaller boulders and patches of cobble. Much of the shoreline and deeper portions of the shoal consist of a single layer of boulders

over the underlying sand substrate. Shoreline areas (at the observed water level of 354.82 m) are dominated by sand, with scattered boulders, cobble and gravel, as well as woody debris. Substrates exposed along the shoreline at the fall drawdown level are dominated by a mix of boulders, cobble and gravel (see photos in Figure A6).

Overall, the total amount of "most suitable" spawning area is 48 m^2, with less suitable areas totaling 310 m^2. The rest of the shoal appears to represent "unacceptable" spawning habitat based on the large substrate particle sizes and presence of sediment and biofouling.

Shoal 7

This shoal is located at the southwestern tip of Big Trout Island (see Figure 1.2). The habitat map and photographs of Shoal 7 are presented in Appendix A, Figure A7. The shoal consists of bedrock and a large boulder field projecting southwest from the point, with boulder and cobble substrates running east along the shoreline. Exposed bedrock (72 m^2) dominates the shallow inshore areas at the western end of the shoal. Boulders, ranging in size from 0.60 m to >1 m, are present along the sides of the point. Several small patches (i.e., approximately 1 m^2 each) of gravel and small cobble are found interspersed among the large boulders on the eastern side of the point. The boulder areas generally consist of a single layer of rock, with the underlying sand substrate visible in many areas. However, the smaller gravel patches appear relatively clean, and may be composed of several layers of particles. These small areas provide the "most suitable" spawning habitat for lake trout in this area. Several small fish were observed on this shoal by Spray et al. (1999) although no spawning activity was evident.

A small amount of additional "most suitable" spawning substrate is present along the shoreline immediately east of the point. This small area (approximately 12.5 m^2) is dominated by cobble (60%) interspersed with small boulders (40%) and is relatively clean. Depth over this area ranges from 0.30 to 1.0 m. A small portion of this area would be dewatered at the maximum winter drawdown limit. This cobble area grades abruptly into a row of large boulders, before dropping to the sandy lakebed. Substrates on the eastern half of the shoal are dominated by boulder (80%) with interspersed cobble, although siltation and biofouling is broadly evident. A total of 75 m^2 of the mapped shoal area would be exposed at the winter drawdown limit,

including the small inshore cobble area. The deeper patches of gravel and cobble, identified as the "most suitable" habitat on the shoal, would remain under water.

Shoal 8

Shoal 8 is located along the southern shore of River Bay, on the west end of Kawagama Lake (see Figure 1.2). The habitat map and several photographs of Shoal 8 are presented in Appendix A, Figure A8. The shoal material is located on a small bedrock shelf, running parallel with the shoreline (25 m long, extending 10 to 12 m into the lake). The entire area was estimated to be approximately 400 m^2. The shoreline at the mid-point of the shoal consists of wave-washed, broken rubble substrate, interspersed with boulders. This substrate, which is relatively clean and suitable for lake trout spawning, generally extends out from the shoreline approximately 5 m, to a maximum water depth of approximately 0.80 m (relative to the fall drawdown level of 354.80 m). The total area of this "most suitable" spawning habitat was approximately 83 m^2. Approximately 80% of this area would be dewatered at the winter drawdown limit. The remainder of the shoal area is dominated by large boulders (in the offshore areas), exposed bedrock (at both the eastern and western edges of the shoal) and sand impacted gravel/cobble in the more protected areas at the southwest corner of the shoal. The remaining areas may provide some "acceptable but less suitable" spawning habitat, with suitability limited by large substrate sizes and a relative lack of interstitial space between rocks.

Summary

Table 3.2 identifies the total area of "most suitable" spawning habitat by shoal, and indicates what proportion of this habitat on each shoal is located within the draw down zone.

Table 3.2
Area of Most Suitable Spawning Habitat and Amount Within the Draw Down Zone

Shoal	Total Area of Most Suitable Spawning Habitat (m^2)	Area of Most Suitable Spawning Habitat by Depth Stratum		Percentage of Most Suitable Spawning Habitat within Draw Down Zone (%)
		0.0 to 0.6 m	>0.6 m	
16	578	206	372	35.6
5	36	0	36	0
18	165	0	165	0
17-1	56	0	56	0
17-2	225	106	119	47
11	48	25	23	52
7	16	6	10	37.5
8	83	66	17	80
Total	**1207**	**409**	**798**	**33.9**

Shoal 16 has the highest amount of "most suitable" spawning habitat (578 m^2) and the highest amount of most suitable habitat within the drawdown zone (206 m^2). Shoal 8 has the highest proportion of "most suitable" spawning habitat within the draw down zone, while all of the "most suitable" spawning habitat on Shoals 5, 18 and 17-1 is located deeper than the draw down elevation. Overall, 1207 m^2 of the "most suitable" spawning habitat was identified on the seven mapped shoals, with 33.9% (409 m^2) being located within the draw down zone.

In addition to the most suitable spawning habitat, approximately 4200 m^2 of "acceptable but less suitable" spawning habitat was identified on the seven mapped shoals. Characteristics resulting in this less suitable designation included biofouling/sedimentation of suitable spawning substrate or substrate areas dominated by large boulders with little preferred spawning material (i.e., cobble).

Generally, the best habitat was within the area that had the most exposure to wave action, with its associated sorting of particle sizes and cleansing action (minimal fine sediments). Due to the long history of similar patterns of seasonal water level management in Kawagama Lake, shorelines contained either large particles (i.e., boulders), bedrock, or fine sediments. Elevated

lake levels during the fall spawning period would not submerge additional substrates that could be considered high quality spawning sites.

3.2 Spawning Surveys

A summary of the lake trout spawning surveys conducted by MNR is presented in Table 3.3 while the complete results are provided in Appendix A (Table A1). This table includes only those shoals where fish were observed.

Table 3.3
Spawning Survey Results

Date	Shoal							Water Temp. (˚C)
	16	18	17	5	8	7	11	
Oct 16	6	0	0	-	1	0	-	11.1 to11.3
Oct 20	54	3	0	-	1	0	-	10.4 to 10.6
Oct 22	20 to 34	-	0	0	0	0	0	9.0 to 9.5
Oct 24	100+	30	10	8	3	1	2	9.1 to 9.3
Oct 27	115	0	0	-	-	0	0	8.9 to 9.1
Oct 29	100+	0	0	30	0	0	0	8.2 to 8.8
Nov 3	3	0	0	2	-	-	-	8.3 to 8.5

No lake trout were observed at Shoals 2, 2A (new), 6, 10, 12, 14, 23, 24, 25, 26, and 27.

Based on the results of the spawning surveys, Shoal 16 is the primary spawning site for Kawagama Lake's lake trout population, which concurs with the results of previous spawning surveys. Shoals 18 and 5 may also support smaller populations of spawning fish, while a few fish ($\leq$ 10) were present at Shoals 17, 8, 7 and 11 during the spawning period.

The peak spawning period occurred over a 5-day period from October 24 to October 29 at water temperatures ranging from 8.2 to 9.3˚C. Fish were observed congregating/staging at shoals on the first night of observation (October 16) at water temperatures of 11.1 to 11.3˚C (no spawning activity was evident). A few fish were present at Shoals 16 and 5 after the spawning peak.

3.3 Egg Collection

3.3.1 Shoal 16

A summary of the egg collection results from Shoal 16 is presented in Table 3.4 and depicted graphically in Figure 3.2, while raw data is provided in Appendix A, Table A2.

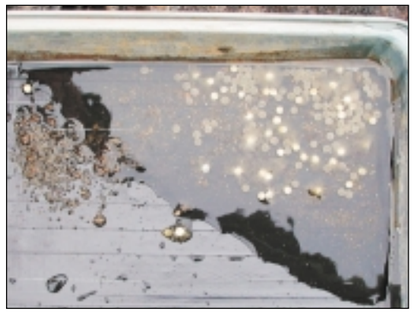
Table 3.4
Shoal 16 Egg Collection Data Summary

Depth Strata (m)	No. Samples	Total No. Eggs	No. Eggs Alive	No. Eggs Dead	Percent Alive
0.0 to 0.30	8	277	192	85	69
0.31 to 0.60	6	454	323	131	71
>0.60	11	573	481	92	84
Total	**25**	**1304**	**996**	**308**	**76**

Egg density at individual sampling sites ranged from 0 to 5472 eggs/m^2, with an overall mean of 849 (±SE 277) eggs/m^2 and a median value of 168 eggs/m^2 (based on an extrapolation of the number of eggs observed within the 0.0625 m^2 sampling grid). Eggs were found in depths ranging from approximately 5 cm to over 2.2 m, although the single largest number of eggs at any one sampling site was found at a water depth of 1.02 m (S16-17). No eggs were observed in six of the samples, the majority of which were located on the eastern side of the exposed island, in very shallow water around the periphery of the island or in deep water sites. Variance in densities among the sampling sites was high.

The percent of live eggs at the time of the survey was approximately 76%, with values ranging from 30% to 100% survival. Highest mortality was generally observed at sites with low numbers of eggs (i.e., <10). At site S16-17, the site with the highest egg density, approximately 84% of the eggs were viable.

The estimated total number of eggs deposited on Shoal 16 is presented in Table 3.5.



P1



P2



P3

Legend

- Most Suitable for Spawning - Clean Cobble with Interstitial Space
- Acceptable but Less Suitable - Some Biofouling and/or Sediment Accumulation, and/or predominantly boulders
- Unacceptable - Heavy Siltation and/or Shallow Substrate (i.e. no interstitial space) and/or Unsuitable Substrate (i.e. bedrock)
- Lake Bottom Elevation Contour
- Water's Edge
- Substrate Delineation Boundary
- S-1 Egg Sampling Location and Number of Eggs Alive/Dead
  - 20 — Total No. Eggs
  - 3 — No. Eggs Dead
  - 17 — No. Eggs Alive
- P1 Photograph and Direction Taken

Note: Water level at the time of the survey - 354.82m

el. 352.5m
el. 353.0m
el. 353.5m
el. 354.0m
el. 354.2m
el. 354.5m
el. 354.8m

S16-5: 0 / 0
S16-6: 2 / 2
S16-4: 20 / 3 / 17
S16-7: 3 / 3
S16-8: 0 / 0
S16-2: 10 / 3 / 7
S16-1: 11 / 2 / 9
S16-9: 61 / 13 / 48
S16-10: 2 / 1 / 1
S16-12: 45 / 21 / 24
S16-13: 147 / 42 / 105
S16-14: 2 / 1 / 1
S16-18: 0 / 0
S16-19: 7 / 1 / 6
S16-24: 0 / 0
S16-3: 11 / 1 / 10
S16-11: 0 / 0
S16-23: 100 / 18 / 82
S16-25: 31 / 3 / 28
S16-17: 342 / 54 / 288
S16-15: 0 / 0
S16-20: 178 / 50 / 128
S16-21: 149 / 29 / 120
S16-22: 153 / 55 / 98

P1
P2
P3

N

0 5 10
meters

Figure 3.2
Kawagama Lake - Lake Trout Reproductive Studies
Ministry of Natural Resources
Shoal 16 - Egg Sampling Locations/Results

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Table 3.5 Estimated Total No. of Eggs – Shoal 16				
Depth Strata (m)	**Total Area (m^2)**	**Egg Density (No. eggs/m^2)**	**Total No. Eggs**	**Proportion of Total No. Eggs (%)**
0.0 to 0.30	58	466	27,044	6.3
0.31 to 0.60	148	692	102,473	23.8
>0.60	372	807	300,333	69.9
Total	**578**	**743**	**429,581**	**-**

The total number of eggs deposited on Shoal 16 is estimated to be approximately 430,000. Approximately 30.1% of this total, or 129,300 eggs were deposited within the winter draw down zone (i.e., above elevation 354.2).

Based on the results of the spawning survey, it is estimated that up to 150 to 200 female lake trout spawned on Shoal 16, assuming that not all individual spawners were observed by the survey team. Based on an average female lake trout fecundity value (i.e., 880 to 2640 egg/kg of body mass) (Scott & Crossman, 1973) and the average size of fish observed on the shoal (i.e., 1 to 2 kg), the number of eggs calculated for Shoal 16 would be reasonable for a spawning population of this size.

3.3.2 Shoal 5

A summary of the egg collection results from Shoal 5 is presented in Table 3.6 and depicted graphically in Figure 3.3, while raw data is provided in Appendix A, Table A3.

Table 3.6 Shoal 5 Egg Collection Data Summary					
Depth Strata (m)	**No. Samples**	**Total No. Eggs**	**No. Eggs Alive**	**No. Eggs Dead**	**Percent Alive (%)**
0.0 to 0.30	0	-	-	-	-
0.31 to 0.60	0	-	-	-	-
>0.60	4	142	116	26	81.6

Egg sampling sites ranged in depth from 1.29 to 1.96 m. No suitable spawning habitat was identified within the shallow water (<0.60 m) depth

stratums, and as such, no specific egg collection samples were undertaken in shallow areas. A diver survey of these areas (i.e. dominated by larger boulders) found no evidence of egg deposition.

The estimated total number of eggs deposited per depth stratum on Shoal 5 is presented in Table 3.7.

Table 3.7
Estimated Total No. of Eggs – Shoal 5

Depth Strata (m)	Total Area (m^2)	Total No. Eggs	Egg Density (No. eggs/m^2)	Proportion of Total (%)
0.0 to 0.30	0.0	-		-
0.31 to 0.60	0.0	-		-
>0.60	36	20,552	568	100

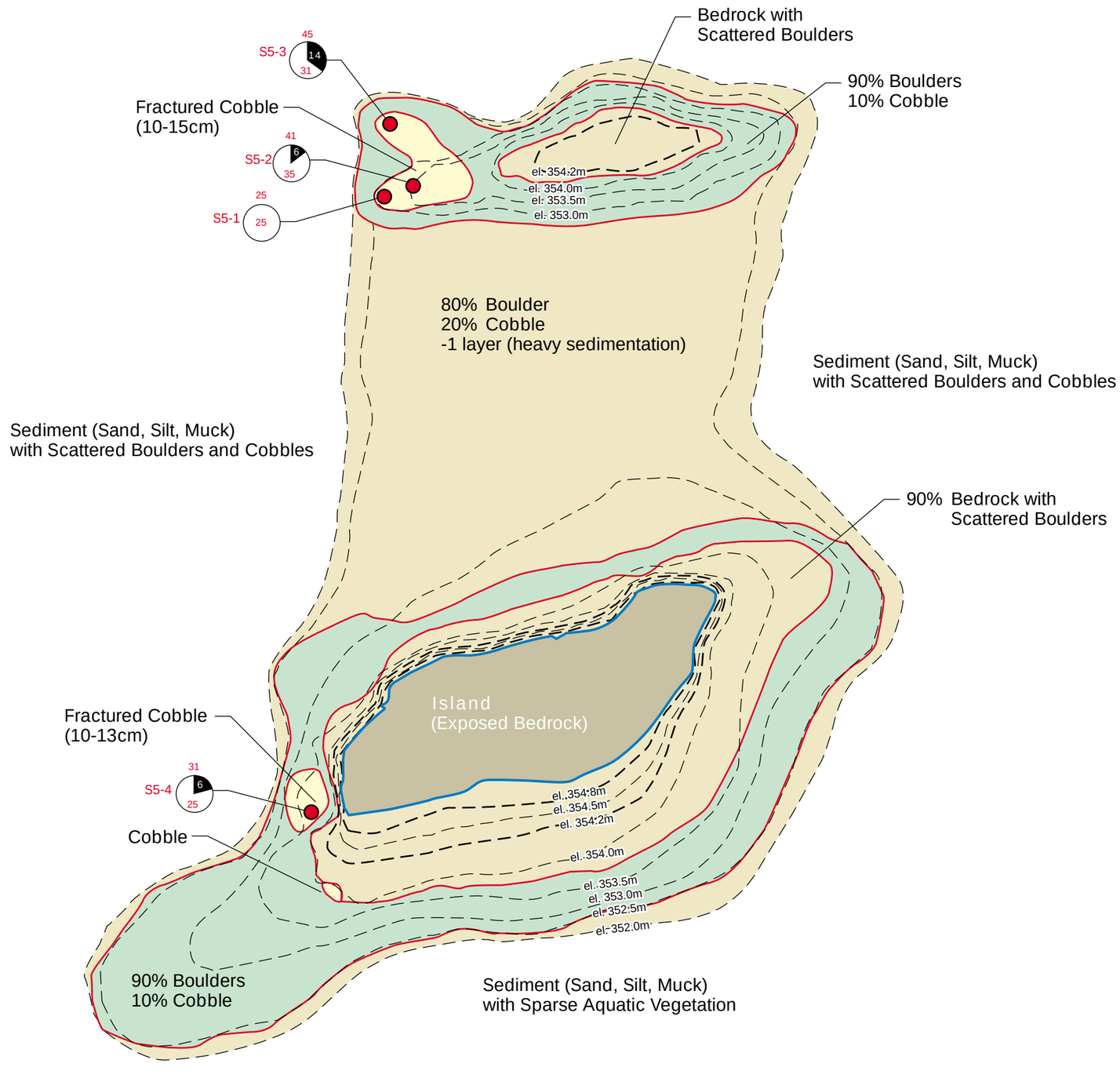
Egg density at the sampling sites ranged from 400 to 720 eggs/m^2 with a mean of 568 (±SE 73) eggs/m^2. Overall egg viability at the time of the survey was approximately 82%. It was estimated that 20,552 eggs were deposited over the two suitable spawning areas on Shoal 5. All eggs collected during the diving surveys were found below the 0.60 m stratum, indicating that none would be exposed during the winter draw down.

3.4 Winter Egg/Larva Survey

The winter egg/larva survey examined only Shoal 16 as the fall survey had documented eggs within the winter drawdown range.

3.4.1 Water Levels

The water level at the time of the survey (March 22) was 354.25 m, which is 7 cm above the rule curve value of 354.18 m for the March 15th to March 31st period. Lake water levels in the days preceding the survey are presented in Table 3.8.



Legend

- Most Suitable for Spawning - Clean Cobble with Interstitial Space
- Acceptable but Less Suitable - Some Biofouling and/or Sediment Accumulation, and/or predominantly boulders
- Unacceptable - Heavy Siltation and/or Shallow Substrate (i.e. no interstitial space) and/or Unsuitable Substrate (i.e. bedrock)
- Lake Bottom Elevation Contour
- Water's Edge
- Substrate Delineation Boundary
- S-1 Egg Sampling Location and Number of Eggs Alive/Dead
  - 20 — Total No. Eggs
  - 3 — No. Eggs Dead
  - 17 — No. Eggs Alive

Note: Water level at the time of the survey - 354.82m

Figure 3.3
Kawagama Lake - Lake Trout Reproductive Studies
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Shoal 5 - Egg Sampling Locations/Results

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Table 3.8 Kawagama Lake Water Levels (March 15th to March 22nd)	
Date	**Water Level (m)**
March 15	354.37
March 16	354.35
March 17	354.34
March 18	354.32
March 19	354.30
March 20	354.28
March 21	354.28
March 22 (a.m.)	354.26
March 22 (p.m.)	354.25

3.4.2 Substrate, Egg and Larva Observations

Ice and Substrate Characteristics

The ice thickness near location S16-17 was approximately 50 cm, and was composed of approximately 20 cm of white surface ice (slush ice) and 30 cm of clearer underlying ice. A similar ice depth was encountered near location S16-13 during the initial hole for and subsequent removal of the ice slab. During/after removal of the ice slab, it was evident that the ice layer had formed before the drawdown was initiated, as the ice on the side of the shoal was perched on the upper portion of the side slope, and was separated from the underlying substrate by a15- to 20-cm airspace. Large boulders within the substrate provided the resting points for and supported this ice layer (Figure 3.4, Photos P1 to P3). An additional thin layer of ice was noted beneath the thick ice layer just above the March 22 water level.

Upon removal of the ice slab, underlying sediments were examined to assess characteristics and their state of "frozenness". All substrates from the top of the ice slab opening to just above the water level were frozen solid, and required considerable effort to remove individual particles (cobbles, gravel, etc) from the frozen matrix. At the lower part of the opening created by the ice slab removal (extending upslope from lake surface elevation 354.25 m), substrates were wet to moist and unfrozen in a layer that extended approximately 7 cm upward from the water surface (i.e. to elevation 354.32 m). Manual excavation (i.e., by hand) of these substrates at the

water/shore interface revealed that the water surface extended laterally into the substrate (i.e., past the shore/water interface), to create an interstitial water level within the substrate. The lateral extension of that water surface would be highly dependant on the permeability of the material, the slope of the area, substrate depth and composition. At the lower most sampling point on Shoal 16 (Figure 3.4, C and D), substrates became progressively smaller/finer as one proceeded laterally into the side slope, and water appeared to extend at no more than 20 cm laterally into the sloping shoreline substrate.

Sampling Areas, Eggs and Larvae

Three general sampling areas were delineated and examined within the exposed side slope, corresponding to the area in close proximity to the 354.3 m contour, and the areas above the 354.5 m and 354.6 m contours (see Figure 3.4).

Investigations began at the shore/water interface and proceeded up-slope. After moving a large boulder (~40 cm diameter) at the lower edge of the ice slab opening (point A), a lake trout larva swam up out of the underlying substrate. Water depth at this point was approximately 10 cm. This larva was retained for measurement and examination.

Investigations then turned to the area at and slightly above the water/shore interface (approximately 354.3 m elevation) to determine whether larva/eggs were present within that area. Two general sampling points were examined, one being at the north side and one at the south side of the ice slab opening. On the north side, substrate excavations/examinations began at sampling point B (Figure 3.4) and proceeded northward along the contour line to point C for a distance of approximately 25 to 30 cm. Frozen surficial substrates were removed to reveal the unfrozen, underlying layer. A live larval lake trout was found approximately 1 to 2 cm below the interstitial water level at point B, within the cobble/gravel substrate matrix. Continued excavation further northward along the contour line (to point C) located five dead larvae within the substrate, all located above the interstitial water level. These larvae were unfrozen, and located on a layer of coarse sand that was approximately 10 cm below the substrate surface and not more than 7 cm above the interstitial water level. On the north side of the ice slab opening (point D), 20 to 30 dead eggs and 5 dead larvae were found within an excavation area of approximately 20 cm by 20 cm. All eggs found were in



P1



P2



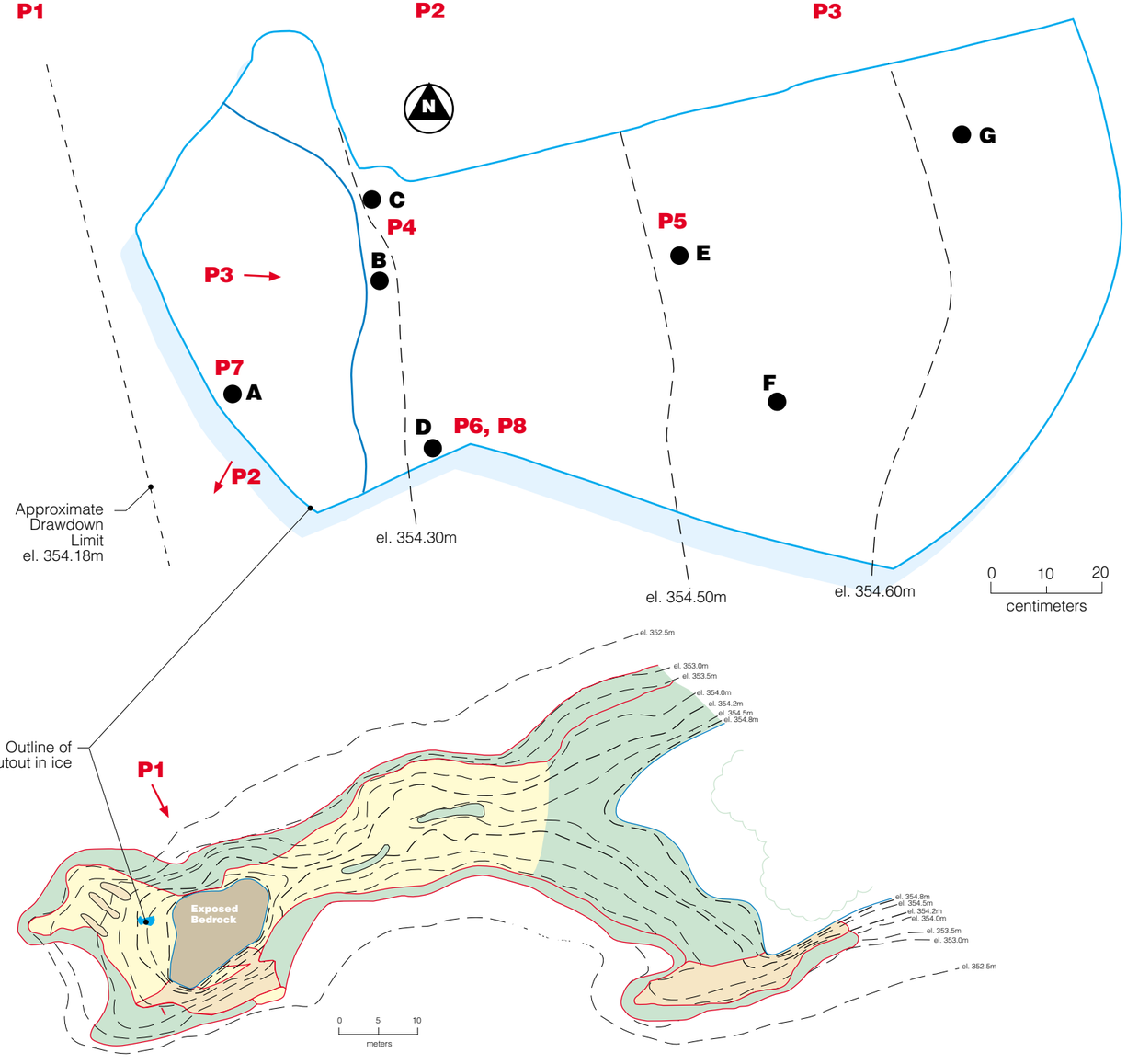
P3

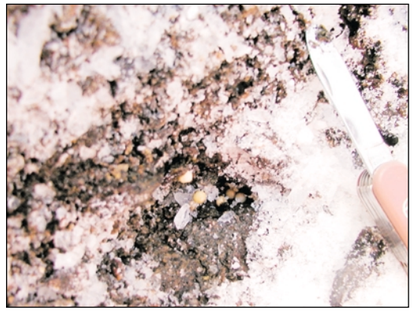


P4



P5





P6



P7



P8

Legend

- Water Level 354.25m
- Substrate Delineation Boundary
- P1 → Photograph and Direction Taken

Sample Location and Observations

A 1 Live yolk-sac larva
- found submerged under a 40cm diameter boulder
- specimen swam up from within gravel layer

B 1 Live yolk-sac larva
- within cobble/gravel substrate at water-land interface
- (1-2cm water depth)

C 5 Dead yolk-sac larvae
- unfrozen located just above water level within substrate
- larvae located on a layer of coarse sand approximately 10cm below substrate surface, and within 7cm of interstitial water level (same as lake level)
- substrate >7cm above water level was frozen

D 20-30 Dead eggs
- previously dead unfrozen
- in moist (not frozen) substrate layer within 7cm of interstitial water level (same as lake level)

5 Dead yolk-sac larvae
- 3 unfrozen located within 7cm of interstitial water level
- 2 frozen larvae (small) in frozen substrate ≈10cm above interstitial water level

E 6 Dead eggs
- frozen, but viable prior to freezing
- beneath first substrate layer

F 8 Dead eggs
- previously dead (white and fungus covered)
- beneath first substrate layer

G 4 Dead eggs
- frozen, but viable prior to freezing
- beneath first substrate layer

Figure 3.4
Kawagama Lake - Lake Trout Reproductive Studies
Ministry of Natural Resources
Winter Survey Results

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one central pocket within the moist, unfrozen layer immediately above the interstitial water level. They were identified (by their white/opaque color) as being previously dead (i.e., unhatched) prior to being dewatered. Three dead, but unfrozen larvae were found in the same layer, while two dead and frozen larvae were found approximately 10 cm above the interstitial water level (see Figure 3.4, Photo P8). Based on the draw down rate of the lake in the days preceding the survey (Table 3.8), the top of the moist substrate (i.e., to elevation 354.32) was dewatered approximately 4 days prior to the date of this survey.

In the second sampling area (approximately 1.0 m upslope), substrate consisted of cobble, gravel and angular rock fragments. At sampling point E, six frozen, but previously alive eggs were located beneath the first layer of substrate. At the second sampling point within this area (F), a number of previously dead eggs (white and/or covered with fungus) were found.

In the upper area (approximately 1.5 m upslope), substrate components consisted of angular slabs of rock rubble, with no eggs or larva apparent on the substrate surface. Removal of the surficial layer to a depth or approximately 10 cm revealed a few eggs (4 in approximately a 100-cm^2 area) within the underlying layers (sampling point G). While these eggs were all frozen (but dead), their color (i.e., pale orange) indicated that they had been alive prior to freezing.

Larval Characteristics and Ages

Two live yolk-sac larvae and five dead larvae were retained for examination and measurement in an attempt to determine their age. Four of the dead larvae were much smaller, and partially decomposed or deformed, such that no body part measurements could be obtained. Of those four, one had been very close to hatch (well formed and still in egg case), one was recently hatched (as indicated by its large yolk sac and the deflection of its head over the yolk sac), while the other two were small but partially decomposed.

Body morphometric characteristics of the two live larvae and one dead larva (largest, with virtually no decomposition other than compressed yolk sac) are provided in Table 3.9.

Table 3.9
Larval Lake Trout Morphometric Characteristics

	Live Larva #1 (Site C)		Live Larva #2 (Site C)		Dead Larva* (Site D)	
Body Morphometry	**Dimension (mm)**	**Percent of Total Length**	**Dimension (mm)**	**Percent of Total Length**	**Dimension (mm)**	**Percent of Total Length**
Total Length	20.4	-	16.45	-	19.3	-
Head Length	4.19	20.5	2.62	15.9	3.99	20.7
Pre-Anal Length	13.03	63.9	10.49	63.8	10.03	52.0
Eye Diameter	1.52	7.5	1.17	7.1	1.68	8.7
Yolk Sac Length	7.08	34.7	5.87	35.7	4.76	24.7
Yolk Sac Depth	3.01	14.8	2.76	16.8	-	-

*Dimensions not as accurate due to some body decomposition.

Auer (1982) indicates that newly hatched yolk-sac larvae are 15.2 mm long, with two stages of yolk-sac larva development (16 to 18 mm, and 19 to 22 mm) identified prior to swim-up. Changes in body morphology that occur between hatch and swim-up include an overall straightening of the body (i.e., no deflection of the head over the yolk sac), and a decrease in yolk sac length and depth compared to the total body length. While the yolk-sac is still present in swim-up stage larva, it is much less apparent. At the swim-up stage, the yolk sac length equals 20 to 31 % of total body length, and its depth equals 6 to 19% of total body length. A length of approximately 22 to 24 mm is attained at the swim-up stage.

Auer (1982) also notes that a period of approximately 35 days at 7^{o}C (longer at colder temperatures) is required from hatch to swim-up. In Kawagama Lake, it is highly likely that the 'hatch to swim-up' period would be longer than 35 days, as water temperatures are expected to be 4^{o}C or less during this period. Auer (1982) notes that lower water temperature have a significant impact on the 'days to hatch' duration, with the change from 7^{o}C to 4.5^{o}C increasing the duration by up to 25% (83 days to hatch at 7^{o}C, 106 days to hatch at 4.5^{o}C). Lower temperatures further lengthen the incubation period

(i.e., 162 days at 1.8^{o}C). A similar result could also be expected for the 'hatch to swim-up' period.

The specimens collected from Kawagama Lake (Table 3.9) compare favorably to the body morphometry values provided in Auer (1982). Based on their size, and the conservative value of 35 days from hatch to swim-up noted above, the live specimens (larva #1 and larva #2) captured during the survey could be 23 and 6 days old respectively. The large dead larva could have been 18 days post-hatch. Three of the remaining dead larvae were all small, and appeared to have been very recently hatched. The last dead larva was in very good condition, and still in the egg case. Given the water level change that occurred prior to the field investigations (Table 3.8), it can be concluded that some larva hatch as late as mid-March.

Blank back

4 Summary and Discussion

Habitat surveys found that the seven lake trout spawning shoals mapped during this study contained approximately 1200 m^2 of high quality spawning habitat, with Shoal 16 representing nearly half of this amount (578 m^2). Spawning surveys confirmed that Shoal 16 is the primary spawning shoal in Kawagama Lake, with over 100 fish being observed on three separate occasions. Shoals 5 and 18 appeared to be secondary spawning areas, with approximately 30 fish observed on each shoal. Based on these results, the spawning population of Shoal 16 represents a significant proportion of the reproductive capacity of Kawagama Lake.

During this study, the peak period of spawning activity occurred from October 24 to 29. Water levels during this period ranged from 354.81 m (the lowest lake elevation occurred in the fall of 2003) to 354.84 m. The rule curve indicates that a level of 354.80 m should be achieved by October 15, but this can be affected by rainfall prior to this date as well as operational factors. On October 15 of 2003, the water level was 354.91 m, which was approximately 10 cm higher than the preferred elevation. Theoretically, any fish spawning on October 15 would have had access to habitat at a higher elevation than targeted by the water management regime, and would have put their eggs at greater risk of being dewatered during the upcoming winter drawdown. However, field observations indicate that spawning during 2003 occurred about 2 weeks after October 15 when the water level was very close to the preferred fall level.

Egg deposition on Shoal 16 occurred in water ranging from 0.04 to 2.26 m deep. Egg densities ranged from 0 to 5472 eggs/m^2 (mean of 849 eggs/m^2), with the highest density found on the western end of the shoal, in water ranging from 0.25 to 1.05 m deep. By way of comparison, Tarandus Associates Limited (1988) found a maximum egg density of 908 eggs/m^2 in Lake of Bays (based on single quadrat samples). Fitzsimons (1995) recorded densities of 6 to 6200 eggs/m^2 at 14 spawning sites in Lake Ontario, and Ellicott and Marsden (2004) found densities from 1.9 to 9623 eggs/m^2 in Lake Champlain on the Quebec-United States border. Thus, the densities observed during this study compare favorably to other locations.

The overall percentage of live eggs observed on Shoal 16 at the time of the survey was 76%, with values ranging from 30 to 100% at various sampling sites. The

average number of live eggs increased slightly with depth, with the 0 to 0.6 m depth stratum averaging 70% live eggs, while the >0.6 m depth stratum averaged 84% live eggs at the time of sampling. These values however provide no indication of future hatch or recruitment to the population.

In total, it was estimated that 429,581 eggs were deposited on Shoal 16. Of this amount, 129,303 (30.1%) were within contours 354.8 m and 354.18 m, which corresponds to the portion of the shoal that would be exposed by the 0.62-m winter drawdown. Eggs deposited below this elevation would not be affected by the winter drawdown.

Egg density at the four sampling sites on Shoal 5 ranged from 400 to 720 eggs/m^2, with deposition occurring in water from1.3 to 2.0 m deep. The percentage of live eggs was approximately 82%. It is estimated that approximately 20,000 eggs were deposited on Shoal 5, which represents less than 5% of the amount deposited on Shoal 16. However, all of the eggs on Shoal 5 were found below the draw down elevation (354.18) indicating that they would not be impacted by the winter draw down.

Based on the results of the field investigations at Shoal 16, it is evident that the winter draw down results in the exposure of eggs and newly hatched yolk-sac larvae to desiccation, freezing and mortality. Frozen eggs that appeared to have been viable prior to freezing (as determined by their orange color) were present in the upper part of the drawdown zone. At lower elevations, within those substrates that were not frozen and within 7 cm of the interstitial water level, all unhatched eggs were previously dead (as evidenced by their white/opaque color). One of these eggs also contained a well developed larva that was very close to, but had not hatched. Correlating the elevation of this larva with lake water level reveals that some larva may hatch as late at mid-March. Wilton (1985) also found that most of the eggs within the Mary Lake draw down zone were dead, but found two eggs contained live embryos. This indicates that mortality may not be immediate after dewatering, provided there is sufficient moisture within the substrate to prevent desiccation and provide oxygen diffusion.

Live yolk-sac larvae were found at two locations on Shoal 16. Both larvae were collected from areas that were below the lake level/interstitial water level at the time. Recently dead, unfrozen larva were found in a layer that extended

approximately 7 cm upward from the interstitial water level. Frozen larva were found above this level.

Upon hatching, yolk-sac larvae remain within the substrate matrix until their yolk-sac is mostly absorbed and they are able to swim and actively search for/capture food. Auer (1982) reports that hatchery reared fry remained in the substrate (after hatch) for 35 days at 7^{o}C. At colder water temperatures, as would be present in Kawagama Lake over the winter, the time to hatch would be extended. If one uses October 27 as the average spawning date for Shoal 16 lake trout (see Table 3.3) and March 15 as the average hatch date, one arrives at an incubation period of 140 days. This value seems reasonable given previously reported data (106 days at 4.5^{o}C, 162 days at 1.8^{o}C, Auer 1982). Using this value to develop a correction factor to apply to the "hatch to swim-up" value at 7^{o}C (35 days), one arrives at a duration of 59 days, which corresponds to a date of mid-May. Again, this seems reasonable, and corresponds well with information previously reported (Martin, 1956; Wilton, 1985; Perkins and Krueger, 1995; A&A, 2003).

The presence of larva within exposed substrates indicates that they have limited ability to move with receding water levels. In laboratory experiments, Wilton (1985) found that yolk-sac larva exhibited little response to water level draw down until they were exposed, and movement back to the water was impossible. This effect was observed for young fry and older fry that had absorbed approximately 85% of the yolk-sac and exhibited strong swimming ability. While live larvae were collected during this study, in both cases they were found below the lake water level. Based on the observations of Wilton (1985) and the presence of dead yolk-sac larvae within the dewatered portion of the draw down zone on Shoal 16, it appears that the majority of larvae cannot move in advance of the receding water level as draw down proceeds. All exposed fry were dead, regardless of whether they had recently died (still moist and unfrozen) or were long dead (frozen). While interstitial moisture may sustain larva for a short period (minutes or hours?), it is insufficient to maintain a viable environment for them over a longer term.

During the winter investigations, it was observed that the water surface extends laterally into the substrate past the water/shore interface as an interstitial water level, with the distance of this extension depending on shoal slope and substrate composition and depth. At the study area on Shoal 16, it appeared that the extension was no more than approximately 20 cm. It is possible that yolk-sac

larvae that remain submerged within this area beneath the exposed substrate will survive (larva generally 10 to 15 cm below the substrate surface). However, this assumes that suitable environmental conditions (i.e., oxygen levels) are maintained, and the water eventually rises above the surface of the substrate to allow them to escape the cobble/gravel matrix.

In summary, the results of the March 2004 field investigations indicate that all eggs and newly hatched larva within the draw down zone of Kawagama Lake perish as water levels recede and they are exposed to desiccation and freezing temperatures. Thus, approximately 30% of all viable eggs and fry from Shoal 16 would perish due to draw down induced exposure. Although no correlation can be directly established with adult lake trout populations, this is a significant loss. Combined with importance of Shoal 16 as the primary contributor to the reproductive capacity of Kawagama Lake's lake trout population, one cannot underestimate the significance of this finding. While other spawning shoals do not appear to be major contributors to recruitment in Kawagama Lake at this time, the winter drawdown would adversely affect approximately 48% of the "most suitable spawning habitat" on the other shoals in the lake.

5 Conclusions and Recommendations

One of the general water management strategies developed for Muskoka River system lake trout lakes was to reduce the differential between winter and fall drawdown levels in the belief that this would result in less mortality of developing eggs and larva. Two potential strategies were developed to effect this improvement, being either an increase in the fall drawdown level, or a reduction in the winter drawdown level. Previous studies in Lake of Bays (Tarandus, 1988) had indicated that the 0.76-m winter drawdown experienced by that lake resulted in approximately 10% mortality to developing eggs and/or fry. Kawagama Lake experiences a 0.62-m drawdown, but is quite different from Lake of Bays in that it also experiences declining summer levels (prior to the fall drawdown) and has fewer and less well documented lake trout spawning sites. The present study was undertaken to provide a comparison with Lake of Bays information, and to investigate whether a reduction in the winter drawdown level (i.e., a higher winter level that is closer to the fall level) would provide any benefits to lake trout eggs and larva in Kawagama Lake.

The study revealed that lake trout spawning activity in Kawagama Lake is concentrated on one primary shoal (Shoal 16). At that shoal, approximately 30% of deposited lake trout eggs were located within the contours (354.8 m to 354.18 m) that would be dewatered by the winter drawdown. Investigations conducted in March 2004 revealed that eggs or larvae that were dewatered by the drawdown experienced mortality. Thus, the present water management strategy, with the winter draw down to 354.18 m, results in the loss of approximately 30% of the potential lake trout recruitment from Shoal 16. Based on present knowledge of spawning sites and lake trout spawning habits, this loss is considered significant. When combined with other sources of natural mortality, this additional stressor may be significantly impacting the lake's lake trout population.

The preferred water management strategy for Kawagama Lake, as identified in the Options Report (Acres 2004), proposes to reduce (i.e., elevate) the winter drawdown by 0.4 m (to 354.6 m elevation). The results of this study indicate that approximately 25% more eggs and/or larvae would be given the opportunity to survive and develop into adult lake trout if this strategy were implemented.

Finally, the concentration of much of Kawagama Lake's lake trout spawning potential into one narrow band on one primary shoal results in a significant environmental/species risk. While the proposed change to the operational plan for the lake is anticipated to provide improvements in the long term, efforts should be made as soon as possible to expand the lake trout's spawning range within Kawagama Lake beyond this single point and narrow band. Artificial substrates have been proven to be an effective means of enhancing and expanding spawning habitat, and should be considered to expand the spawning habitat base in the lake. Further reductions in the fall water level should be undertaken cautiously as significant amounts of high quality spawning habitat is not present above the present fall elevation. Any potential enhancement programs or future changes to water level should be undertaken with adequate research and study to ensure that positive outcomes are assured. Opportunities to involve and partner with the Kawagama Lake Cottagers' Association in these activities should be fully explored and implemented.

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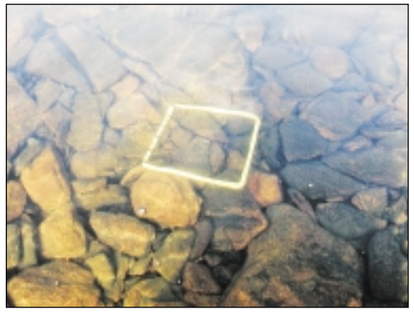
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APPENDIX A

HABITAT MAPS AND DATA



P1



P2



P3

el. 352.5m

Sediment (Sand, Muck) with
Scattered Boulders/Cobble

90% Boulder
10% Cobble

el. 353.0m
el. 353.5m
el. 354.0m
el. 354.2m
el. 354.5m
el. 354.8m

80% Boulder
20% Cobble

40 - 60% Cobble
30 - 50% Boulder
with Gravel (clean)

P3

P6

P2

Upland
Vegetation

Exposed
Cobble/Boulder

Exposed
Bedrock

P1

40 - 60% Cobble
30 - 50% Boulder
with Gravel (clean)

40 - 60% Cobble
30 - 50% Boulder
with Gravel (fouled)

el. 354.8m
el. 354.5m
el. 354.2m
el. 354.0m
el. 353.5m
el. 353.0m

el. 352.5m

90% Boulder
10% Cobble

P5

90% Gravel
10% Cobble

90% Bedrock

Bedrock

90% Boulder
10% Cobble

P4



P4



P5



P6

Legend

- Most Suitable for Spawning - Clean Cobble with Interstitial Space
- Acceptable but Less Suitable - Some Biofouling and/or Sediment Accumulation
- Unacceptable - Heavy Siltation and/or Shallow Substrate (i.e. no interstitial space) and/or Unsuitable Substrate (i.e. bedrock)
- Lake Bottom Elevation Contour
- Water's Edge
- Substrate Delineation Boundary
- P1 Photograph and Direction Taken

Note: Water level at the time of the survey - 354.82m

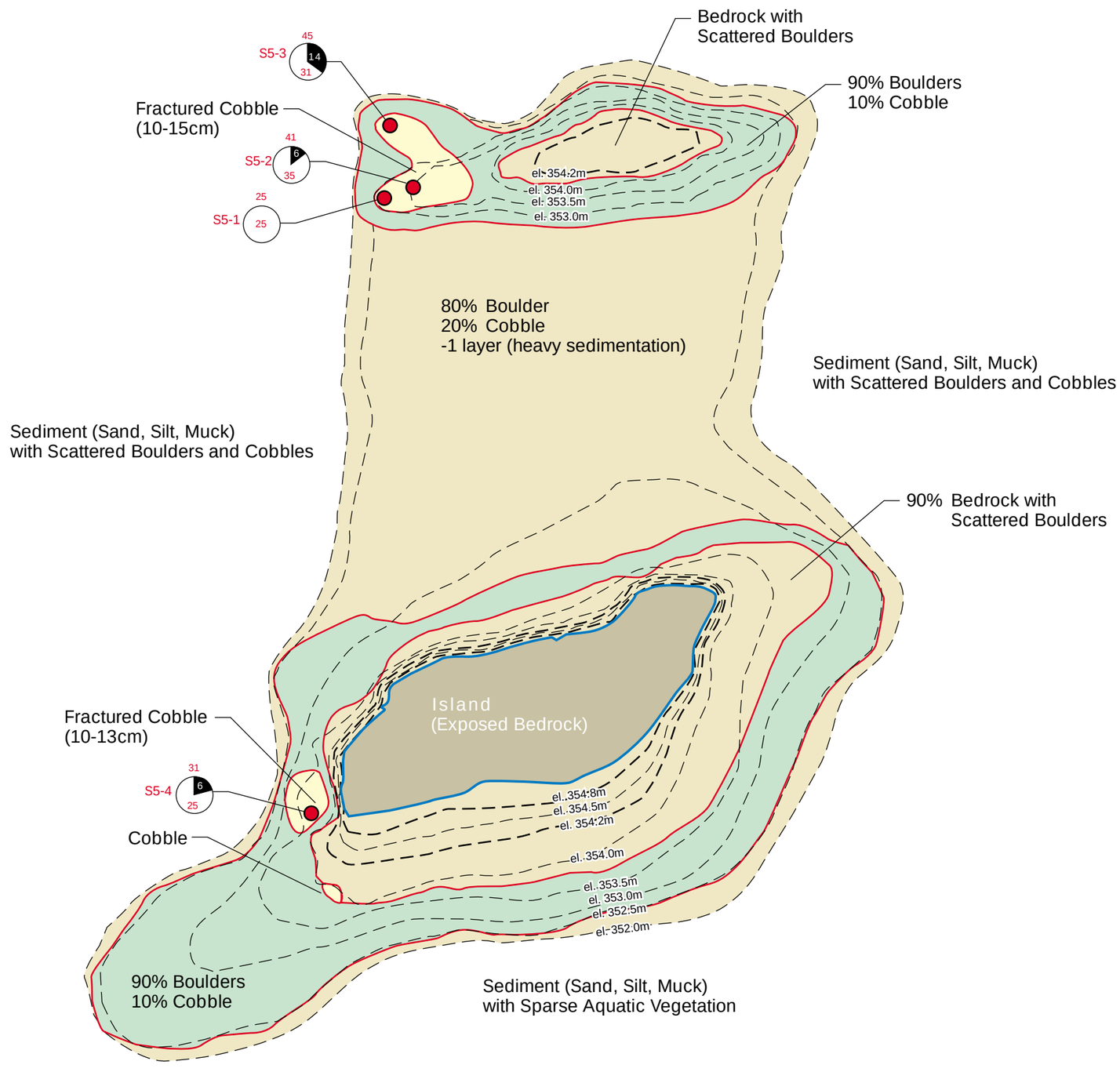
N

0 5 10

meters

Figure A1
Kawagama Lake - Lake Trout Reproductive Studies
Ministry of Natural Resources
Shoal 16 - Habitat Conditions

ACRES International



Legend

- Most Suitable for Spawning - Clean Cobble with Interstitial Space
- Acceptable but Less Suitable - Some Biofouling and/or Sediment Accumulation, and/or predominantly boulders
- Unacceptable - Heavy Siltation and/or Shallow Substrate (i.e. no interstitial space) and/or Unsuitable Substrate (i.e. bedrock)
- Lake Bottom Elevation Contour
- Water's Edge
- Substrate Delineation Boundary
- S-1 Egg Sampling Location and Number of Eggs Alive/Dead
  - 20 — Total No. Eggs
  - 3 — No. Eggs Dead
  - 17 — No. Eggs Alive

Note: Water level at the time of the survey - 354.82m

Figure A2
Kawagama Lake - Lake Trout Reproductive Studies
Ministry of Natural Resources

Shoal 5 - Habitat Conditions and Egg Sampling Locations/Results

ACRES International

80% Cobble
20% Boulder

Area 2

Sand/Muck

Sand/Muck

95% Boulder
5% Cobble

Marker Buoy

50% Cobble
50% Boulder
(Biofouling, Sediment
Accumulation)

50% Cobble
50% Boulder

Area 1

el. 351.5m

el. 352.0m

el. 352.5m

el. 353.0m

el. 353.5m

el. 354.0m

el. 354.2m

el. 354.5m

el. 354.8m

Unacceptable
(Heavy Siltation, Biofouling)

50% Sand
30% Boulder
20% Cobble

P1

Dock

Exposed Cobble/Boulder

P2

Upland Vegetation

N

0 5 10

meters

Legend

- Most Suitable for Spawning - Clean Cobble with Interstitial Space
- Acceptable but Less Suitable - Some Biofouling and/or Sediment Accumulation
- Unacceptable - Heavy Siltation and/or Shallow Substrate (i.e. no interstitial space) and/or Unsuitable Substrate (i.e. bedrock)
- Lake Bottom Elevation Contour
- Water's Edge
- Substrate Delineation Boundary
- P1 Photograph and Direction Taken

Note: Water level at the time of the survey - 354.82m



P1



P2

Figure A3
Kawagama Lake - Lake Trout Reproductive Studies
Ministry of Natural Resources
Shoal 18 - Habitat Conditions

ACRES International

70% - 90% Boulder

50% - 60% Boulder
40% - 50% Cobble
(Siltation, Biofouling)

70% - 90% Boulder

70% Cobble
30% Boulder

50% - 60% Boulder
40% - 50% Cobble
(Siltation, Biofouling)

90% Boulder

90% Boulder

Sand with Scattered
Boulders/Cobbles/
Gravel (1layer)

50% - 60% Boulder
40% - 50% Cobble
(Siltation, Biofouling)

70% Cobble
30% Boulder
(Siltation, Biofouling)

Gravel, Small Cobble,
Scattered Boulders
over Sand

el. 352.5m

el. 353.0m

P2

el. 353.5m

el. 354.0m

el. 354.2m

el. 354.5m

Dock

el. 354.82m

P1

Exposed Shoreline Substrates
(Gravel, Boulder over Sand)

High Water Mark

P3

N

0 5 10

meters

Legend

- Most Suitable for Spawning - Clean Cobble with Interstitial Space
- Acceptable but Less Suitable - Some Biofouling and/or Sediment Accumulation, and/or predominantly boulders
- Unacceptable - Heavy Siltation and/or Shallow Substrate (i.e. no interstitial space) and/or Unsuitable Substrate (i.e. bedrock)
- Lake Bottom Elevation Contour
- Water's Edge
- Substrate Delineation Boundary

Note: Water level at the time of the survey - 354.82m



P1



P2



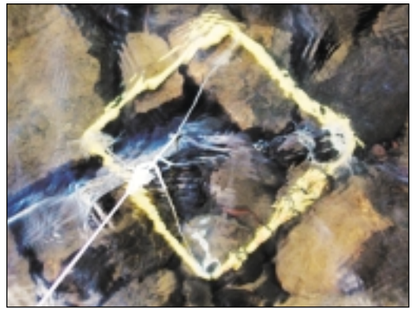
P3

Figure A4-1
Kawagama Lake - Lake Trout Reproductive Studies
Ministry of Natural Resources
Shoal 17-1- Habitat Conditions

ACRES International



P1



P2



P3

Legend

- Most Suitable for Spawning - Clean Cobble with Interstitial Space
- Acceptable but Less Suitable - Some Biofouling and/or Sediment Accumulation, and/or predominantly boulders
- Unacceptable - Heavy Siltation and/or Shallow Substrate (i.e. no interstitial space) and/or Unsuitable Substrate (i.e. bedrock)
- Lake Bottom Elevation Contour
- Water's Edge
- Substrate Delineation Boundary

Note: Water level at the time of the survey - 354.82m

Shoal appears to continue further out
(not visible from surface)

100% boulders 0.60 - 1.5m

50% Cobble
50% Boulder
- algae/periphyton growth on rocks

90% Boulders with patches
of 10 - 20 cm Cobble

20% >1m
25% 0.25 - 1.0m
50% 0.06 - 0.25m
5% <0.06m
- angular rock
- well-washed

el. 350.0m
el. 351.0m
el. 352.0m
el. 352.5m
el. 353.0m
el. 353.5m
el. 354.0m
el. 354.2m
el. 354.5m
el. 354.82m

P3 P2 P1

Trees

Steep Shoreline

N

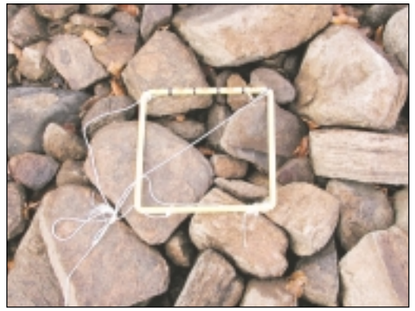
0 5 10
meters

Figure A4-2
Kawagama Lake - Lake Trout Reproductive Studies
Ministry of Natural Resources
Shoal 17-2 - Habitat Conditions

ACRES International



P1



P2

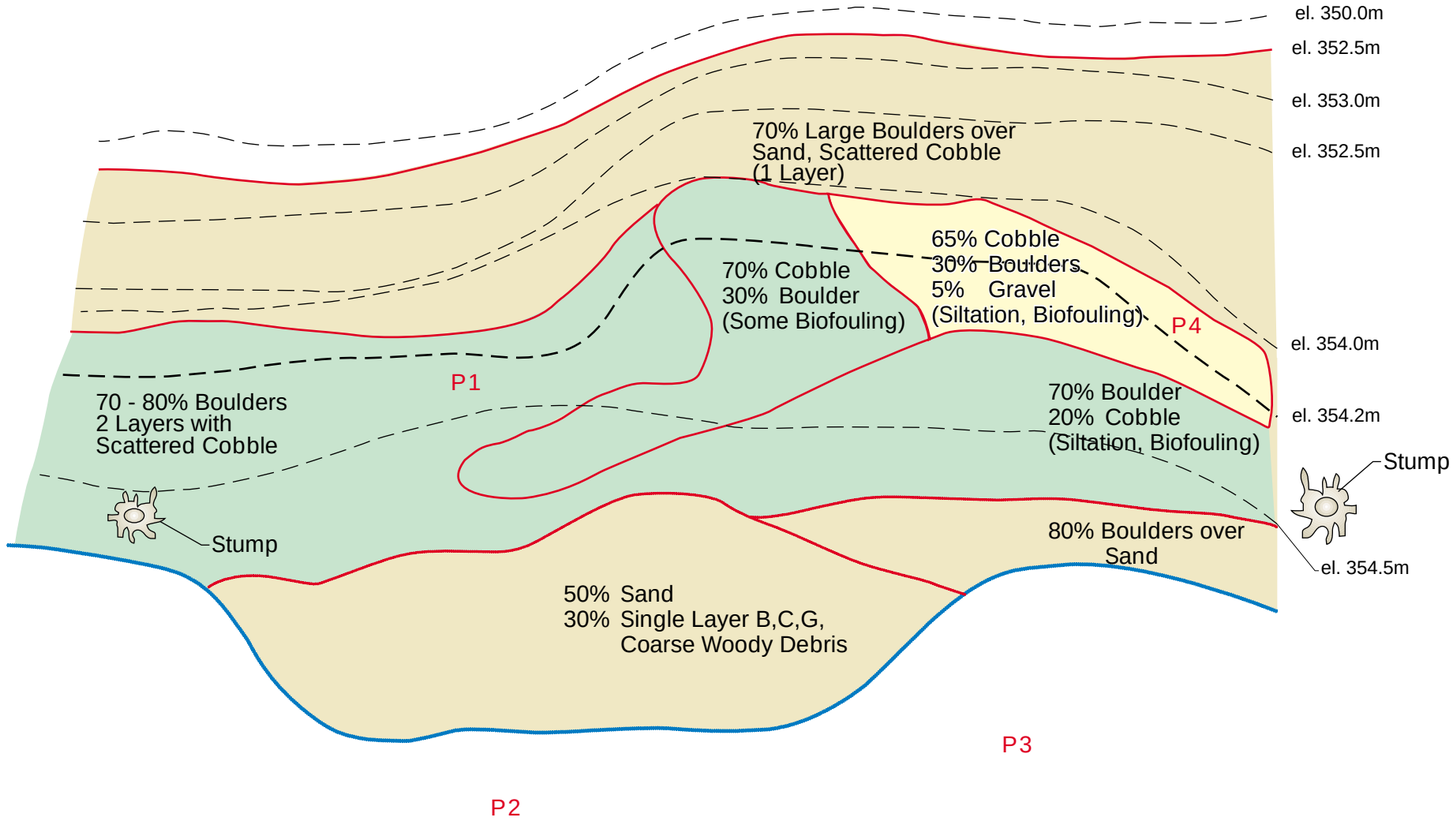


P3

Legend

- Most Suitable for Spawning - Clean Cobble with Interstitial Space
- Acceptable but Less Suitable - Some Biofouling and/or Sediment Accumulation, and/or predominantly boulders
- Unacceptable - Heavy Siltation and/or Shallow Substrate (i.e. no interstitial space) and/or Unsuitable Substrate (i.e. bedrock)
- Lake Bottom Elevation Contour
- Water's Edge
- Substrate Delineation Boundary

Note: Water level at the time of the survey - 354.82m





P4

Figure A5
Kawagama Lake - Lake Trout Reproductive Studies
Ministry of Natural Resources
Shoal 11 - Habitat Conditions

ACRES International



P1



P2



P3

Legend

- Most Suitable for Spawning - Clean Cobble with Interstitial Space
- Acceptable but Less Suitable - Some Biofouling and/or Sediment Accumulation
- Unacceptable - Heavy Siltation and/or Shallow Substrate (i.e. no interstitial space) and/or Unsuitable Substrate (i.e. bedrock)
- Lake Bottom Elevation Contour
- Water's Edge
- Substrate Delineation Boundary
- B — Large, Exposed Boulders
- P1 — Photograph and Direction Taken

Note: Water level at the time of the survey - 354.82m

Upland Vegetation

Cobble/Boulder Beach

Exposed Bedrock Point

P1

P2

P3

Bedrock

el. 354.5m

el. 354.2m

el. 354.0m

el. 353.5m

el. 353.0m

el. 352.5m

el. 352.0m

Exposed Rock

Bedrock

80% Boulder
20% Cobble

Sand/Muck with Scattered Boulders

60% Cobble (clean)
40% Boulders (clean)

Bedrock

80% Boulders (> 1m)

Sand/Muck with Scattered Boulders

Scattered Gravel/Small Cobble patches among large Boulders. (each ≈ 1m^2)

N

0 5 10

meters

Figure A6
Kawagama Lake - Lake Trout Reproductive Studies
Ministry of Natural Resources
Shoal 7 - Habitat Conditions

ACRES International



P1



P2

Sand with scattered
Large Boulders

80 - 90% Boulder over Sand

60% Cobble
55% Boulder
5% Gravel
(fairly clean)

80% Cobble
15% Sand
5% Gravel

Scattered 0.5m
Cobble Patches

Wave Washed
Shoreline

90% Bedrock

el. 353.0m

el. 353.5m

el. 354.0m

el. 354.2m
el. 354.5m
el. 354.8m

P1

P2

P3

Exposed Bedrock Shoreline

Upland Vegetation

Cottage

N

0 2.5 5
meters



P3

Legend

- Most Suitable for Spawning - Clean Cobble with Interstitial Space
- Acceptable but Less Suitable - Some Biofouling and/or Sediment Accumulation
- Unacceptable - Heavy Siltation and/or Shallow Substrate (i.e. no interstitial space) and/or Unsuitable Substrate (i.e. bedrock)
- Lake Bottom Elevation Contour
- Water's Edge
- Substrate Delineation Boundary
- P1 Photograph and Direction Taken

Note: Water level at the time of the survey - 354.89m

Figure A7
Kawagama Lake - Lake Trout Reproductive Studies
Ministry of Natural Resources
Shoal 8 - Habitat Conditions

ACRES International