WATER DRAWDOWN AND ITS EFFECTS ON LAKE TROUT *(SALVELINUS NAMAYCUSH)* REPRODUCTION IN THREE SOUTH-CENTRAL ONTARIO LAKES

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ABSTRACT

Wilton, M.L. 1985. Water drawdown and its effects on lake trout *(Salvelinus ncmayaush)* reproduction in three south-central Ontario lakes. Ont. Fish. Tech. Rep. Ser. No. 20: iii & 9 p.

Observations and data gathered from Bark Lake indicate that reproduction of lake trout *(Salvelinus namaycush)* is no longer possible because of water drawdown of as much as 10 m annually. The fishery is now sustained by hatchery plantings. Data and observations from Mary Lake indicate that natural reproduction of lake trout may be severely curtailed at one of two shoals due to winter drawdown of as much as 0.83 m. Bella Lake has no dam or water level drawdown. Spawning occurs in less than 0.3 m but ice thickness lessens toward shore and as a result, there is no egg loss.

Keywords: water drawdown, reproduction, *Salvelinus*

WATER DRAWDOWN AND ITS EFFECTS ON

LAKE TROUT *(SALVELINUS NAMAYCUSH)*

REPRODUCTION IN THREE

SOUTH-CENTRAL ONTARIO LAKES

INTRODUCTION

The area located between the Ottawa Valley and Georgian Bay, south of the French and Mattawa Rivers and north of the Kawartha Lakes, contains many oligotrophic lakes which provide suitable environments for lake trout *(Salve-1-inus namayaush')* • Water control structures at the outlets of many of these lakes regulate water levels for hydroelectric generating stations downstream, as well as for cottage and recreational demands. Water drawdowns in these lakes characteristically occur during late fall and winter and coincide with the incubation period of lake trout eggs. The purpose of this paper is to document observations on lake trout spawning and water drawdown in three of these lakes.

BARK LAKE

Bark Lake (45°27'N, 77°51'W), situated near Madawaska, Ontario, is on the Madawaska River watershed which flows southeasterly to the Ottawa River (Fig. 1). It is approximately 6,000 ha in area, has a mean depth of 30 m and a maximum depth of 90 m. In the late 1930s a hydro dam was constructed at the south end of Bark Lake, raising the water level by 11 m. Regulation now produces annual water level fluctuations of as much as 10 m (Fig. 2). No clearing was carried out prior to the building of the dam. As a result, many dead trees remained standing for a period of up to 25 years. As these trees fell they produced a great deal of driftwood which was subsequently rafted, pulled ashore for drying and finally burned by work crews during the late 1960s.

Local residents maintain that subsequent to flooding, angling success in Bark Lake gradually declined through the 1940s and 1950s.

Lake trout were found to be spawning at locations later left dry by drawdown during the incubation and early post-hatching periods.

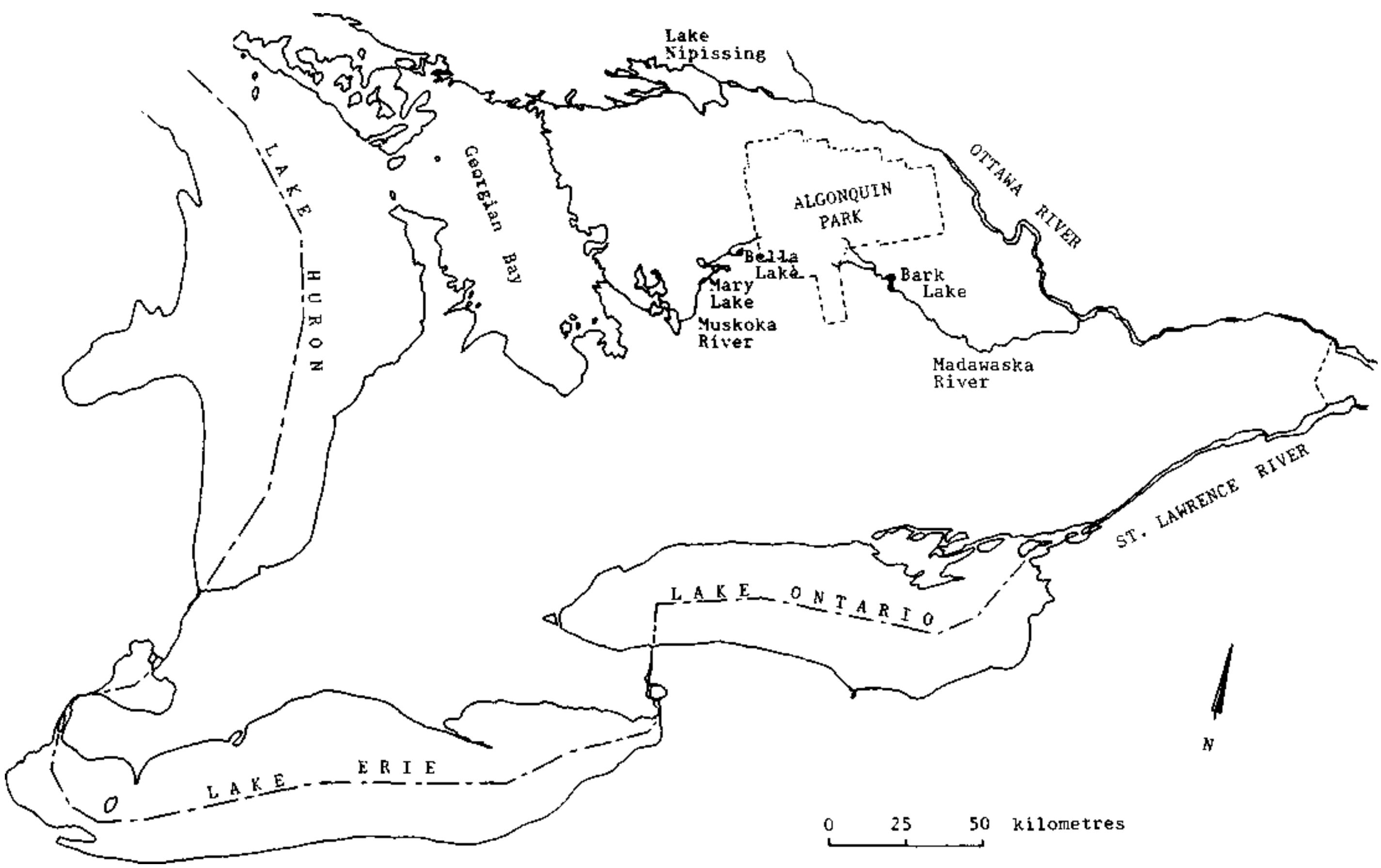

Figure 1. South-central Ontario showing Bark, Mary and Bella Lakes.

Figure 2. Water drawdown, Bark Lake, Ontario, February 1970, showing high watermark on rock face.

Consequently, plantings of hatchery stock were made during the late 1960s and early 1970s which resulted in a rejuvenated lake trout fishery by the late 1970s.

SPAWNING DEPTHS

To ascertain whether or not the original spawning beds, as identified by local, elderly residents were still in use, small mesh gill-nets were set at four locations 10.5 - 12 m below the present high watermark in October 1965. Simultaneously, netting was carried out in the shallow water adjacent to these four locations, 1.5 - 3 m below the high watermark. All lake trout caught were tagged and released. Of the 12 lake trout captured on the old deep-water beds none were recaptured on those beds. Of the 94 captured in the shallow-water nets, however, 10 were recaptured from the shallow-water beds and 3 were recaptured from the deep-water beds, suggesting that the beds in use previous to flooding are no longer utilized for lake trout spawning, but that the lake trout are now utilizing shallow-water spawning areas created as a result of flooding.

During the netting, between 10 and 50 brown bullhead *(Ictalurus nebulosus)* were captured in each of the shallow-water net sets, but none were taken in deep water. As many as possible of these fish were examined and commencing October 15 as many as 70 lake trout eggs were found in the digestive tracts of all brown bullhead examined. This further suggests that the lake trout were not spawning on the old deepwater beds, but were merely passing across them to reach the new shallow-water beds where spawning now takes place.

Fall gillnetting in conjunction with tagging during the spawning run from 1966 to 1972, consistently indicated that no lake trout were spawning deeper than 3 m below the surface in Bark Lake.

INCUBATION AND HATCHING

In order to establish a relationship between incubation periods and water drawdown, from 1969 to 1972 inclusive, a small quantity of lake trout spawn was taken each fall, fertilized, and incubated in screened containers suspended below floating drums which were anchored in 10 m of water in Bark Lake and cleaned at weekly intervals. Containers could not be placed on the spawning beds because of rapid post-spawning drawdown; sometimes as much as 0.6 m per day. This work is summarized in Table 1 and Fig. 3.

Table 1. Bark Lake incubation data.

Year	Date spawn taken	Mean hatching date	Incubation period Days	Incubation period Degree days (°C)	Water draw-down (m)
1969-70	Oct. 17	Mar. 11	145	492.0	8.6
1970-71	Oct. 10	Jan. 25	107	591.6	3.9
1971-72	Oct. 20	Mar. 2	133	594.6	4.1
1972-73	Oct. 22	Apr. 4	164	319.0	3.8

DRAWDOWN LOSSES

The minimum drawdown occurring during the incubation period in the years 1969 to 1972 was 3.8 m. Since it appears that all known lake trout spawning in Bark Lake now takes place at depths of less than 3m, the eggs from all four years would have been lost.

It was observed while attempting to incubate lake trout eggs in wire mesh cages on one bed during the 1968 spawning run, that as the water in Bark Lake was drawn down toward the point where the eggs would be dry, increasing amounts of bark and small wood particles were washed into the cages. While egg density may have been a mortality factor as well, these particles may have contributed to the loss of 97% of the eggs in one container. As was previously mentioned, no tree removal was

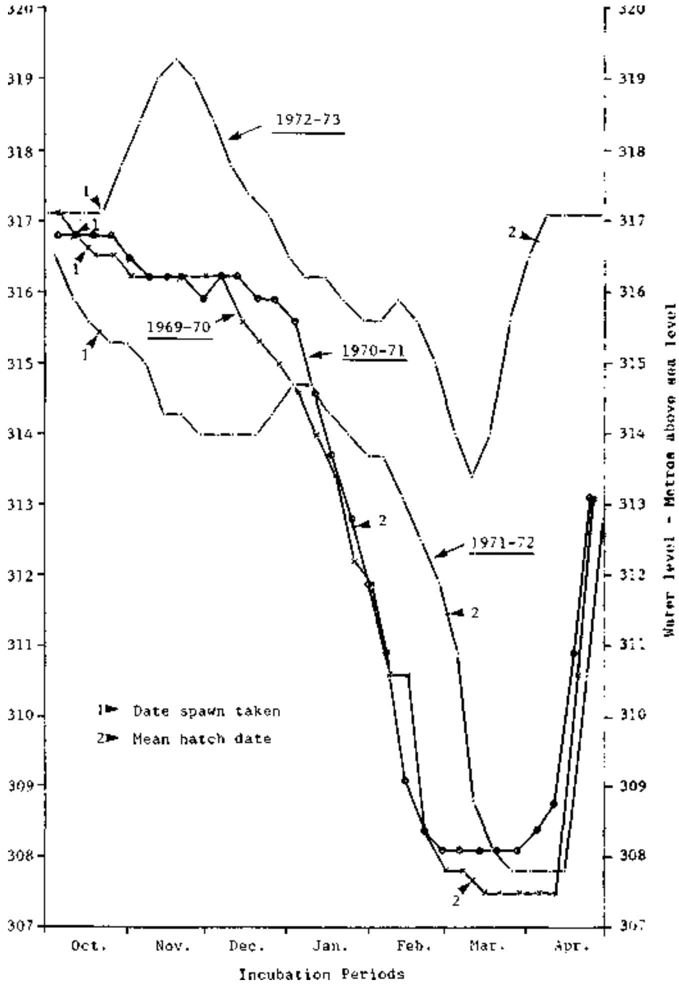

Figure 3. Bark Lake drawdown pattern during incubation, 1969-70 to 1972-73 (Metres above sea level).

carried out prior to the building of the Bark Lake dam.

MARY LAKE

Mary Lake (45°15'N, 79°15'W), situated near Huntsville, Ontario, is on the Muskoka River watershed which flows southwesterly to Georgian Bay (Fig. 1). It has a surface area of 1,060 ha, a mean depth of 24 m and *a* maximum depth of 56 m. The water control structure constructed at the outlet in the early 1930s raised the water by approximately 1 m. The operation of this dam is subject to an agreement between the Ministry of Natural Resources and Ontario Hydro, which states that the water level will not be drawn down more than 0.45 m between October 1 and March 1 of the year next following, but that an additional drawdown of as much as 0.38 m may take place after March 1 but before March 15 in preparation for the spring freshet. Total fall/winter/spring drawdown in Mary Lake therefore may reach 0.83 m.

SPAWNING DEPTHS

Observations made during the 1975 and 1976 spawning seasons on Mary Lake indicated that on one major spawning shoal (Rocky Island), lake trout spawn at depths of between 0.2 m and 0.6 m.

The only other site at which spawning activity was observed was a deeper water shoal located at Dead Man Island. Diving with S.C.U.B.A. at this shoal on the night of October 19, 1979, indicated that the majority of spawning there takes place at depths of from 1 - 1.3 m.

INCUBATION, HATCHING AND SWIM-UP

Two locations where lake trout eggs had been observed in shallow water at Rocky Island shoal during the 1976 spawning period were marked with tape. On March 13, 1977, holes were cut through the ice at these locations exposing a total of 63 eggs, 60 of which were above water because of advancing drawdown and 3 which were still submerged (Fig. 4 and 5).

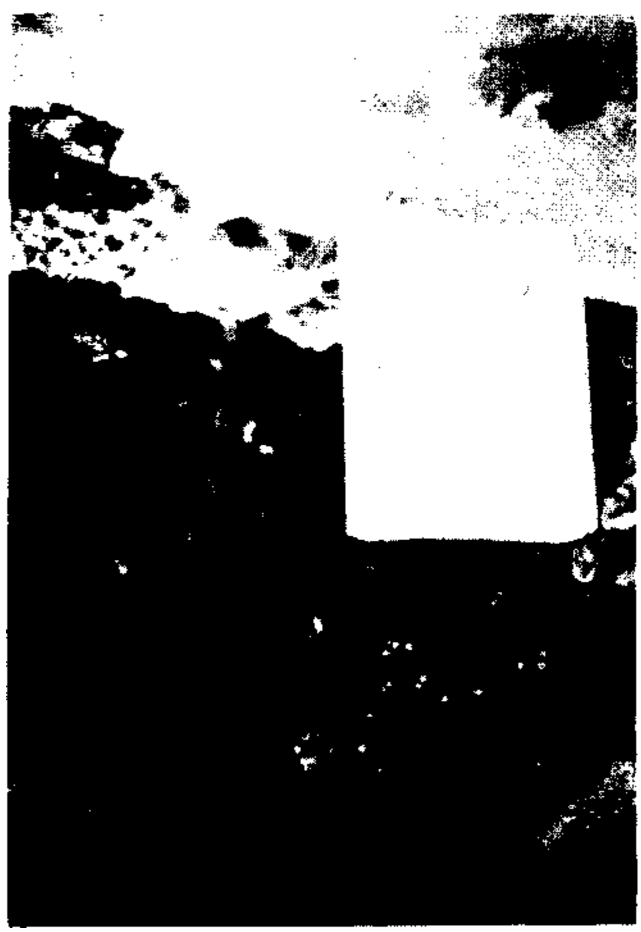

Figure 4. Lake trout egg loss due to water drawdown, Rocky Island shoal, Mary Lake, Ontario, March 13, 1977.

Figure 5. Post spawning drawdown, Mary Lake, Ontario, March 13, 1977. Dead eggs above water, live eggs

rawoown, roary Latce, untario, Marcn eggs above water, live eggs below.

While most of those above the water were dead, 2 eggs still had live embryos within, indicating either there was sufficient moisture among the rocks to prevent total dessication, or that exposure had been recent. Indentations were observed in these 2 eggs indicating that drying had commenced. Those eggs still under water were all viable. Thus it was decided to investigate whether or not long term survival might be possible under the winter ice, considering the possibility of seepage from shore plus the insulating factor afforded by ice and snow.

A recording thermometer was placed beneath the ice at the Rocky Island spawning shoal on January 5, 1978, close to one of the locations where eggs had been seen the previous October. At this time the water level was still high so eggs and thermometer were both submerged. The minimum temperature recorded between January 5 and January 21 was +1.0 C, indicating that the thermometer sensor was still under water. The temperature stayed steady between January 21 and February 5 at approximately +0.8 C. There was then a steady decline in temperature which would appear to indicate lowering of the water with subsequent exposure of the thermometer sensor to the air under the ice. During the period February 6 to February 18 the minimum temperature recorded was -2,0°C. This temperature was reached on February 15 and held until February 16, probably having been caused by a cold snap which commenced on February 15, when at 7:30 a.m. the air temperature was -30 C. Other than this drop, temperatures beneath the ice stabilized in the vicinity of -1.0°C. While ice and snow cover certainly provide insulation from extreme air temperatures, very cold air temperatures, particularly over an extended period may result in the freezing of eggs left exposed by drawdown.

In an experiment to determine the response of lake trout sac fry to simulated drawdown conditions, eggs were removed from Mary Lake and incubated at approximately 4 C in a home laboratory. These eggs hatched on January 28, 1981. A series of tests were then conducted at intervals of several weeks. Rock was collected from Mary Lake similar to that found on the spawning shoals and was placed in a large sloping container. The fry were then introduced into the container in the upper areas of the water and rock. Water was subsequently siphoned slowly from the container in order to lower the water level.

During initial testing on February 24, 1981, the yolk sacs were approximately 50% absorbed and swimming ability appeared strong but as yet was undirected. Invariably the fry would roll beneath the yolk sac when at rest and did not appear to be stimulated by water drawdown until uncovered, by which time movement was not possible.

By March 18, the yolk sacs were approximately 75% absorbed, but the fry preferred to rest among the rocks in the upright position even though strong swimming ability was exhibited during testing. There was still no response to drawdown until the fry were totally exposed, by which time movement was again not possible.

By April 2 the fish had grown much longer and the yolk sacs were approximately 85% absorbed. There was still no response during testing to drawdown until total exposure had occurred, at which time much flailing commenced. Since the fish were, by this time, larger and less encumbered by the yolk sac, it may be possible that some would be able to move by chance down to areas where water was still present. It was felt, however, that the majority of fry at this time would still be lost to drawdown.

DRAWDOWN LOSSES

In an effort to establish lake trout spawning depths, prior to drawdown, four holes each measuring approximately 0.5 m x 2.0 m, were cut through the ice at Rocky Island shoal on December 30, 1978 and January 1, 1979 adjacent to where spawning activity was observed the previous fall. The holes were situated with the long axis running at right angles to shore and extended from shore to water approximately 1.2 m deep. Bottom samples were then obtained from 0 m depth to 1.2 m depth in 0.3 m depth intervals using a vacuum pump, and examined for the presence of lake trout eggs.

The vacuum pump consisted of a 3 horsepower gasoline engine driven water pump having a 1.5 m length of 15 mm diameter copper pipe at the intake end of the vacuum line, and a sealed plastic bucket incorporated into the vacuum line (Fig. 6). The copper pipe served as a depth measuring device and a suction nozzle with which to probe among rocks to dislodge eggs, while the sealed plastic bucket contained a 2 mm mesh screen which retained lake trout eggs for counting. Results are summarized in Table 2.

Figure 6. Vacuum pump used for egg sampling on spawning shoals, Mary Lake, 1978. Sealed plastic bucket traps eggs which are dislodged by copper pipe and drawn through plastic line by intake suction.

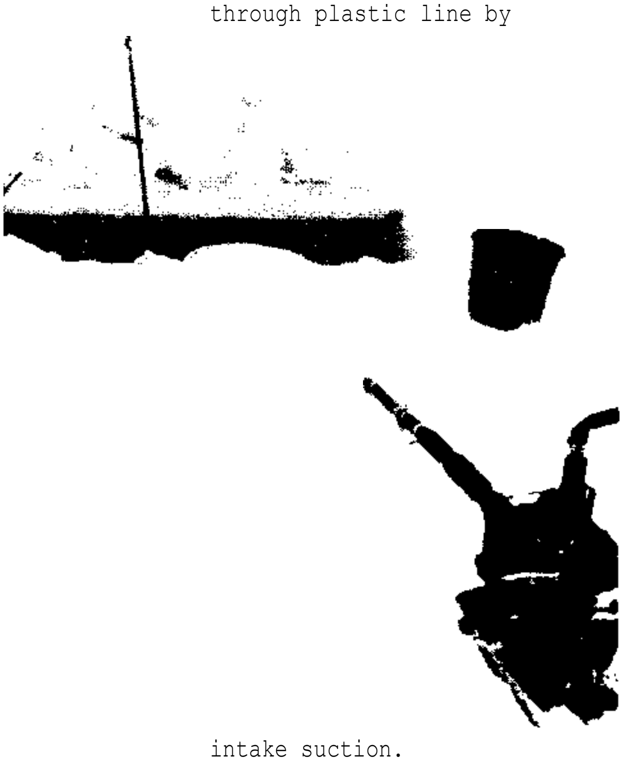

Table 2. Egg depth, Rocky Island shoal, Mary Lake, December 30, 1978 and January 1, 1979.

Hole no.	Depth (m)	Dead eggs	Live eggs	Total
1	0-0.3	8	A	12
	0.3-0.6	2	1	3
	0.6-0.9	0	0	0
	0.9-1.2	0	0	0
		10	5	15
2	0-0.3	12	0	12
	0.3-0.6	6	2	8
	0.6-0.9	0	0	0
	0.9-1.2	0	0	0
		18	2	20
3	0-0.3	0	0	0
	0.3-0.6	3	1	4
	0.6-0.9	0	0	0
	0.9-1.2	0	0	0
		3	1	4
4	0-0.3	0	0	0
	0.3-0.6	2	0	2
	0.6-0.9	0	0	0
	0.9-1.2	0	0	0
		2	0	2

Of the 41 eggs retrieved through sampling with the vacuum pump, 8 were viable and had reached the eyed stage with vertebral columns visible. All of the eggs were located in water 0.6 m or less in depth. Thus, it appears that all the live eggs sampled from the Rocky Island shoal would have been lost from drawdown, since the March 19, 1979 water level was 0.61 m below the October 23, 1978 level, the date on which the heaviest spawning activity was observed at Rocky Island shoal (Fig. 7).

On October 20, 1979, underwater observations were made at the Rocky Island spawning shoal. Fewer than 10 lake trout were observed on the shoal that night indicating that the run was probably past its peak, since as many as 25 trout had been observed at the peak of spawning activity. The entire shoal was checked systematically for signs of cleaning and egg laying from a depth of approximately 4.5 m to approximately 0.46 m, at which depth it becomes difficult to manoeuvre with S.C.U.B.A. Two egg locations were marked at that time, one at a depth of 0.46 m and the other at a depth of 0.41 m. No further indications of spawning activity were found below these depths on the spawning shoal. The following afternoon the remaining portion of the spawning shoal which

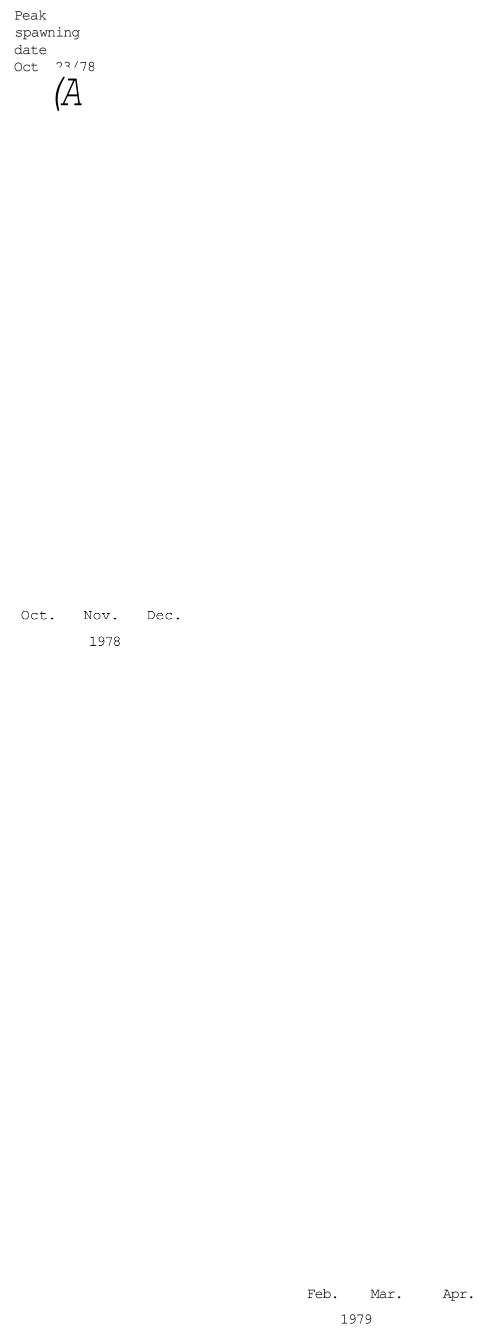

Figure 7. Mary Lake drawdown pattern during incubation, 1978-79. (Metres above maximum drawdown.)

was shallower than 0.46 m was systematically searched. At that time 8 sites containing eggs were found at depths ranging from 0.15 to 0.36 m. It therefore appears that all lake trout eggs deposited at the Rocky Island shoal during the 1979 spawning run would be lost through dessication from water drawdown of 0.83 m during the incubation and pre swim-up fry period.

On the night of October 19, 1979, underwater observations were made at the Dead Man Island shoal in Mary Lake. Spawning activity was evident with up to 20 lake trout observed and we were able to swim among the fish without disturbing them. Egg locations were marked and their depths below the surface ranged from 0.99 to 1.30 m. It therefore appeared that all lake trout eggs deposited at the Dead Man Island shoal were safe from dessication, even with a maximum drawdown of 0.83 m, as the minimum spawning depth was 0.99 m.

Nighttime observations on both shoals using lights and S.C.U.S.A. indicated that the number of lake trout using both shoals for spawning purposes was approximately equal.

Bella Lake (45°26'N, 79°02'W), also situated near Huntsville, Ontario, is near the upper reaches of the Muskoka River system (Fig. 1). It is a much smaller lake than either Bark or Mary, with an area of 330 ha, a mean depth of 16 m and a maximum depth of 39 m. Bella Lake has no water level control structure at its outlet as do Mary and Bark lakes and therefore incubating lake trout eggs are not subjected to manipulated water levels.

Observations indicated that even though lake trout spawn in shallow water in Bella Lake, eggs would not be frozen during incubation because of the way in which ice formation occurred.

SPAWNING DEPTHS

On the night of October 18, 1977, adult lake trout were observed spawning at 2 locations in Bella Lake immediately adjacent to shore in shallow water. Many eggs were seen, all in less than 0.3 m of water, and the locations were marked.

INCUBATION AND HATCHING

On February 8, 1978, the locations at Bella Lake where eggs were sighted on the night of October 18, 1977 were revisited. The ice cover was removed and 3 eggs were observed without disturbing any rocks. Two appeared to be healthy and one was dead. The eggs were still in the same depth of water as originally seen (approximately 0.3 m), indicating virtually no water fluctuation since spawning. On March 16, 1978, the ice cover was once again removed and the rocks were moved to search for fry. Two egg shells were found indicating that hatching had taken place between February 8 and March 16. As well, one lake trout fry with a sizable yolk sac was observed under a rock.

ICE FORMATION

In lakes like Bella where there are no water level manipulations there is a question whether or not lake trout eggs deposited in shallow water would be lost due to ice formation. If such were the case then drawdown losses could be of less significance than indicated in Bark and Mary Lakes, since some of the eggs lost to drawdown could be vulnerable to freezing, and therefore killed regardless of drawdown. As previously mentioned, egg locations were marked in Bella Lake during the 1977 lake trout spawning season. It was observed while removing the ice cover over these eggs on February 8, 1978, that the ice closer to the shore was noticeably thinner than the offshore ice. For example, one block of ice removed was 0.10 m thick on the inshore edge and 0.15 m thick on the offshore edge (Fig. 8). This phenomenon may be the result of several factors, namely:

1. Pileup of snow against shore from prevailing northwest winds giving greater insulation to inshore ice.
2. Anchoring of ice to shore does not allow for cracking, sinking, and subsequent formation of new slush ice, as occurs with offshore ice.
3. Proximity to shore and bottom increases likelihood of heat exchange from unfrozen ground and seepage of ground water.

This may also partly explain why even though lake ice always forms first at shore, it is generally the shore ice which breaks up first in the spring. It would appear from these observations that lake trout eggs deposited in shallow water adjacent to shore are therefore not likely to be harmed by ice formation.

DISCUSSION

The relationship between water level fluctuations and lake trout reproduction has been studied in a number of areas. In Lake Minnewanka, Alberta, Rawson (1945) reported that the recent completion of a second hydro dam raise the lake level above the original level by about 26 m, giving rise to annual fluctuations of as much as 11 m. He found that whereas spawning may previously have occurred at depths between 1.5 and 6.2 m, some eggs were now deposited between depths of 7.6 and 9.4 m and "no doubt in shallow water also". He concluded that there was no danger to the eggs if drawdown was not to exceed 3 m by the end of February but "it is unlikely that any appreciable number of lake trout eggs would escape in 1944 or any year in which the usual drawdown of about 30 feet [9.1 m] occurred".

Miller and Paetz (1959) also suggested that trout and char populations in high altitude lakes in Alberta have deteriorated very markedly, mainly because of the elimination of suitable spawning sites after power developments. On the other hand, Cuerrier (1954) working on Lake Minnewanka, Alberta, concluded that natural spawning is successful in the lake since greater vertical distribution of spawning now occurs than *it* did prior to dam construction. This is contrary to my findings in Bark Lake and most other areas where extensive drawdowns occur.

In Ontario lakes, Whitfield (1950) found that in Lake Wanapitei, where drawdowns averaged 2.4 m, the annual loss of eggs averaged 26.3%. Martin (1955) felt that in Hay Lake, where drawdowns were as much as 1.5 m, most egg depositions would be exposed to the air. In Lake Opeongo, however, a large lake with deeper spawning grounds (0.9 to 3.7 m) *a* maximum possible drawdown of 0.6 m had little effect on spawning success.

In Maine lakes, DeRoche (1969) found, that lake trout spawn in Thompson Lake and Cold Stream Pond at water depths ranging from 0.2 to 1.2 m, but that most spawning is done at depths of about 0.3 m. He maintained that drawdown of as little as 0.3 m occurring after lake trout spawning could cause very high egg loss.

Figure 8. Ice removed at Bella Lake to check natural lake trout incubation success, February 8, 1978. Note that upper (inshore) portion of ice block is considerably thinner than lower (offshore) portion.

Similar conclusions have been reached in Europe, in the case of the lake spawning Arctic char *(Salvelinus alpinus)*• In Lake Toron, Sweden, spawning depths extended from approximately 1 to 15 m after the building of control dams (Runnstrom 1951). In some years up to 50% of the char spawn was exposed. However, Runnstrom (1951) felt that there was such an abundance of spawn deposited in deeper waters that neither the destruction of eggs laid in shallow water, nor planting of hatchery fry had any effect on year-class strength.

Emergence from the spawning beds usually occurs at the swim-up fry stage. Royce (1951), Martin (1955), DeRoche (1969), Gillespie (1983) and MacLean and Hicks (Harkness Lab., unpubl. data) all found that emergence usually does not take place in lakes at this latitude until early May, or when water temperatures approach 8 - 10°C.

Contrary to the findings in the present study, Runnstrom (1951) found, on the basis of laboratory tests, that char fry became good enough swimmers several weeks after hatching to be able to follow receding water levels. In my experiments it was found that most lake trout sac fry were unable to move ahead of drawdown a full 8 weeks after hatching. It is likely too that these fry would be more vulnerable to predation, particularly if suitable substrate was not available.

In Norway, Aass (1964) concluded that year-class strength of Arctic char may be adversely affected in Palsbufjord in years when water drawdown takes place early in the winter because approximately three-quarters of the bottom area is laid dry.

In Bark Lake, Ontario, the lake trout appear to have abandoned the old, deeper spawning beds which are now 10.5 - 12 m below high watermark and they are using new, shallow-water beds in less than 3 m of water. The minimum drawdown during the lake trout incubation period in this lake between 1969 and 1972 was 3.8 m. As a result, all eggs in these years would be lost.

An improvement in the Bark Lake fishery, resulting from annual plantings of 15,000 marked yearling lake trout was evident from creel survey data collected in 1966, 1969, 1972 and 1979, by which time 87% of lake trout caught by anglers were of hatchery origin (L.K. Buckingham, unpubl. data). Natural reproduction in Bark Lake is now virtually absent.

In Mary Lake, where maximum water level drawdowns may reach 0.83 m, lake trout still spawn on one spawning bed at depths of 0.99 - 1.24 m. No egg loss occurs as a result of drawdown. On a shoal where spawning occurs at 0.15 - 0.6 m, however, there likely is a loss of all eggs.

Bella Lake has no control dams and is not subject to major water level fluctuations. Spawning largely takes place in less than 0.3 m of water. Experiments conducted in this lake indicate that these eggs would probably not be lost to ice cover as the ice in shallow water is significantly thinner due to the insulating effects of snow cover, anchoring of ice to shore, ground heat exchange and water seepage.

CONCLUSIONS

It is evident from previous studies and this paper that the effects of water level fluctuations on lake trout reproductive success vary from lake to lake. Where major drawdowns occur as in Bark Lake (max. 10 m) and Lake Minnewanka (max. 11 m) egg and possibly fry losses can be high. In Bark Lake, water drawdowns resulted in almost the complete loss of natural reproduction of lake trout. If drawdown patterns allowing natural reproduction cannot be achieved, hatchery stocking of lake trout may be required in lakes such as Bark, if a viable lake trout fishery is to be attained. However, this would not negate the possibility that unique genetic stocks may be lost.

In lakes with more moderate drawdowns, one of the problems managers must solve is how much water drawdown can occur before losses adversely affect year-class strength. Timing of drawdowns may also be critical in such lakes, since even after hatching it is unlikely that sac fry will swim ahead of drawdown prior to reaching the swim-up fry stage. Negotiations between the responsible fishery agency and the water level regulator may be required to minimize egg or fry losses and ensure the continuance of lake trout stocks. Water level regulation regimes which provide a 'margin of safety' are especially critical in lakes such as Mary where the lake trout spawn in shallow water and at least some of the lake trout spawning shoals are exposed by drawdowns.

In lakes where spawning occurs in very shallow water (0.3 m) but where there are no water control dams and no major natural water level fluctuations, as in Bella Lake, egg survival can be high. Water level fluctuations are probably not a stress to lake trout in these lakes.

It is difficult to make general assumptions about the impact of water level manipulations and fluctuations on lake trout reproductive success as conditions vary so much from lake to lake that an individual assessment of each lake may be in order.

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