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Arctic Grayling and Burbot Studies in the Fort Knox Water Supply Reservoir, Stilling Basin, and Developed Wetlands, 2002

by Alvin G. Ott
and William A. Morris

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Photo by Alvin Ott, Pond F in the Wetland Complex

ARCTIC GRAYLING AND BURBOT STUDIES IN THE FORT KNOX WATER SUPPLY RESERVOIR, STILLING BASIN, AND DEVELOPED WETLANDS (2002)

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Acknowledgements

Our thanks to Fairbanks Gold Mining Inc. (Richard Dye, Clyde Gillespie, Tom Irwin, Bill Jeffress) for their support of our field work and their continued commitment to conduct concurrent rehabilitation in the wetlands between the tailing impoundment and the water supply reservoir. We also thank Alaska Department of Fish and Game employees Nancy Ihlenfeldt, Laura Jacobs, Phyllis Weber Scannell, Jack Winters, and Alan Townsend, who assisted with fieldwork. Jack Winters, Phyllis Weber Scannell, Bill Jeffress, and Clyde Gillespie provided constructive review of our report.

Executive Summary

Water Quality

- dissolved oxygen concentrations continue to be low in the water supply reservoir (WSR) – page 11
- dissolved oxygen concentrations decrease with depth in both summer and winter – page 11
- main source of dissolved oxygen during winter is input from Solo Creek – page 11
- conductivity generally has decreased since the water supply reservoir flooded – page 15

Arctic grayling

- Arctic grayling successfully spawned in the wetland complex in spring 2002 – page 23
- spawning in the wetland complex was completed between May 30 and June 2 when peak daily water temperatures exceeded 10°C – page 23
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- the estimated population in spring 2001 was 5,623, a slight increase from spring 2000 – page 29
- annual growth rates for small (< 250 mm) Arctic grayling are comparable with growth rates seen in the WSR during the first three years following construction – page 29
- outmigration of Arctic grayling from the WSR was substantial between spring 2001 and 2002; about 30% of the 2001 marked fish left the WSR – page 29

Burbot

- successful spawning of burbot in the WSR was assumed based on catches of small juvenile burbot in hoop traps – page 33
- the estimated population for burbot > 200 mm in summer 2002 was 1, 763 – a substantial decrease from summer 2001 – page 32
- the estimated population for burbot > 400 mm in summer 2001 and 2002 was 134 and 131, essentially no change – page 32
- annual growth rates continue to be higher for small burbot (< 275 mm) and for larger burbot (> 400 mm) – page 33

Introduction

Fairbanks Gold Mining, Inc. (FGMI) began construction of the Fort Knox hard-rock gold mine in March 1995. The mine is located in the headwaters of the Fish Creek drainage about 25 km northeast of Fairbanks (Figure 1). The project includes an open-pit mine, mill, tailing impoundment, water supply reservoir (WSR), and related facilities. In 2001, FGMI began development of the True North Mine located west of Pedro Dome. Trucking of ore from the True North Mine to the Fort Knox Mine for processing began in April 2001.

During construction of the WSR, we monitored activities (e.g., stream diversions, erosion control, culvert placement) in the field and summarized the various aspects of dam construction (Ott and Weber Scannell 1996, Ott and Townsend 1997). Construction of the WSR dam and spillway was complete by July 1996.

Rehabilitation, to the extent practicable, has been concurrent with mining activities and natural revegetation of disturbed habitats has been rapid. Development of wetlands between the tailing dam and the head of the WSR began in summer 1998 with additional civil work, seeding, and willow sprigging occurring annually since 1998. Repair work on the dike separating Ponds D and E in the wetland complex was done in fall 2002.

Fish research initiated in 1992, focused on streams in and downstream of the project area (Weber Scannell and Ott 1993). In 1993, sampling to determine if a population of fish was available to colonize the WSR continued, and we began to collect fish data in abandoned settling ponds and mine cuts that would be flooded by the WSR (Weber Scannell and Ott 1994). In 1994, we established and sampled stream reaches above and below the area to be flooded (Ott et al. 1995).

Stream sampling continued in 1995 and we estimated the size of the Arctic grayling (*Thymallus arcticus*) and burbot (*Lota lota*) populations that would be available to colonize the WSR. The Arctic grayling population in Fish Creek, upstream of

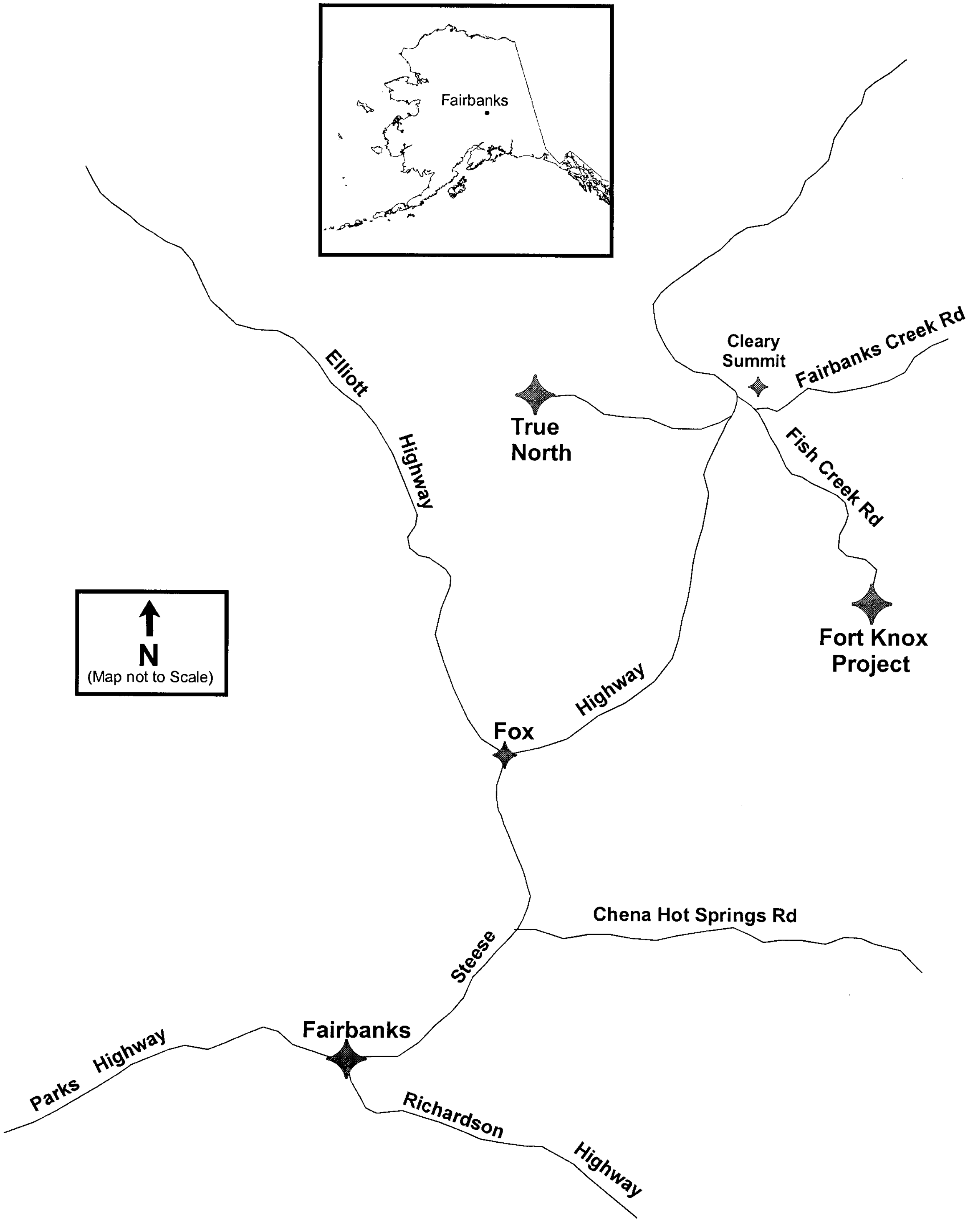


Figure 1. Fort Knox project location.

the WSR dam in 1995 was estimated at 1,700 individuals <150 mm, and 4,350 individuals >150 mm. The number of burbot, between 150 and 331 mm, in the upper Fish Creek drainage, was estimated at 876 fish.

From 1996 to present, we have monitored Arctic grayling and burbot use of the WSR, gathering information on growth, production of age-0 fish, and catch per unit of effort (CPUE) (Ott and Weber Scannell 1996, Ott and Townsend 1997, Ott and Weber Scannell 1998, Ott and Morris 1999, Ott and Morris 2000, Ott and Morris 2001, and Ott and Morris 2002). Our water quality monitoring program began in 1997 and continues annually. We expanded the scope of our fisheries work to include the constructed wetlands in spring 1999 and began field work in the stilling basin below the WSR dam in spring 2001. Our report summarizes fish and water quality data collected during 2002 and discusses these findings in relation to previous work.

Methods

Sampling Sites

Water quality sampling began in fall 1997 in the WSR and in summer 1999 in the developed wetlands. Multiple fyke-net sampling sites have been used (Figures 2 and 3) to target Arctic grayling. Changes in fyke-net locations have been due to finding the most effective catch sites and to major water surface elevation changes. Sites were added in the constructed wetlands after Channel #5 was constructed in spring 1999. In spring 2002, fyke-nets were fished at four stations (#11, #14, #16, and #17) in the WSR and at three stations in the stilling basin below the WSR. The general area for each fyke-net was fixed in spring 2002 as the sites were not affected by the water surface elevation in the WSR. In spring and fall 2002, hoop traps targeting burbot were fished throughout the WSR, both east and west of the Gil Extension road crossing.

Water Quality

Temperature (°C), dissolved oxygen concentration (mg/L), dissolved oxygen percent saturation (barometrically corrected), pH, specific conductance (u S/cm), and depth (m) were measured with a Hydrolab® Minisonde® water quality multiprobe connected to a Surveyor® 4 digital display unit. The meter was calibrated to suggested specifications prior to use in the field. The dissolved oxygen concentration was calibrated using the open-air method. Conductivity and pH were calibrated with standard solutions. Water quality measurements were made at the surface, at 1 m depth intervals, and at the bottom.

Fish

Field sampling methods and gear included visual observations, fyke-nets, seines, and hoop traps (Figure 4). Burbot and Arctic grayling captured during May and June were measured and marked with a numbered Floy® internal anchor tag. During the burbot recapture event in late fall, all fish were measured and marked fish were recorded.

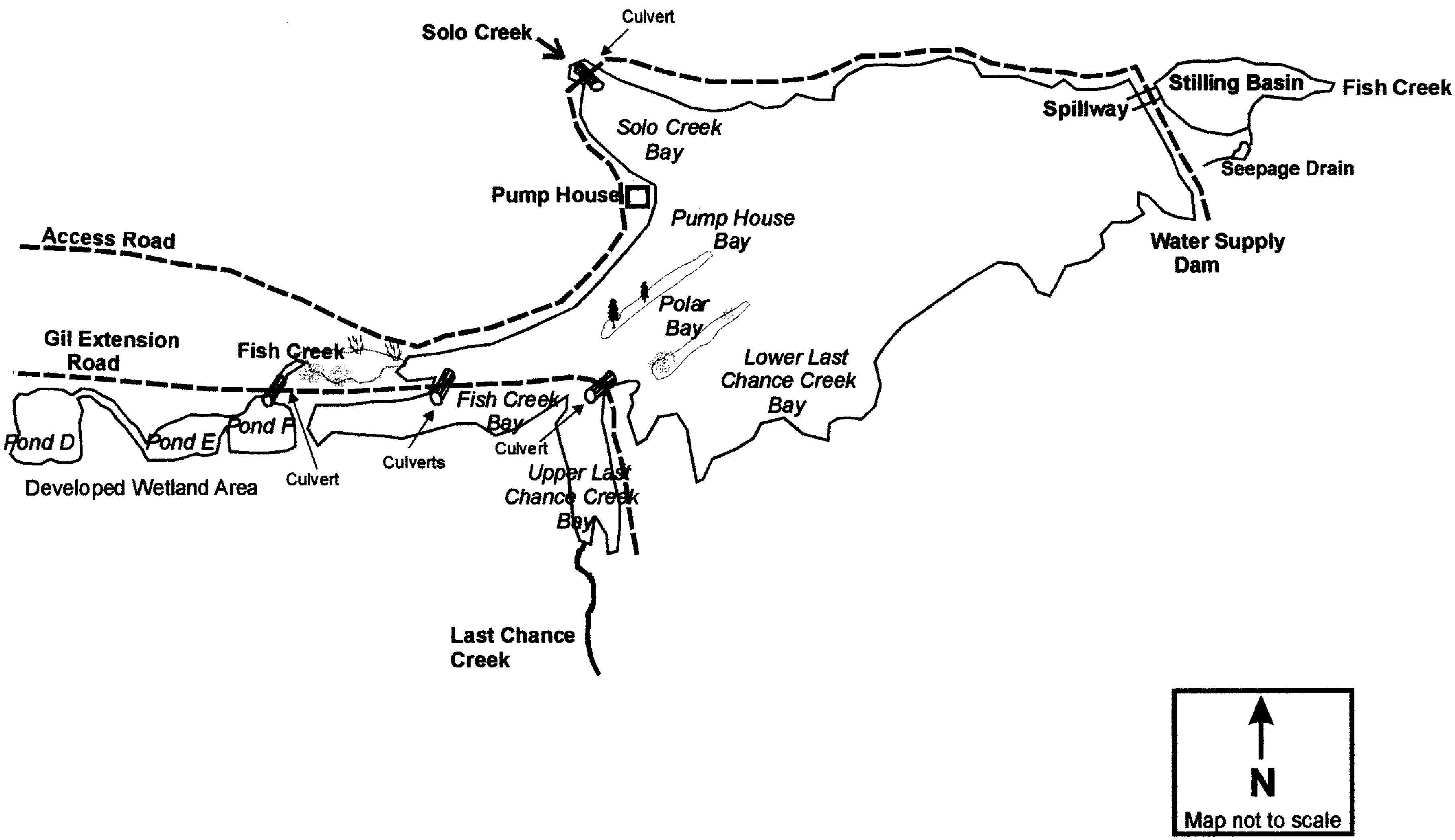


Figure 2. Sample areas in the Fort Knox water supply reservoir, stilling basin, and developed wetlands.

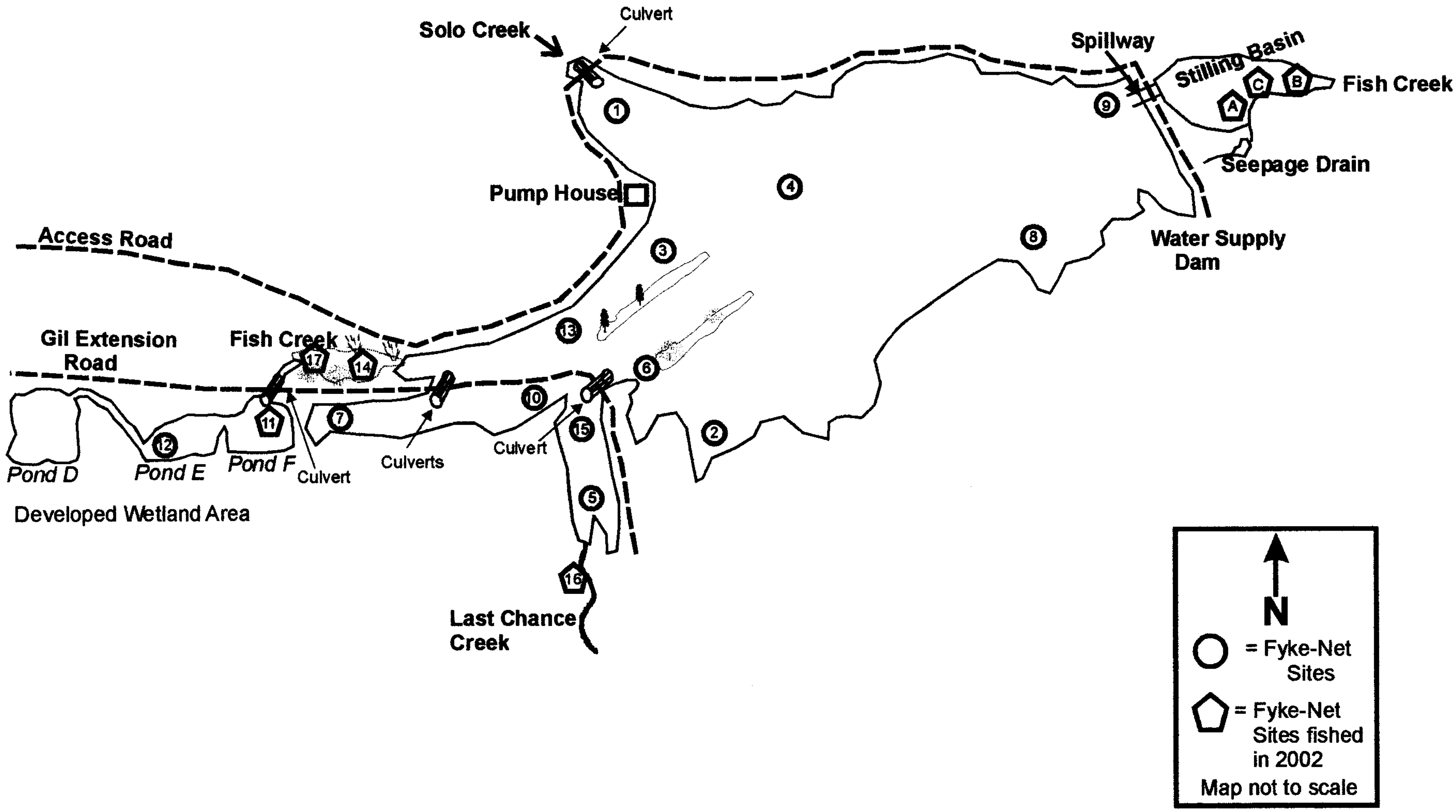


Figure 3. Fyke-net sample sites in the Fort Knox water supply reservoir, stilling basin, and developed wetlands (1996-2002).

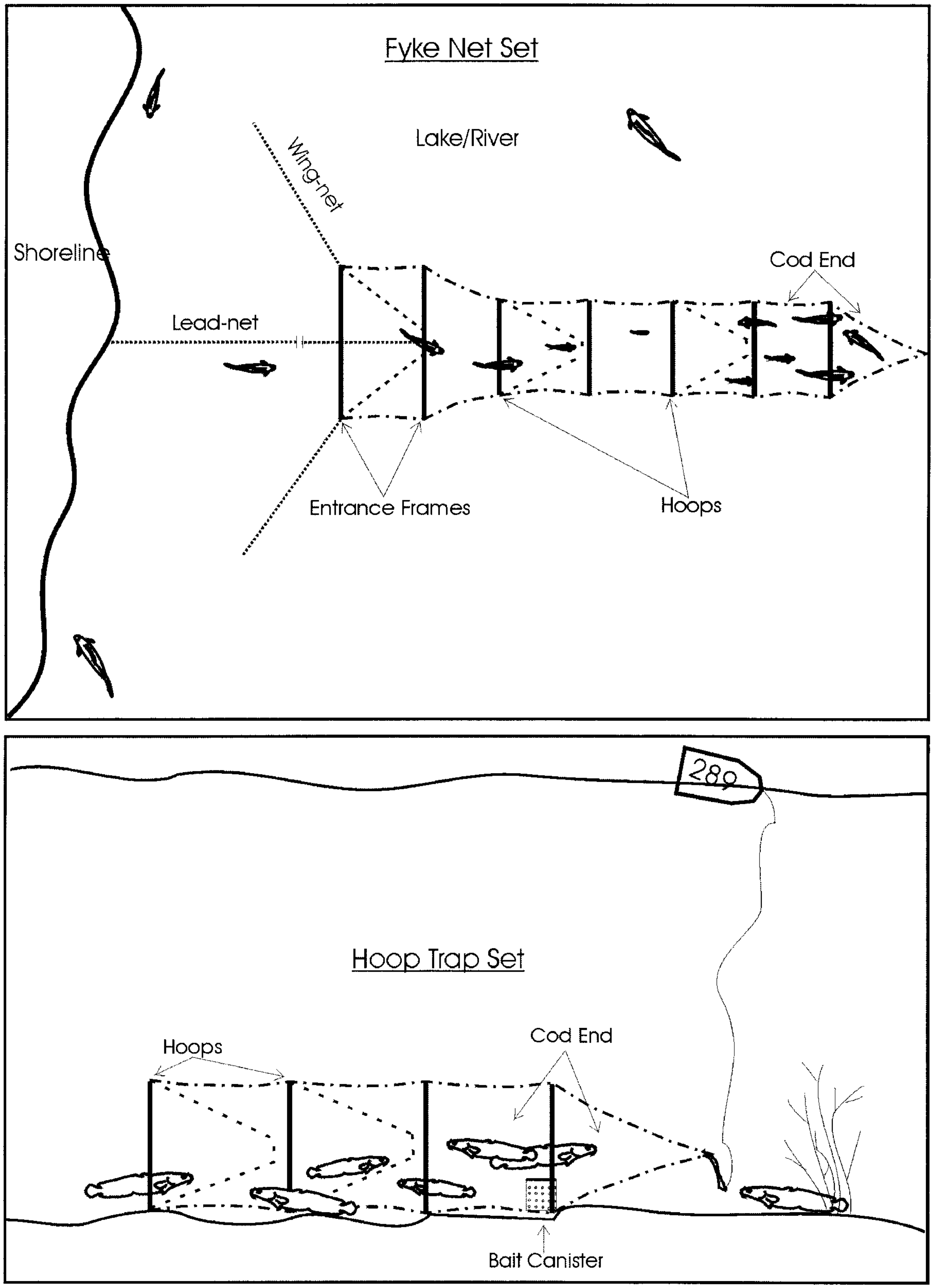


Figure 4. Diagram of fyke-net and hoop trap sets.

Three sizes of fyke-nets were used. Entrance frames were either 0.9 m^2 or 1.2m^2 or 0.69 m by 0.99 m (mini-fyke). The larger fyke-nets were 3.7 m long, had five hoops, a 1.8 m cod end, and two 0.9 m by 7.6 m wing nets attached to the entrance frame. The mini-fyke nets were 3.7 m long, had four hoops, a 1.8 m cod end, and two 0.91 m by 4.6 m wing nets. All netting was 10 mm square mesh. Center leads varied from 7.6 m to 30.4 m and were deployed to the maximum extent possible without submerging the top of the entrance frame. Nets were set with the center lead either perpendicular to or at an angle to the shore. Unbaited fyke-nets were fished about 24 hrs and either reset or removed.

Hoop traps baited with whitefish were used to capture burbot. Traps generally were fished 48 hrs and were rebaited if reset. Hoop traps were 1.6 m long with four hoops 54 cm in diameter. Netting was 8.5 mm bar mesh. All traps were kept stretched and open with spreader bars. Each trap had two throats and a cod end that was tied shut.

The abundance of Arctic grayling and burbot was estimated using Chapman's modification of the Lincoln-Petersen two-sample mark-recapture model (Chapman 1951),

$$\hat{N}_c = \left\{ \frac{(n_1+1)(n_2+1)}{(m_2+1)} \right\} - 1,$$

where $\hat{N}_c$ = estimated population, n_1=fish marked in first capture event, n_2=fish captured during recapture event, and m_2=fish captured during recapture event that were marked in the capture event. Variance was calculated as: (Seber 1982)

$$\text{var}(\hat{N}_c) = \left\{ \frac{(n_1+1)(n_2+1)(n_1-m_2)(n_2-m_2)}{(m_2+1)^2(m_2+2)} \right\}.$$

95% CI for the population estimate was calculated as

$$95\% C.I. = N_c \pm (1.960)\sqrt{\hat{\text{var}}(\hat{N}_c)}.$$

Results and Discussion

Water Supply Reservoir, Water Quality

Five water quality sample sites were established and sampled in the WSR beginning in fall 1997 (Figure 5). Two new sites were added in fall 2002 – both located upstream of the Gil Causeway crossing. Data collected at these seven sites during all sample events are presented in Appendix 1.

Ponding of water behind the WSR dam began in November 1995. Water levels varied widely in 1996 and 1997, due to water use and winter seepage below the dam that exceeded freshwater input. The WSR reached the projected maximum surface elevation of 1,021 feet on September 29, 1998 following summer rainfall. The WSR contains 3,363 acre-feet (1.096 billion gallons) of water when water begins to flow through the low-flow channel in the spillway.

Water levels during summers 1999 and 2000 were fairly constant and flow through the low-flow channel in the spillway was present. In winter 2000/2001, about 1,464 acre-feet (477 million gallons) of water were pumped from the WSR to the tailing impoundment and water did not flow over the spillway until mid-summer 2001 (Table 1). Water use during winter 2001/2002 was much lower than in the previous winter and water began flowing over the spillway on May 10, 2002.

Table 1. Winter water use from the WSR, 1997 through 2002.

Year	Acre-Feet of Water Removed
1997/1998	660
1998/1999	605
1999/2000	577
2000/2001	1,464
2001/2002	320

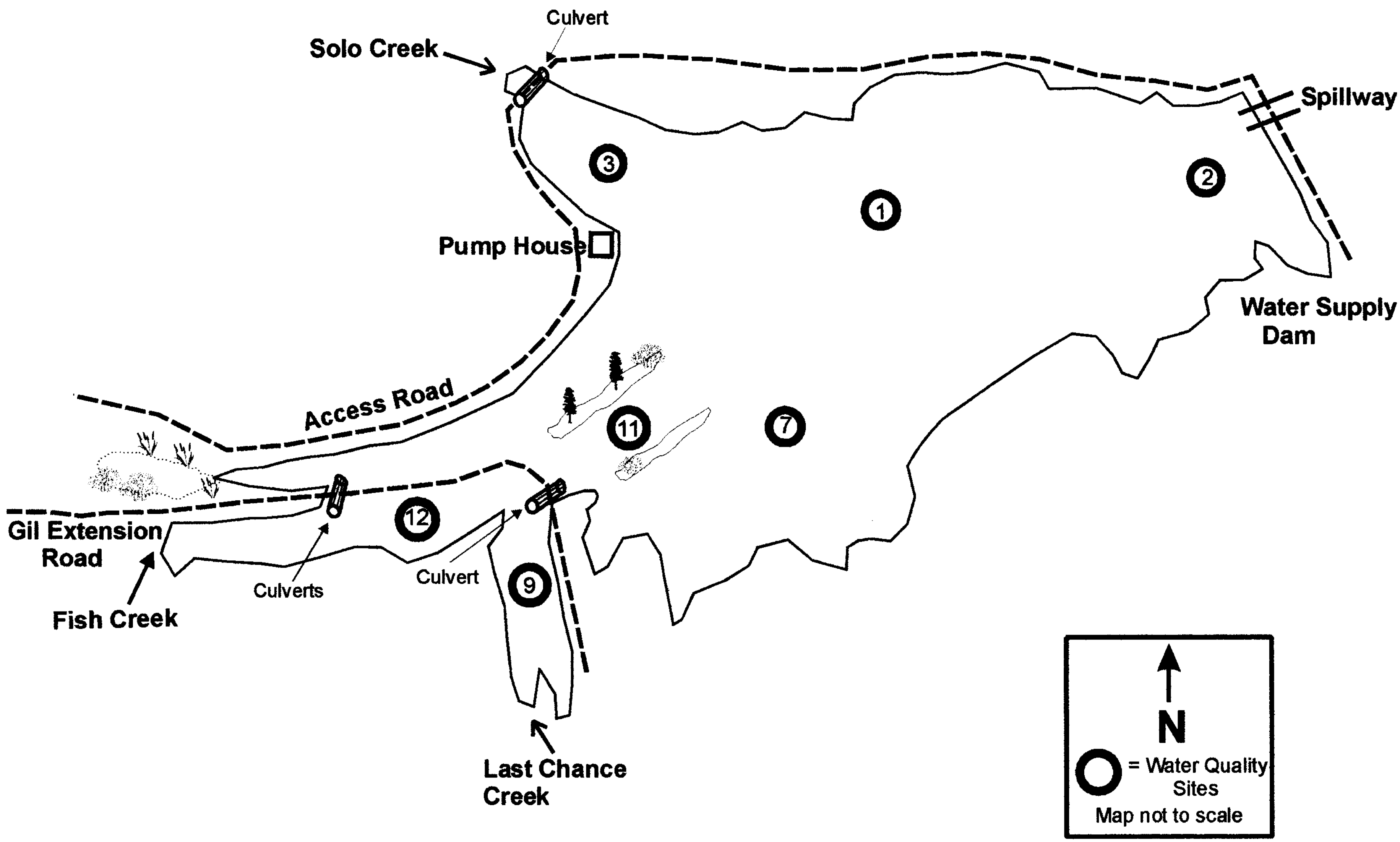


Figure 5. Water quality sample sites in the Fort Knox water supply reservoir.

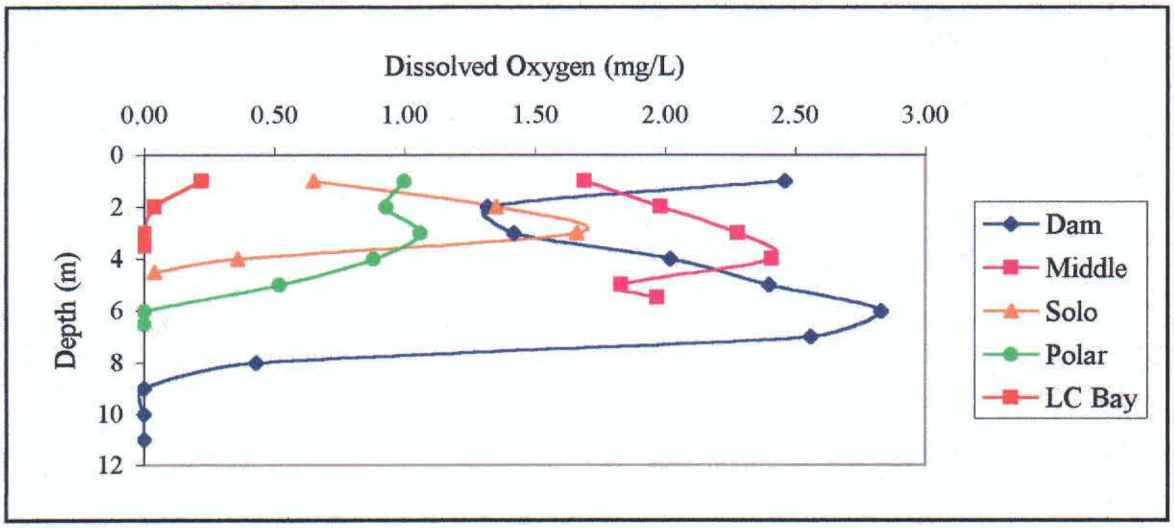
Seepage flow below the freshwater dam is monitored frequently. Seepage flow has remained fairly constant for the last four years (Table 2).

Table 2. Seepage flow rates below the WSR dam.

Year	Rate of Flow (cfs)	Geometric Mean (cfs)
1999	1.16 to 1.82	1.47
2000	1.03 to 1.86	1.38
2001	1.03 to 1.78	1.31
2002	1.13 to 1.78	1.41

Water quality information was collected in the WSR in April (late winter), May (immediately after breakup), and September (prior to freezeup) in 2002. In April, before breakup, patterns of dissolved oxygen (DO) in Solo Bay and in the middle of the reservoir were similar, but higher in the middle portion of the water column (Figure 6). It was suspected that the source of the higher DO water was Solo Creek and additional sample holes were drilled. Much higher concentrations were found in an area about 20 m from the shore (Figure 6). It would appear, based on the DO concentrations found at all five sites in April 2002 that the major source of DO was from Solo Creek. Solo Creek water during winter is likely responsible for the successful overwintering of Arctic grayling and burbot in the WSR. An increase in DO in Polar Bay to slightly above 1.00 mg/L at the 3 m depth suggests some input from Last Chance Creek.

Site #2, located near the spillway in the deepest portion of the WSR, has decreased DO concentrations with depth to 2 m, then increased concentrations from 2 to 6 m, followed by further decreases from 7 m to the bottom in late winter 2002 (Figure 7). A similar pattern was seen in April 2001, but overall the winter DO concentrations were higher in winter 2001 - the same year of substantial winter water removal (Table 1).



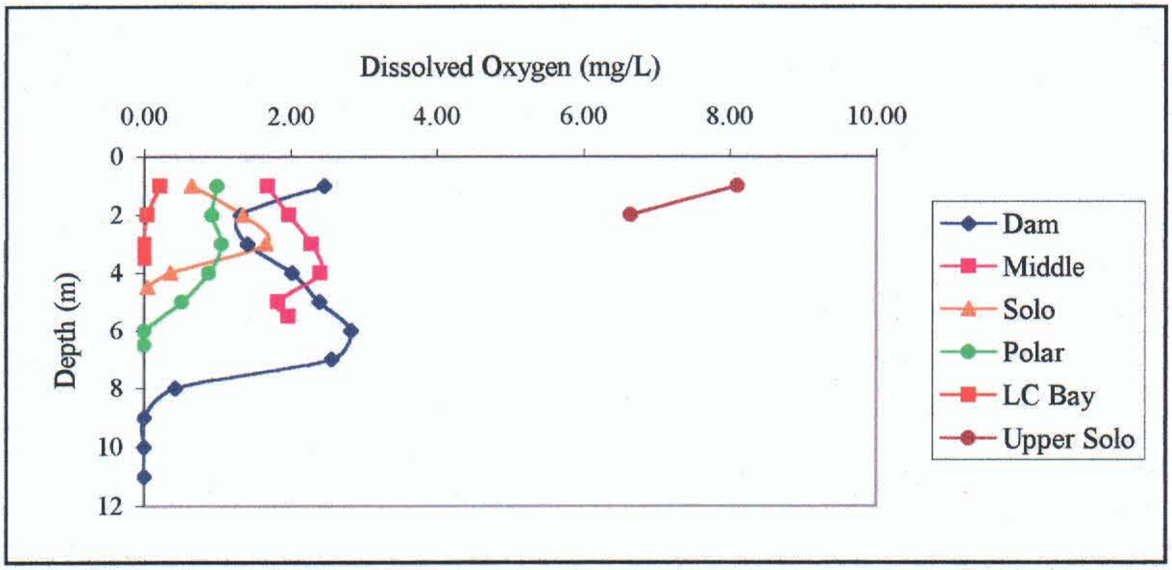
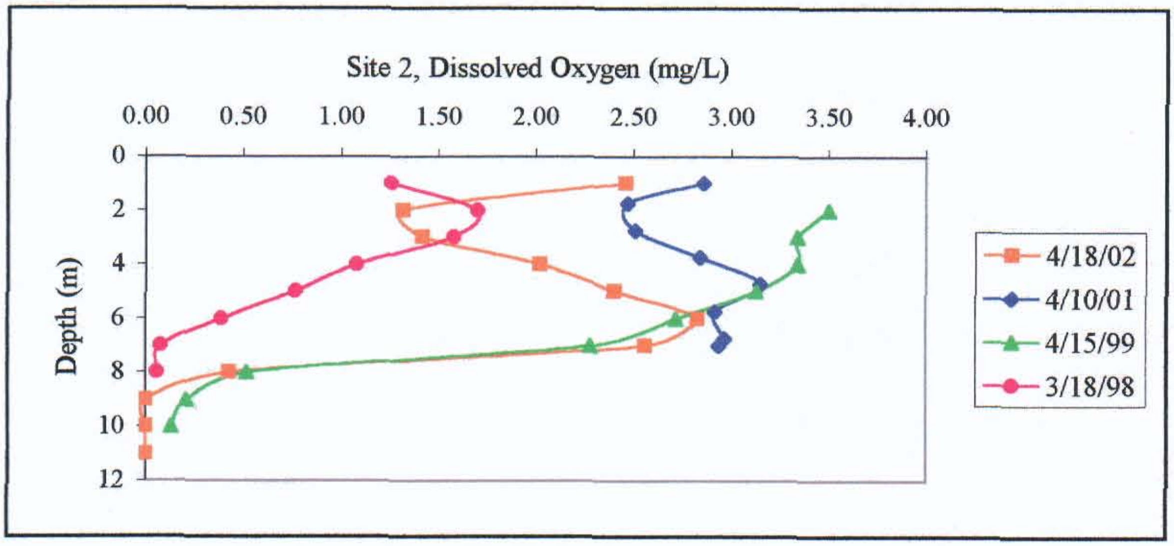


Figure 6. Dissolved oxygen concentrations at all five sites by depth in the WSR in late winter 2002, including a site located in upper Solo Bay where high dissolved oxygen concentrations were found. The above two graphs are the same except that the bottom graph includes a second site in Solo Bay where dissolved oxygen concentrations were substantially higher.



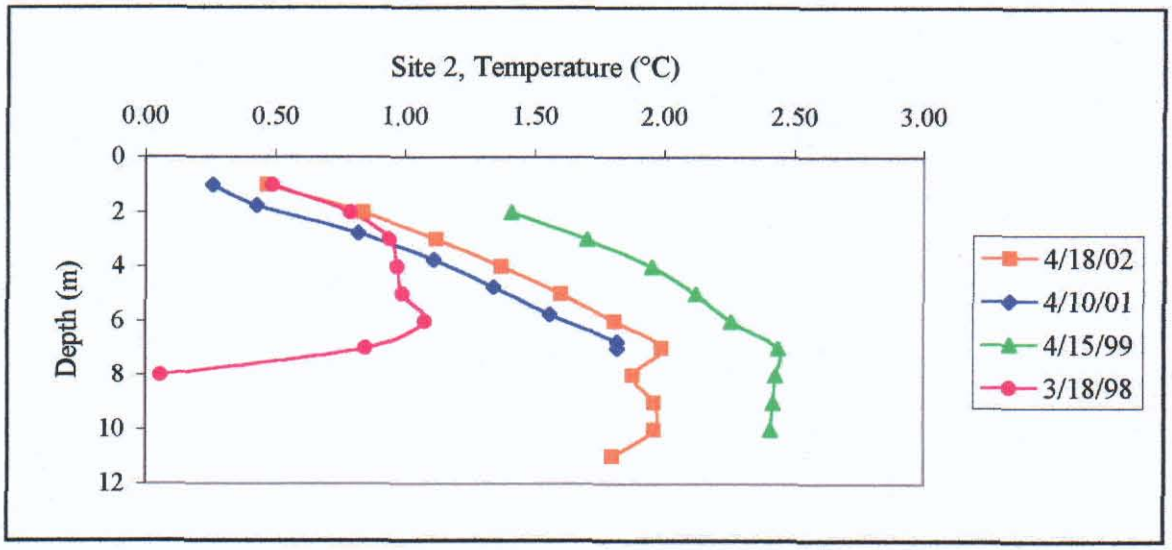
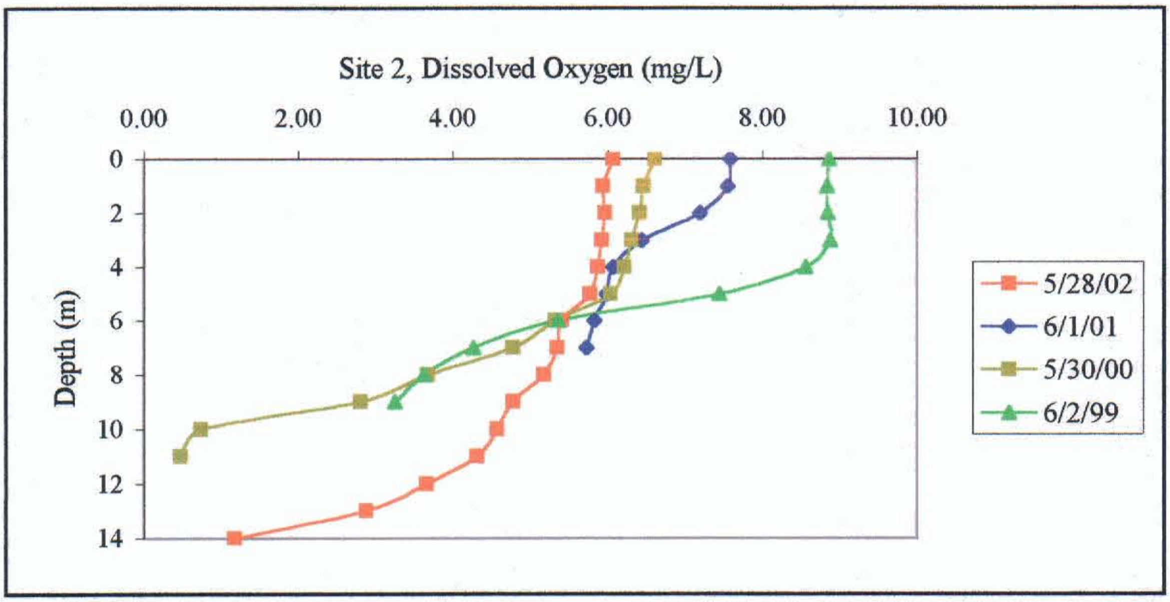


Figure 7. Dissolved oxygen concentration and temperature at Site #2 (near spillway) by depth in the WSR in late winter 1998, 1999, 2001, and 2002.

In spring 1999, 2000, 2001, and 2002, just after breakup, DO concentrations decreased with depth (Figure 8). Except for 1999, DO concentrations were highest in spring 2001 (Figure 8).

We concluded that the removal of large quantities of low oxygen water during winter from the hypolimnetic zone of the WSR has a beneficial effect to the overall concentrations of DO. Removal of a substantial percentage of the low DO water consistently present in the deeper portions of the WSR, and a constant supply of high DO water from Solo Creek appears to maintain higher DO concentrations within the water body during winter. No comparable volume of water has been removed either before or after winter 2000/2001 to offer any means of comparison.

Both conductivity and pH were highest in the WSR in late winter in 1998 (Figure 9). The pH dropped about one unit in spring 1999. Conductivity has shown a steady decrease the last several years with the exception of spring 2001 (Figure 9). Again, the removal of water from the hypolimnetic zone, where conductivities are consistently higher, probably explains the decrease seen in late winter 2001.



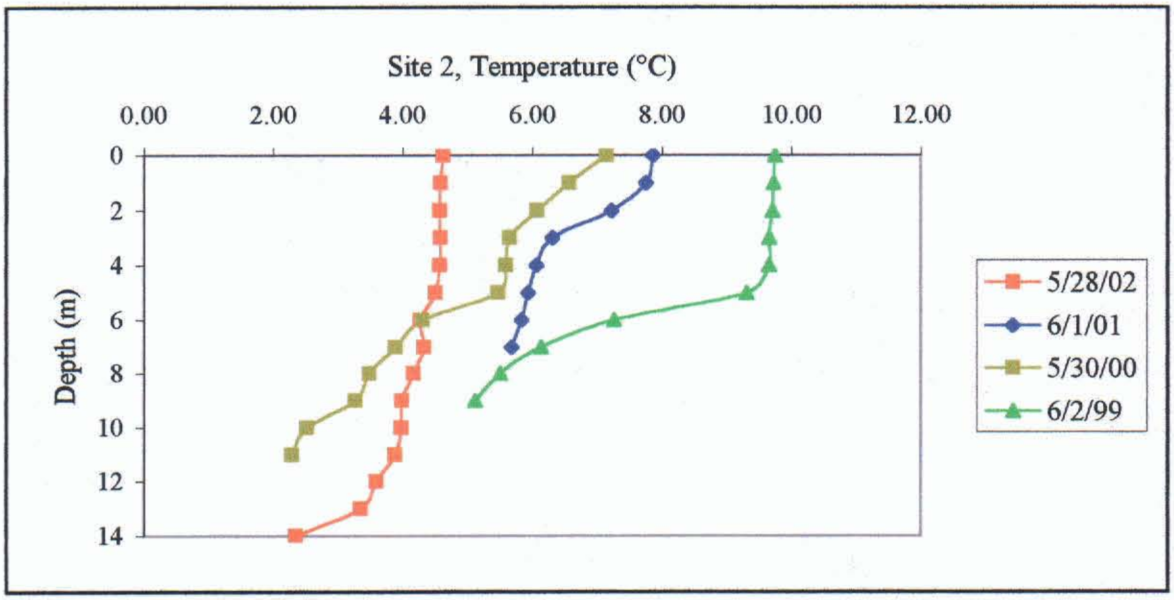


Figure 8. Dissolved oxygen concentration and temperature at Site #2 (near spillway) by depth in the WSR in early spring 1999, 2000, 2001, and 2002.

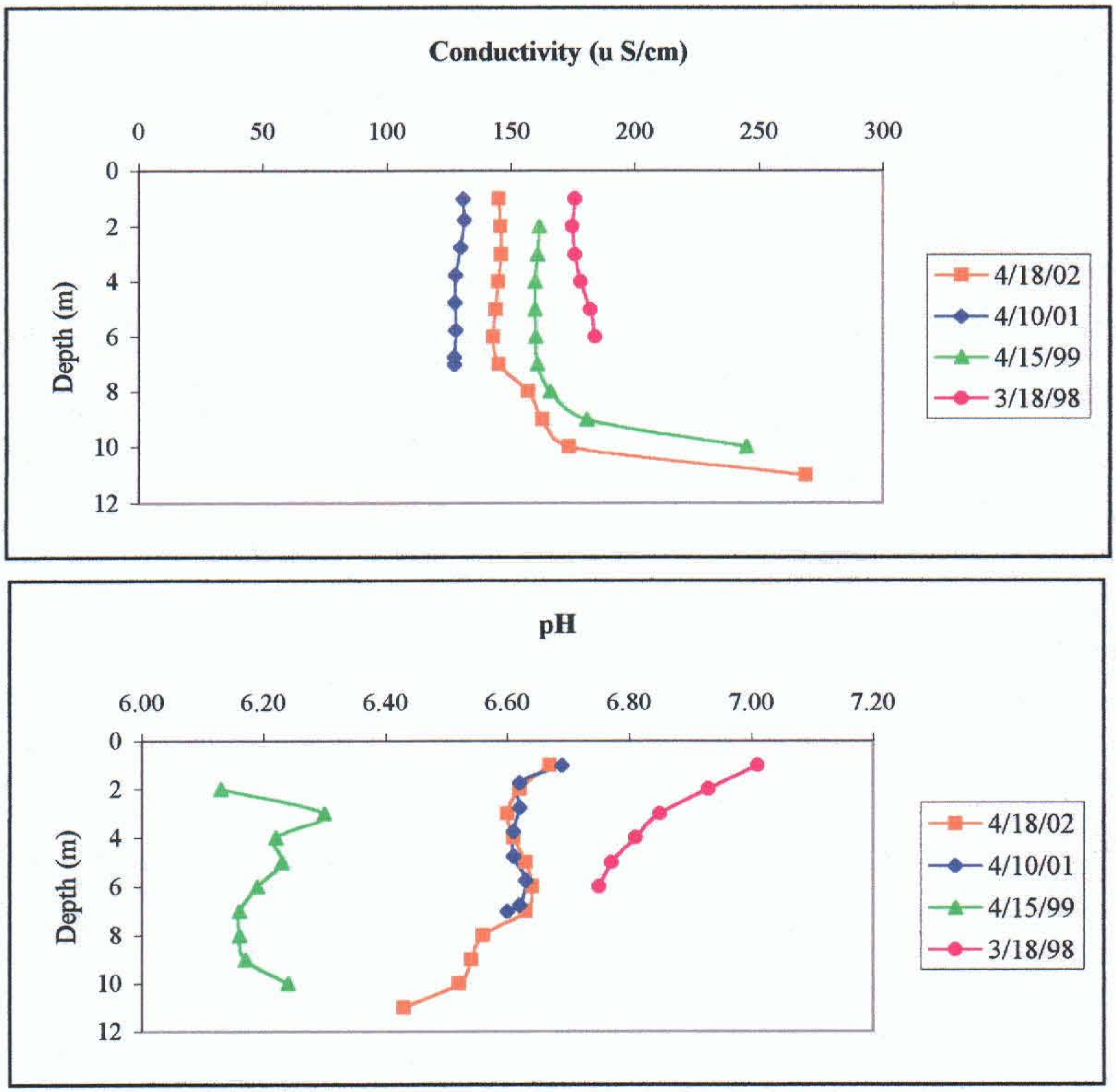


Figure 9. Conductivity (u S/cm) and pH at Site #2 (near spillway) by depth in the WSR in late winter 1998, 1999, 2001, and 2002.

Stilling Basin, Arctic grayling and Burbot

The stilling basin, located immediately below the WSR spillway, is fed by groundwater, seepage flow and by water from the WSR when flows pass over the spillway (Figure 3). In spring 2002, we began sampling (fyke-nets and angling) on May 3 when the stilling basin was ice-free, but the WSR was still 100% ice covered. By May 10, 2002, water was flowing through the low flow channel in the spillway. Flows increased substantially over the next week, but the WSR was not ice-free until May 26. Between May 10 and 16, water temperatures in the stilling basin fell in response to the cold water input from the WSR (Figure 10).

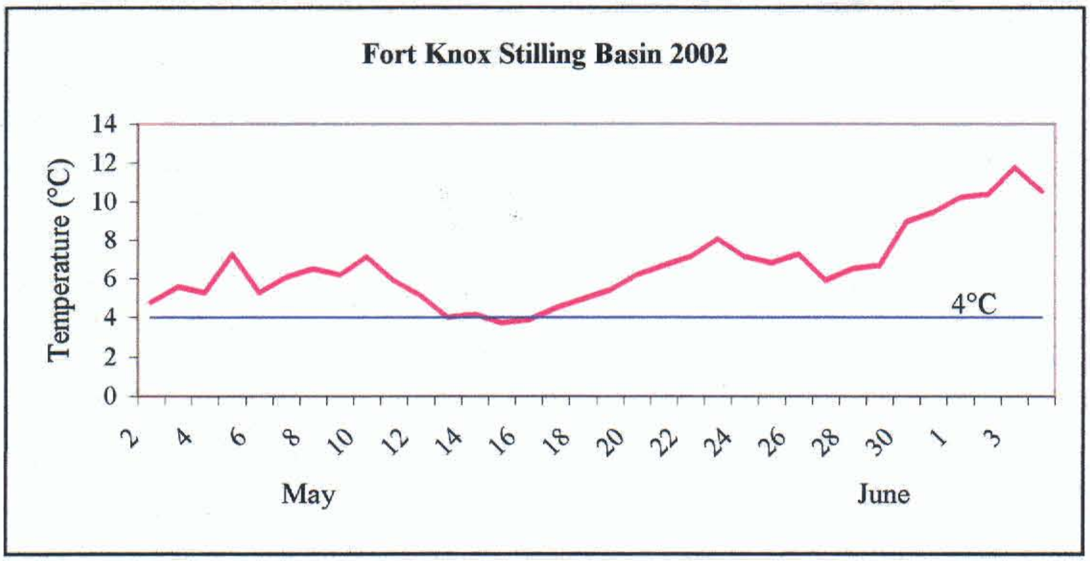


Figure 10. Peak water temperature in the outlet of the stilling basin below the Fort Knox freshwater dam in spring 2002.

We caught 435 Arctic grayling > 200 mm long, 117 of which had been marked in the WSR in previous years, including 17 that were tagged in spring 2002 in either the developed wetlands or Last Chance Creek. Outmigration of these fish from the WSR to the stilling basin probably began on May 10. Length frequency distribution of fish caught in the stilling basin indicates that most, if not all age classes, are present (Figure 11). We assume that most of the outmigration from the WSR to the stilling basin occurs during spring when fish are active and moving to either spawning or rearing areas and water is flowing over the dam.

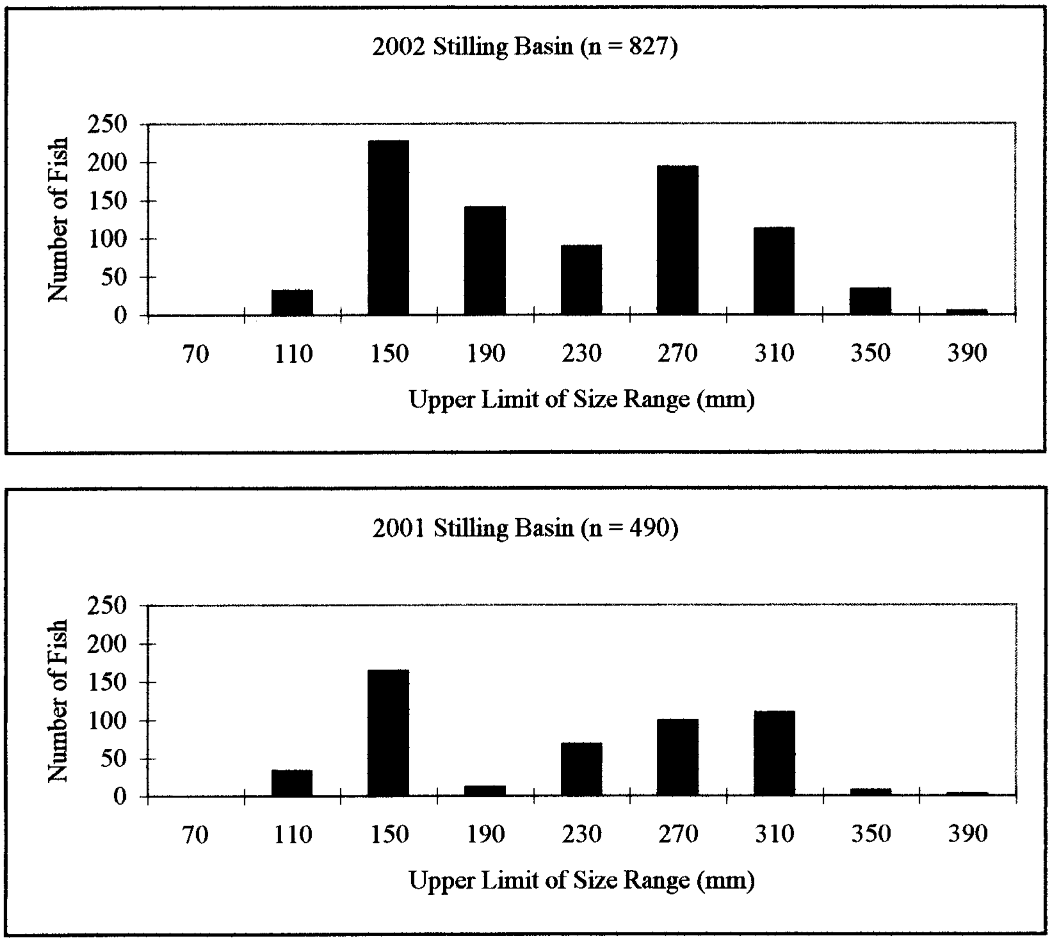


Figure 11. Length frequency distribution of Arctic grayling captured in the stilling basin below the WSR in spring 2001 and 2002.

From May 10 until about May 24, there were fairly large daily differences between the proportion of ripe and unripe fish. Daily changes likely were due to new unripe fish entering the stilling basin from the WSR where water temperatures were colder and ripening of fish was delayed. Peak temperatures in the stilling basin decreased from May 10 to 16, but began to rise on May 22. The WSR was completely ice-free by May 26. As water temperatures increased, the proportion of spent Arctic grayling increased, reaching 90+% by June 4 (Figure 12). Sampling ended on June 4, when the majority of the female Arctic grayling handled were judged to be spent and few, if any, ripe fish had been caught since May 30.

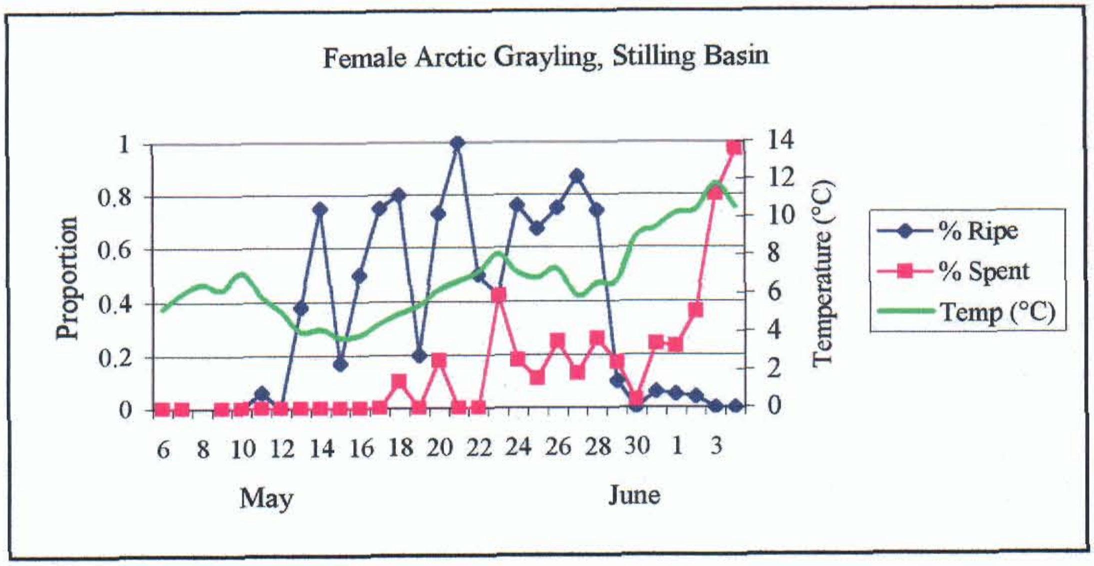


Figure 12. The proportion of ripe and spent female Arctic grayling in the stilling basin in May-June 2002. Peak daily water temperature at the outlet of the stilling basin also is shown in this figure.

We caught 93 burbot in the stilling basin fyke-nets from May 10 to June 4. The highest catches occurred between May 15 and 20. Burbot were small (average = 186 mm, SD = 61) and none had been marked in the WSR. Outmigration of burbot from the WSR appears to be limited, at this time, to fish <200 mm that would not have been marked if caught in the WSR.

Water Supply Reservoir, Last Chance Creek, and Developed Wetlands, Arctic Grayling

Arctic grayling were found throughout the Fish Creek drainage prior to construction of the WSR dam. Fish were most concentrated in Lower and Upper Last Chance Creek Ponds. The Arctic grayling within these ponds appeared stunted; fish larger than 220 mm long were rare, the annual growth rate was 9 mm, and size at maturity was small (148 mm for males, 165 mm for females). Successful spawning occurred primarily in the outlet and inlets between Polar Ponds #1 and #2. All of these ponds have been flooded by the WSR and are now referred to as Upper Last Chance and Polar Bays (Figure 2).

We continued to sample Arctic grayling in the WSR during the ice-free season following construction of the WSR dam. Flooding of the Fish Creek valley by the WSR inundated Polar #1 and #2 ponds, thus eliminating the spawning habitat associated with the pond complex. Some adults used Last Chance Creek for spawning but success, based on visual surveys for age-0 fish, was never high. After flooding of the WSR catches of small (< 200 mm) Arctic grayling from 1996 through 1999 were very low. Ponds C, D, E, and F were all interconnected, fed by surface flow during some breakups, but only by ground water during the remainder of the ice-free season. Flow through the pond complex is relatively stable, and not influenced markedly by storm events. These conditions (i.e., stable flow, warm water, stream and wetland habitats) are ideal for Arctic grayling spawning and survival and growth of age-0 fish. Water flow out of the pond complex entered the WSR via a perched culvert that did not provide for upstream passage of fish. It should be noted that the perched culvert was installed in 1995 in accordance with an approved plan and a Fish Habitat Permit. The isolation of the wetland complex from the WSR was to prevent fish from entering the wetland complex that might be used as a passive treatment facility for total dissolved solids at mine closure.

The near absence of age-0 Arctic grayling in spring 1996 through 1998 led to the decision to construct an outlet channel from Pond F to the WSR. In spring 1999, FGMI constructed the outlet channel (Channel #5, Figure 2). Immediately upon completion of construction, Arctic grayling entered the wetland complex and successfully spawned in Channel #5, in the pond complexes, and in interconnecting channels in 1999, and again in

2000 and 2001. In 2002, spawning was limited to Channel #5 and Ponds E and F. Extensive aufeis (about 4 m) in the inlet channel to Pond D, in Pond D, and in Pond F kept water temperatures in these reaches cold (< 4.0°C). The adult Arctic grayling selected and spawned in Channel #5 where water temperatures were substantially higher.

Arctic Grayling Spawning (Timing – Temperature)

In spring 2002, we fished fyke-nets in the developed wetlands and in Last Chance Creek from May 10 until June 3 to gather information on the relationship between temperature and Arctic grayling spawning. Continuous temperature data recorders were set near each fyke-net site to record temperature each half hour. Arctic grayling were first captured in the wetland complex on May 16. Peak water temperature on May 16 was 1.97°C. Catches increased substantially on May 19 when the water temperature reached a high of 2.92°C. In Last Chance Creek, the first fish were caught on May 20 at a peak water temperature of 1.37°C. Large numbers of fish were caught on May 23 when the water temperature peaked at 1.21°C. Water temperature data for Last Chance Creek and the wetland complex are presented in Figure 13.

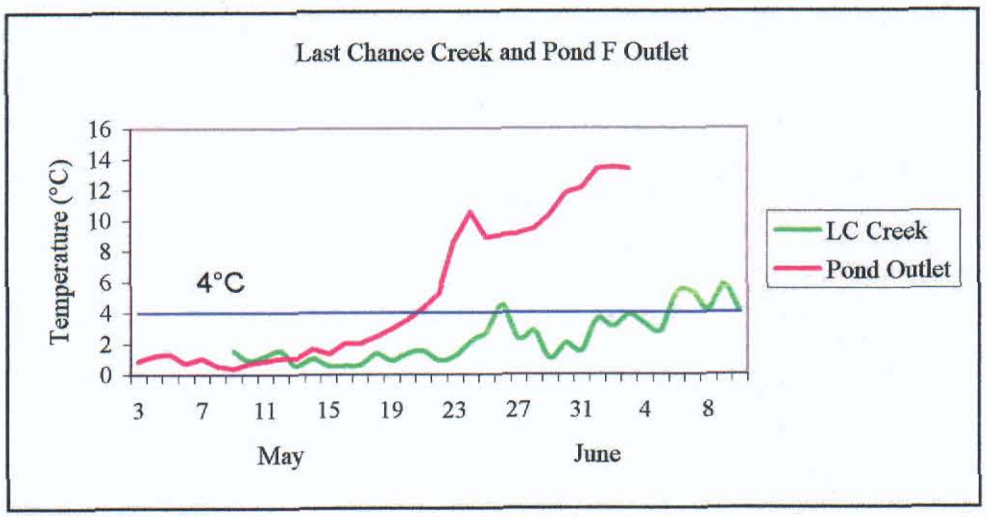


Figure 13. Peak daily water temperature in Last Chance Creek and in Pond F outlet channel in spring 2002. Note the much colder water temperatures in Last Chance Creek – the channel for several km upstream of the net site was filled with 2 to 4 m of ice.

We caught 439 Arctic grayling in Last Chance Creek between May 20 and 30, 2002. All tagging ceased on May 30, but we continued to capture Arctic grayling and assess the females' condition (not ripe, ripe, partially spent, and spent). Most of the fish handled in Last Chance Creek were mature adult fish. The proportion of ripe fish varied among the sample dates and probably reflected periodic water temperature increases and decreases. Except for May 26, the water temperature in the creek never exceeded 4.0°C until June 6 (Figure 14). Only a few of the adult females captured in Last Chance Creek were spent. Many appeared to have gone from a condition judged to be ripe to an unripe condition without spawning (Figure 14). Adults entered this system in a ripe condition and a majority remained ripe until late May, when the percent ripeness began to decrease in early June. In early June, the female's eggs appeared to be changing consistency and color, from firm and clear to soft and opaque. Only a few spent or even partially spent fish were ever caught. We concluded that the cold water temperatures lasting into early June created a condition in which the females began to reabsorb their eggs. Last Chance Creek was visually surveyed several times in July and age-0 fish were not found. This evidence supports our conclusion that cold water temperatures and egg resorption contributed to extremely poor spawning success in Last Chance Creek.

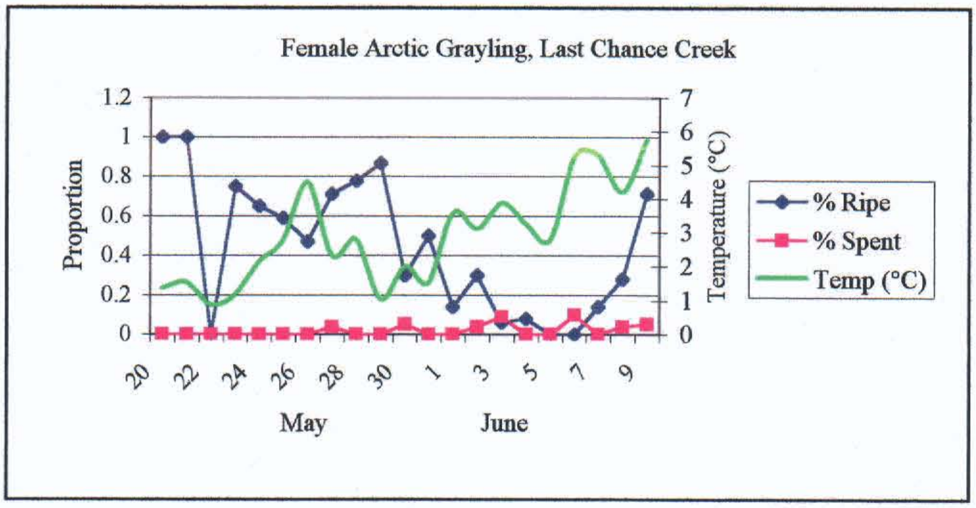


Figure 14. The proportion of ripe and spent female Arctic grayling in Last Chance Creek in May-June 2002. Peak daily water temperature near the fyke-net site also is shown in this figure.

In the wetland complex, we fished fyke-nets from May 16 to June 3, capturing 1169 Arctic grayling through May 30 when tagging ceased. Most of the fish handled were mature adults. The first Arctic grayling was caught on May 16, but catches increased substantially on May 19 and remained high throughout the entire sample period. Peak daily water temperature reached 2.92°C on May 19. Peak daily water temperatures first exceeded 4°C on May 21 and the peak temperatures remained over 4°C for the remainder of the sample period (Figure 13). Between May 30 and June 2, all female Arctic grayling handled were partially spent, and by June 2 over 80% were judged completely spent (Figure 15). Peak water temperatures from May 30 to June 2 were 11.76, 12.07, 13.31, and 13.46°C.

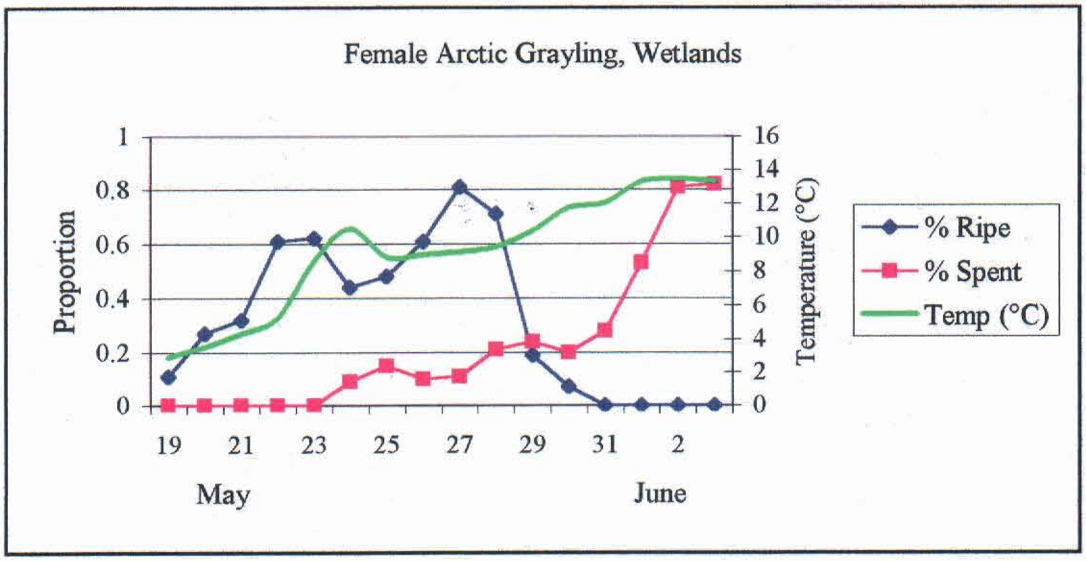


Figure 15. The proportion of ripe and spent female Arctic grayling in the wetland complex in May-June 2002. Peak daily water temperature in the outlet channel from Pond F also is shown in this figure.

In July 2002, we made visual fish surveys in the wetland complex. Age-0 Arctic grayling were abundant in Ponds E and F, in the outlet channel below Pond F, and although not numerous, age-0 fish were found in the stream that flows through Pond C. We visually inspected the channel between Ponds D and E daily and adult Arctic grayling were never seen. Therefore, we believe the age-0 fish in the stream that flows through Pond C moved upstream about 1 km from the spawning areas.

We collected age-0 Arctic grayling in the wetland complex in July, August, and September 2002. The average size of age-0 fish on September 3, 2002, was 88 mm (Table 3). In early October fyke-nets were fished, but no age-0 fish were caught. Most of the age-0 fish probably had left the wetland complex for the WSR. The average length of age-0 fish in early September 1999 that also were collected in the wetland complex is very similar to what we found in early September 2002 (Table 3).

Table 3. Age-0 Arctic grayling caught in the wetland complex in summer 2002 and in early September 1999.

Date	Number of Fish	Average Length (mm)	Range (mm)	Standard Deviation
7/19/02	41	44	32-57	4.8
8/22/02	113	84	66-102	7.2
9/3/02	145	88	60-114	9.5
9/1/99	21	91	76-97	5.4

The length frequency distribution of adult Arctic grayling captured in Last Chance Creek and in the developed wetlands is presented in Figure 16. Comparison of the length frequency distributions of spawning sized Arctic grayling indicates that fish attempting to spawn in Last Chance Creek are considerably larger than those spawning in the wetlands (mean length 295 mm in Last Chance Creek, mean length 254 mm in wetlands) (Wilcoxin Rank Sum W = 20.950, Mean Rank Last Chance Creek fish = 1200.3, Mean Rank Wetlands fish = 655.8, $p<0.00001$). Based on recaptures (fish originally tagged in the Upper and Lower Last Chance Creek Ponds prior to flooding of the WSR) and the larger size, we believe these Arctic grayling are maintaining a certain level of fidelity to areas used for spawning prior to construction of the freshwater dam in 1995.

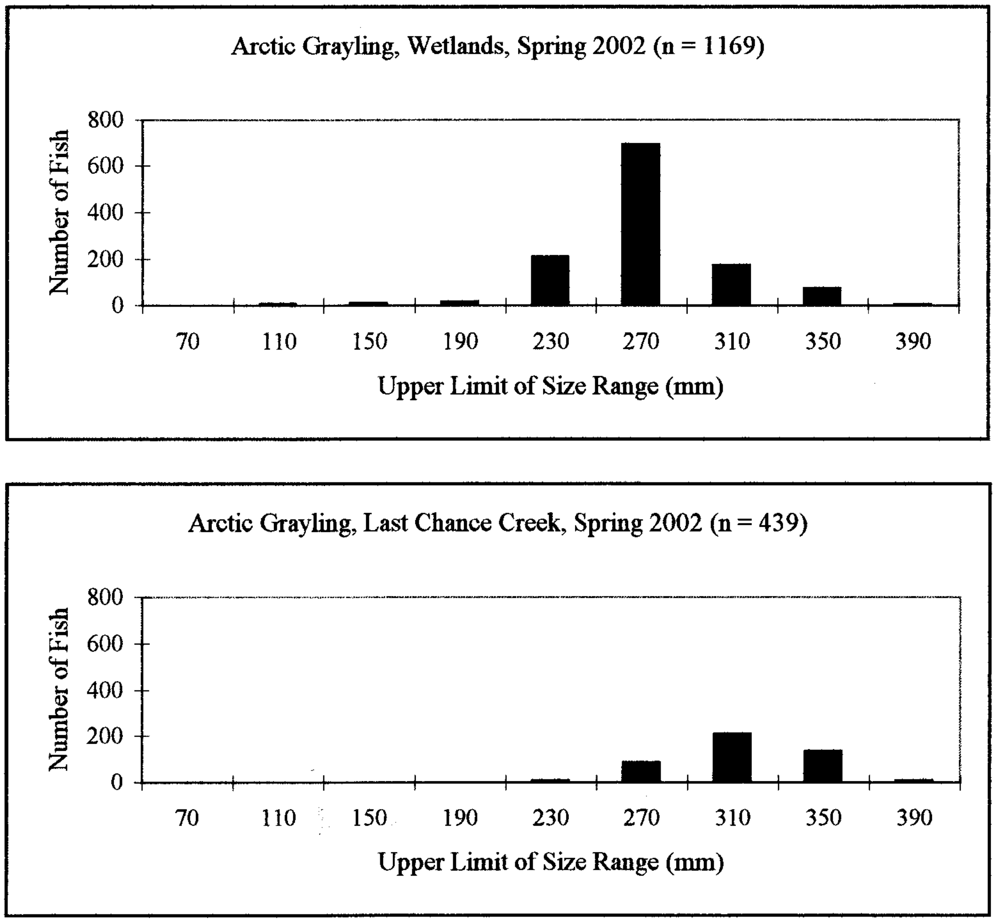


Figure 16. Length frequency distribution of Arctic grayling spawners in Last Chance Creek and the developed wetlands in spring 2002.

Arctic Grayling (Mark/Recapture, Population Estimate, Growth)

We estimated the abundance of Arctic grayling in the WSR using spring 2001 as the mark event (n_1 = 1078) and spring 2002 as the recapture event. In spring 2002, we caught 1151 Arctic grayling > 220 mm (n_2 = 1151), with 220 recaptures (m_2 = 220). Our spring 2001 estimated Arctic grayling population in the WSR for fish > 200 mm was 5,623 (95% CI 5,030 to 6,217) (Figure 17 and Appendix 2). Increased numbers of Arctic grayling in the WSR are directly related to recruitment of new fish from successful spawning in the developed wetland complex since spring 1999.

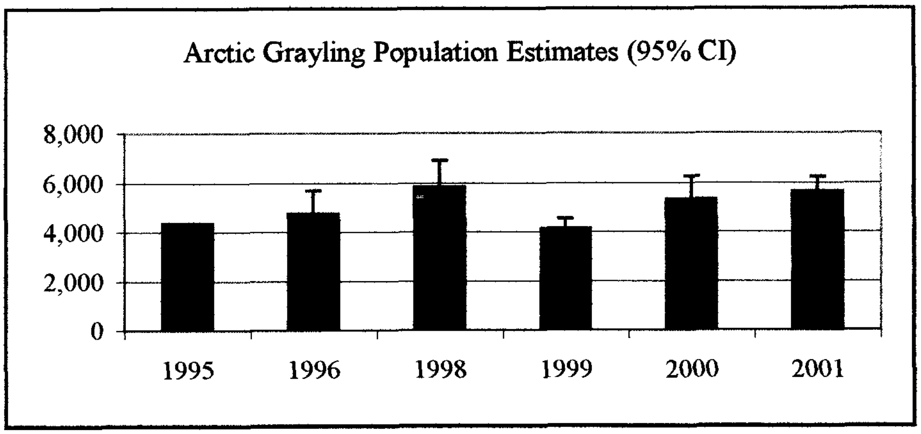


Figure 17. Estimates of the Arctic grayling population in the WSR at the Fort Knox Mine (1995 to 2001). Capture and recapture events were done using fyke-nets.

Comparison of 2001 and 2002 length frequency diagrams for fish marked in spring 2002 indicated that fish < 220 mm in spring 2002 would have been too small to enter our estimable population in 2001 (i.e., they would have been under 200 mm long in 2001 and would not have been marked) (Figure 18). Therefore, in computing the 2001 population estimate, we used only fish larger than 220 mm in 2002.

We also did not include Arctic grayling that had been marked in years prior to 2001 in our estimate. During the 2002 spring sample event, 73 Arctic grayling with tag scars were seen. The cumulative length frequency distribution of Arctic grayling having shed their tags shows a trend towards larger fish losing tags at a differentially higher rate than smaller fish (Figure 19). Specifically, there appeared to be a jump in the rate of tag loss around 250 mm and again at around 300 mm (Figure 19).

When the length frequency distribution of fish with tag scars (n = 73, average length = 293 mm, SE = 3.68) was compared to that of the entire group of fish captured in 2002 (n = 1485, average length = 266 mm, SE = 0.85), the tag scar fish appeared to be consistently larger (Wilcoxin Rank Sum: Mean Range Tag Scar = 1109.7, Mean Rank

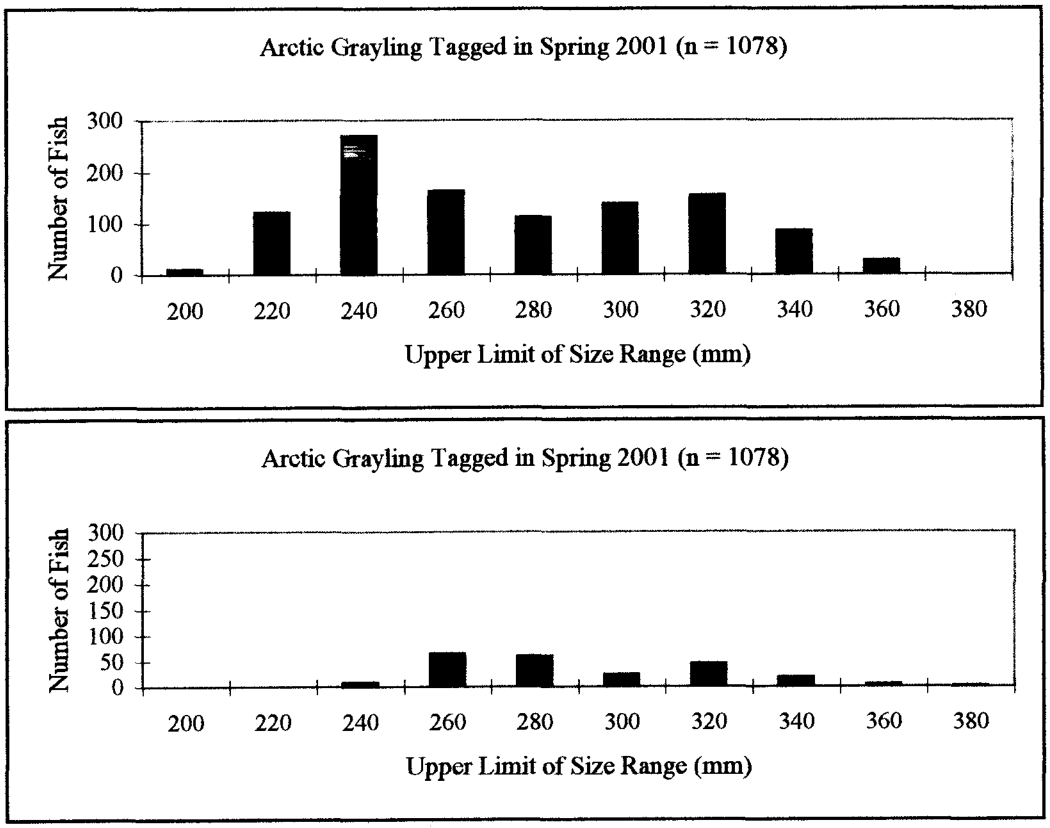


Figure 18. Length frequency distribution of Arctic grayling tagged in spring 2001 and recaptured in spring 2002 in Last Chance Creek and the developed wetlands.

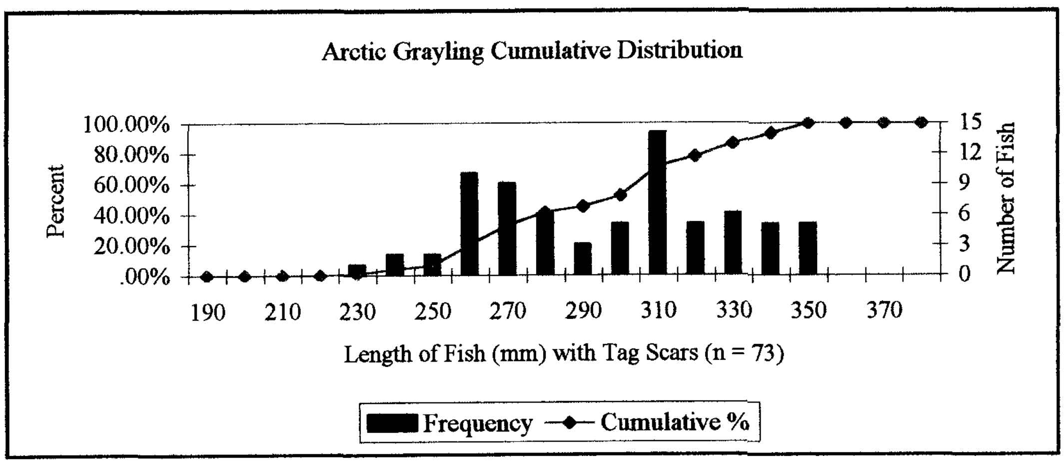


Figure 19. Cumulative length frequency distribution of Arctic grayling caught in spring 2002 with tag scars.

Non-Tag Scar = 763.3, W = 6.42, p = 0.0000) (Figure 20). However, when the length frequency distribution of fish with tag scars was compared to the distribution of recaptured fish (fish that retained their tags) (n = 306, average length 288 mm, SE = 1.69) no difference was detected (Wilcoxin Rank Sum: Mean Rank Tag Scar = 203.8, Mean Rank Retained = 186.7, W = 1.194, p = 0.23) (Figure 20). The lack of noticeable difference between the length frequency distributions of fish that lost versus fish that retained tags is likely an artifact of the reasonably tight size range of fish tagged (> 200 mm) as well as the fact that all fish tagged come from the same distribution of fish. Analysis of the tag loss generally supports the conclusion that larger fish lose tags at a higher rate than small fish. Therefore, by excluding fish tagged more than one year ago in the estimate, we reduce bias introduced from long-term tag loss.

Evidence of Arctic grayling movement out of the WSR was first documented in spring 2001 with fish tagged in the WSR caught in the stilling basin below the freshwater dam. In spring 2002, we recaptured 317 Arctic grayling marked in the WSR in spring 2001, 96 of the recaptures were in the stilling basin. Nearly 30% of our marked fish left the WSR between spring 2001 and 2002. Based solely on catches of Arctic grayling (> 200 mm) in the stilling basin in spring 2001 and 2002 (n = 253 and 435), there are a considerable number of large fish leaving the WSR.

In previous years, we have calculated growth for the entire population of fish > 200 mm that were marked and recaptured in that year. In spring 2002, we had 297 recaptures that were marked in 2001 and a sufficient sample size for showing growth rates by size. The average growth rate of Arctic grayling prior to the WSR was 9 mm per year. Once the WSR was in place, annual growth rates from 1996 through 1998 were 41, 38, and 39 mm (Ott and Morris 2002). Annual growth rates from spring 2001 to spring 2002 for Arctic grayling < 210 mm when tagged averaged 45 mm, but for fish >290 mm the average growth ranged from 2 to 6 mm (Figure 21).

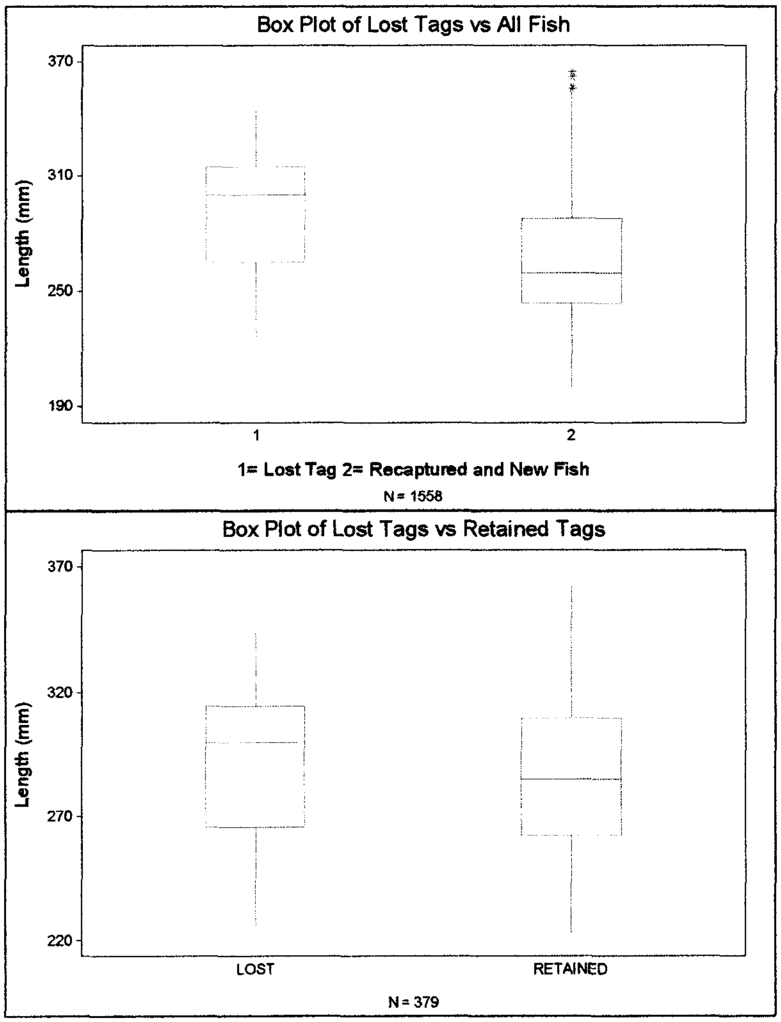


Figure 20. Box plots of fish with tag scars/fish that lost tags versus all fish recaptured and tagged in 2002 (top) and fish that lost tags versus recaptures that did not lose tags (bottom).

Growth rates for the smaller, generally juvenile fish, are still comparable to the growth rates seen in the WSR during the first three years following construction of the freshwater dam. The smaller growth rates for large Arctic grayling likely reflect the energetic demands of reproduction.

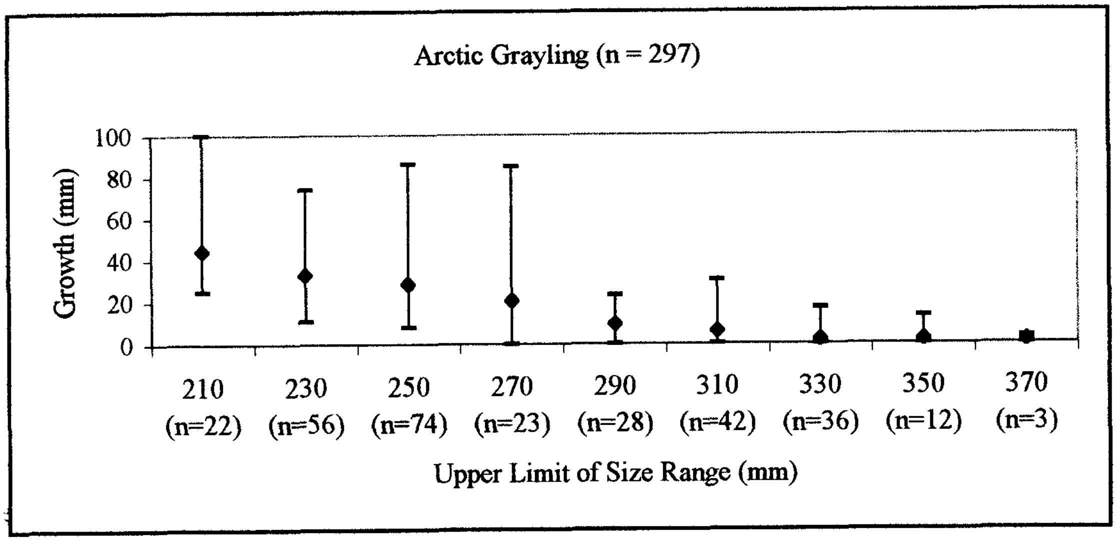


Figure 21. Maximum, minimum, and average growth rates for Arctic grayling > 200 mm between spring 2001 and 2002 in the WSR.

The length frequency distribution for Arctic grayling collected in spring 1995, 1996, 1998, 1999, 2000, 2001, and 2002 is presented in Figure 22. From 1995 to 1999, Arctic grayling recruitment was not documented. Fish were growing larger rather than spawning successfully in the WSR. After construction of Channel #5, Arctic grayling adults successfully spawned in the wetland complex each year since spring 1999. Some recruitment of fish <200 mm is first seen in spring 2000. The first major recruitment was found in spring 2001 (Figure 22). However, the relative number of Arctic grayling < 200 mm in 2002 was low – much lower than in spring 2001. One possible explanation for lower catch rates of small Arctic grayling was the WSR completely flooded in spring 2002, but not in 2001. In spring 2001, one of the fyke-net sets was in shallow water in the WSR where use by juvenile Arctic grayling probably is higher. In 2002, we fished all the nets in the wetland complex and in Last Chance Creek.

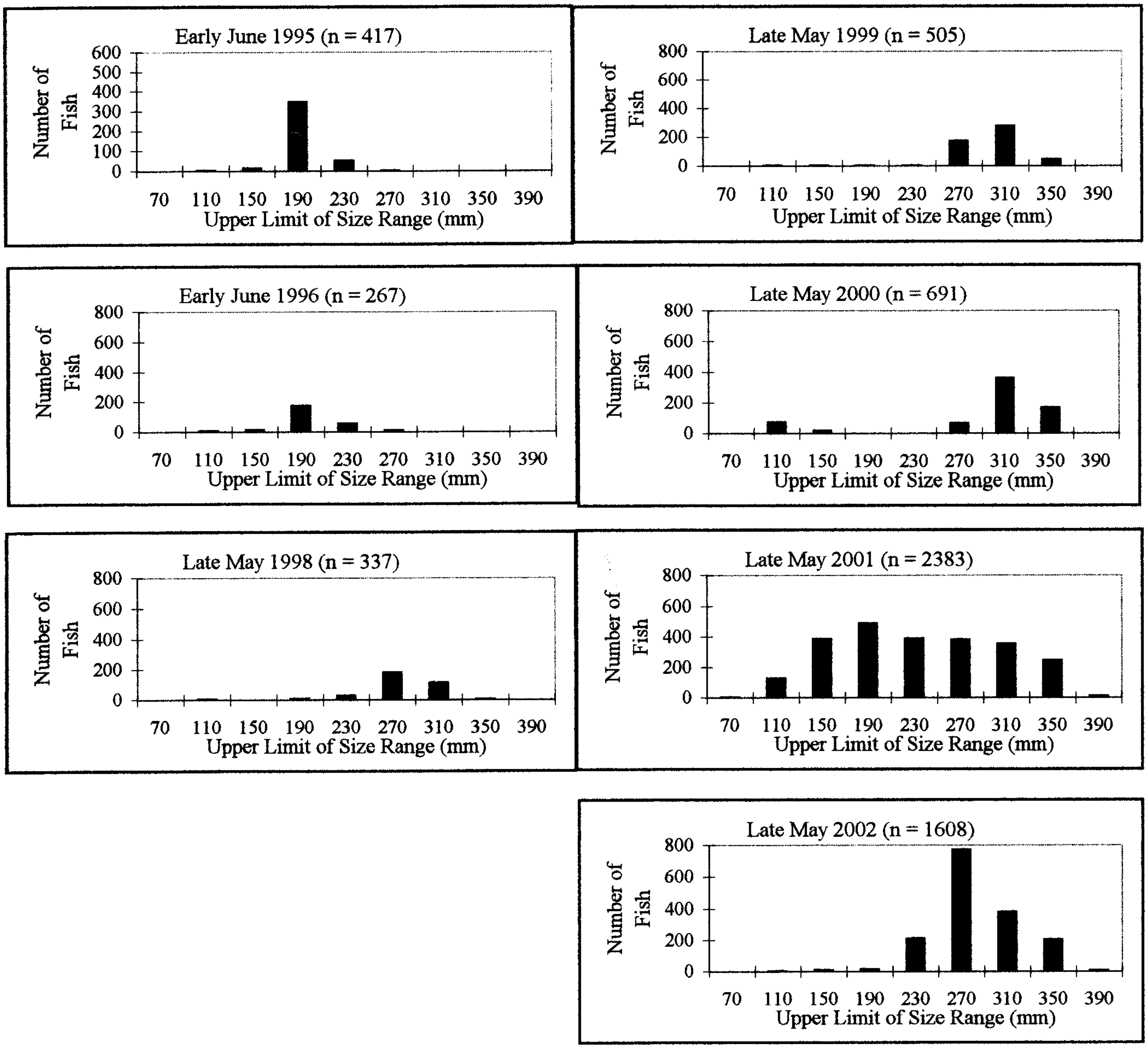


Figure 22. Length frequency distribution of Arctic grayling in the WSR and wetland complex (1995 through 2002).

Water Supply Reservoir, Burbot

Burbot were found in Lower Last Chance Creek Pond and in Polar Ponds #1 and #2 prior to construction of the WSR dam (Ott and Weber Scannell 1996). In May 1995, we conducted a mark/recapture effort and estimated abundance of burbot (150 to 331 mm) to be 825 fish (Ott and Weber Scannell 1996). Flooding of the WSR began in November 1995, and the Last Chance Creek and Polar Ponds were inundated, isolating burbot upstream of the WSR.

Estimates of the burbot population in the WSR were made during the ice-free season following construction of the WSR (Figure 23 and Appendix 3). Burbot population estimates in the WSR for 1997 and 1998 were 622 and 703 fish. The estimated population of burbot >200 mm long peaked in 1999 and began to decrease slightly in the next two years with a substantial decrease in 2002 (Figure 23). We also estimated the population of burbot > 400 mm long for both 2001 and 2002. The estimated number of larger burbot was 134 in 2001 and 131 in 2002. These data indicate that fish that were lost in the population were smaller fish, probably those between 275 and 375 mm that have been in poor condition for a number of years.

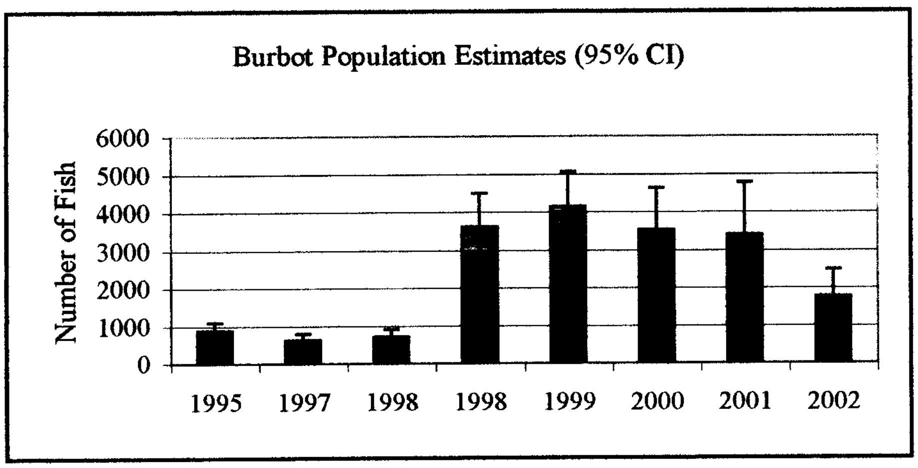


Figure 23. Estimates of the burbot population in the WSR at the Fort Knox Mine (1995 to 2002). The first 1998 estimate was inseason while the second 1998 estimate is based on the 1999 recapture event when adequate recaptures of small burbot occurred making the population estimate possible.

It is likely that many of these burbot, already stressed by their poor condition, simply did not survive in the poorer water quality observed in winter 2001/2002. Further, catches of burbot in the stilling basin, indicate that although outmigration has occurred, most of the burbot are small and none of those caught have been tagged previously in the WSR.

Catch per unit of effort for hoop traps fished in the WSR has been calculated since 1996 (Appendix 2). Catch rates from 1998 through 2001 were similar, but there was a sharp decrease in spring 2002. The decreased catch rate supports the fact that the calculated population of burbot in the WSR >200 mm also had decreased substantially.

Annual growth of burbot was tracked from 1998 through 2002. Average growth by size class is shown in Figure 24. Annual growth continues to be higher for the small burbot (< 275 mm) and the large burbot (> 350 mm). Growth rates for the intermediate sized burbot remains low and these fish generally are in poorer condition.

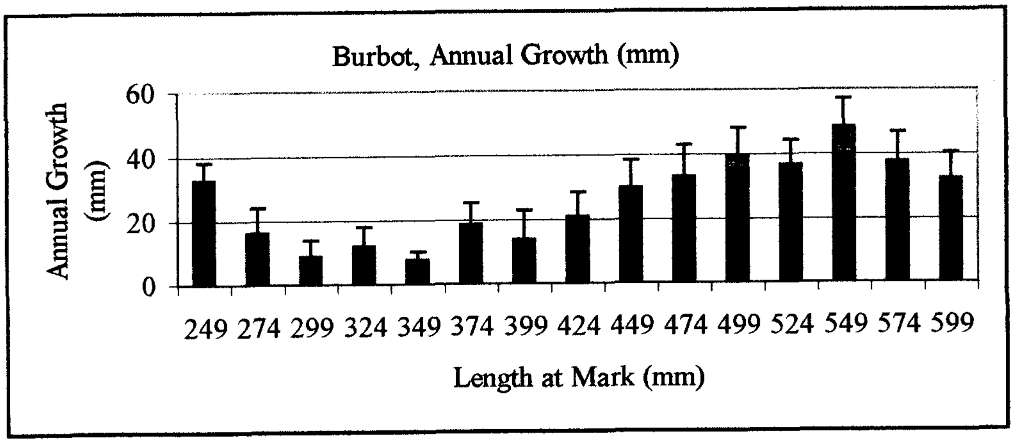


Figure 24. Annual growth of burbot tagged in the WSR from 1998 through 2001 with recaptures in 1999 through 2002.

Calculated length frequency distributions for burbot captured from May 1995 to June 2002 are shown in Figure 25. The population continues to be dominated by burbot from 275 to 375 mm long. Even though the population is still dominated by the 275 to 375 mm burbot, the catch in that size range has dropped from about 450 in 2001 to about 250 in 2002. Recruitment of small burbot can be seen in both 2001 and 2002 with a slight increase in burbot < 225 mm caught in spring 2002. In spring 2003, we plan to use both minnow traps and hoop traps. In hoop traps, many of the small burbot if caught are eaten by the larger burbot and the minnow traps may give us a better indication of relative abundance of burbot <250 mm.

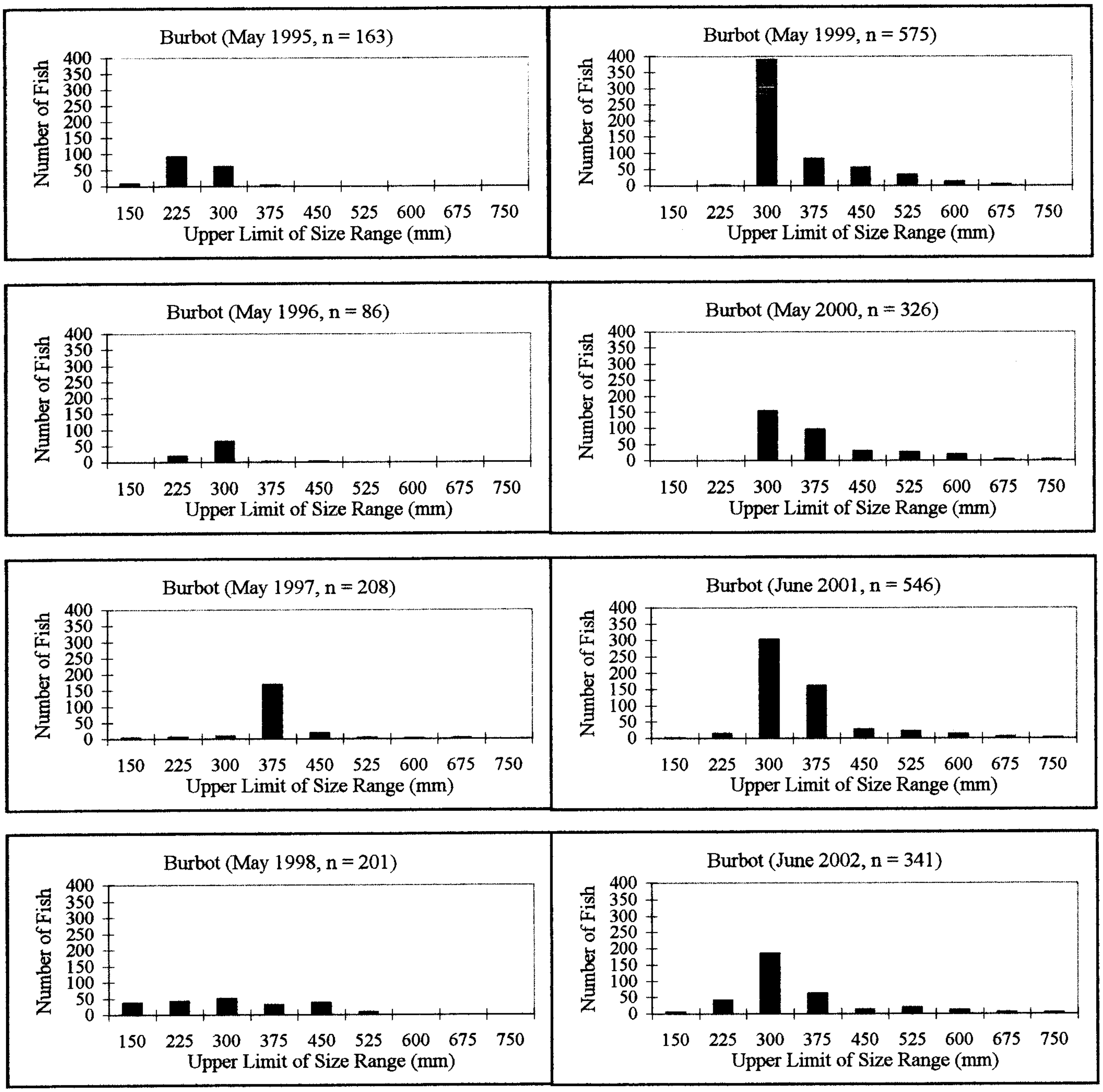


Figure 25. Length-frequency distribution of burbot caught in the WSR, 1995 to 2002.

Conclusion

We predicted prior to construction of the WSR dam that opportunities existed to enhance fish resources, specifically the Arctic grayling population, in the Fish Creek valley. In 1993, in collaboration with FGMI a goal was established to create a viable Arctic grayling population in the WSR from fish trapped upstream of the dam. The objective was to reach a density of 10 to 20 Arctic grayling >200 mm per hectare of surface area (i.e., 800 to 1,600 Arctic grayling >200 mm for the WSR) ten years after project completion (FGMI 1993).

FGMI worked with the department to optimize habitat diversity in the area to be flooded by the WSR. Concurrent reclamation of the Fish Creek valley between the tailing dam and the WSR began following construction. Civil work has occurred every year in the Fish Creek valley. In 1996, most of the area was reshaped, a berm was constructed to maintain water levels in Ponds A and B, channels were constructed between the ponds in the valley, most of the area was seeded, and willow sprigging was done in selected areas. In 1999, a channel (i.e., Channel #5) was constructed to connect Ponds C, D, E, and F with the WSR. In fall 2001, civil work was done in Last Chance Creek in an attempt to stabilize the stream channel. In fall 2001 and 2002, additional civil work was done on the channel and berm separating Ponds D and E. These projects, collectively, have resulted in rapid revegetation in the valley. Channel #5 that connected several ponds with the WSR has been used extensively by Arctic grayling for spawning each year since 1999.

Progress to Date

Baseline fish and water quality data were collected by the department prior to construction of the Ft. Knox project. Monitoring of the fishery resources and water quality has continued in the WSR and developed wetlands for the following reasons: (a) to gather data to evaluate predictions that a viable Arctic grayling population would or would not occur; (b) to provide data on successes and failures of restoration activities that could be applied to future projects; (c) to fill the department's commitment to monitor the project and provide data for the environmental audits required by the State's mill site lease; (d) to provide biological information needed for management decisions when the area is converted to public recreation and use at the end of mining operations; and (e) to gather information on the fish and wildlife use of the developed wetlands to be used to assess mitigation under the U.S. Army Corps of Engineer's permit for the project.

The goal of having a viable Arctic grayling population in the WSR and developed wetlands of between 800 and 1,600 fish >200 mm was attained in 1998. Successful spawning and survival of age-0 Arctic grayling has been documented every year since Channel #5 was constructed and there is evidence of substantial recruitment to the population. The estimated population for spring 2001 for Arctic grayling >200 mm was 5,623. Furthermore, there are now fairly large numbers of Arctic grayling leaving the WSR over the spillway – 435 Arctic grayling >200 mm were caught in spring 2002 in the stilling basin. A potential added benefit of this outmigration from the Fort Knox WSR and developed wetlands is a source of recruitment of Arctic grayling to the Chena River system and fishery.

The burbot population in the WSR also has increased substantially from that found prior to the WSR. The increase in burbot was not predicted based on baseline information collected. A decrease in numbers was documented in summer 2002, but the population of larger burbot (>400 mm) appears to be stable and small burbot (<200 mm) are present indicating successful spawning in the WSR. Based on the relocation of large (>700 mm) radiotagged burbot in March/April 2002 in Solo Bay, we believe that spawning occurs in Solo Creek Bay. Freshwater input from Solo Creek also contains the highest dissolved oxygen concentrations in winter in the WSR. Some of these smaller burbot also are leaving the WSR and may add to the recruitment of this species in the Chena River system.

Water quality data collected has shown that the flooding of permafrost, ice-rich organic materials in this valley has created a condition in which dissolved oxygen concentrations are depressed with depth in both winter and summer. Essential to the overwintering survival of fish in the WSR is the freshwater input from Solo Creek. We also were able to determine, contrary to recommendations made prior to construction of the WSR, that winter water removal from the bottom may actually aid in maintaining higher dissolved oxygen concentrations during winter by either removing the water with the highest chemical oxygen demand or perhaps simply by removing the water with the lowest dissolved oxygen.

Wildlife use of the lower Fish Creek valley generally has increased since creation of the WSR and rehabilitation of the valley. Moose (*Alces alces gigas*) use the area in spring for calving and numerous moose use the valley during portions of the fall and winter; up to 13 moose have been observed at one time in the valley. Moose are frequently observed browsing in the rehabilitated uplands and also can be seen foraging on aquatic vegetation in the constructed wetlands. Black bears (*Ursus americanus*), grizzly bears (*Ursus arctos*), red foxes (*Vulpes vulpes*) and wolves (*Canis lupus*) also have been observed in the valley and wolves appear to have denned in the valley in at least one year since rehabilitation. Aquatic mammals are numerous as well. Beavers (*Castor canadensis*) and mink (*Mustela vison*) are common and river otters (*Lutra canadensis*) have been observed during at least one winter season feeding on Arctic grayling in the stilling basin below the spillway.

Numerous waterfowl species have been observed throughout the spring and summer seasons in the valley. Red-necked grebes (*Podiceps grisegena*) have fledged young in the WSR over the past two years. In summer 2002, a juvenile common loon (*Gavia immer*) was observed on the reservoir in October; adults were observed there since early spring. Mallard (*Anas platyrhynchos*), green-winged teal (*Anas crecca*), greater (*Aythya marila*) and lesser scaup (*Aythya affinis*), northern pintail (*Anas acuta*), blue-winged teal (*Anas discors*), northern shoveler (*Anas clypeata*), American wigeon (*Anas americana*), canvasback (*Aythya valisineria*), redhead (*Aythya americana*), long-tailed duck (*Clangula hyemalis*), surf (*Melanita perspicillata*) and white-winged scoter (*Melanita fusca*), Barrow's goldeneye (*Bucephala islandica*), bufflehead (*Bucephala albeola*), common merganser (*Mergus merganser*) and ring-necked ducks (*Aythya collaris*) have all been observed using portions of the wetland complex, WSR or the stilling basin. Pacific loons (*Gavia pacifica*), horned grebes (*Podiceps auritus*) and sandhill cranes (*Grus canadensis*) also have been observed on the WSR or surrounding area.

Bald eagles (*Haliaeetus leucocephalus*) are seen annually during spring, concentrating their hunting efforts near shallow riffle areas containing spawning Arctic grayling. In

Bald eagles (*Haliaeetus leucocephalus*) are seen annually during spring, concentrating their hunting efforts near shallow riffle areas containing spawning Arctic grayling. In spring 2001 and 2002, golden eagles (*Aquila chrysaetos*) also were observed targeting fish in the wetlands and WSR. Other raptors and birds of prey seen commonly in the rehabilitated valley include northern harriers (*Circus cyaneus*), rough-legged hawks (*Buteo lagopus*) and northern hawk owls (*Surnia ulula*). Ospreys (*Pandion haliaetus*) have occasionally been observed. Additionally, in spring 2000 a migrating band of hundreds of Lapland longspurs (*Calcarius lapponicus*) stopped in the constructed wetlands to feed on their migration north.

Numerous shorebirds are present each year at various locations throughout the valley. American golden (*Pluvialis dominica*) and semi-palmated plovers (*Charadrius semipalmatus*), lesser yellowlegs (*Tringa flavipes*) and various sandpipers and other shorebirds commonly are observed.

Future Plans

The department will continue to work cooperatively with FGMI to gather data on the fish resources and water quality to provide a basis for management decisions that will need to be made at mine closure and to identify further options for enhancing the aquatic habitat in the Fish Creek valley. One potential option is the construction of a second wetland complex located along the north side of the Fish Creek valley between the tailing dam and the WSR. This stream complex system, if constructed, would be fed by water from the tailing impoundment at mine closure. Options to further stabilize the aquatic and riparian habitat in Last Chance Creek drainage will be pursued. If additional reclamation activities were successful in Last Chance Creek, about 6 to 8 km of stream habitat would be available for use by Arctic grayling and burbot. Finally, compilation of long-term data on the WSR and developed wetlands will aid both industry and government agencies in better decision making in the future.

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Appendix 1. Water Quality, Water Supply Reservoir

Site 1 is located about 100 m upstream of the Water Supply Dam							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(u S/cm)	pH
1	9/30/02	0	6.90	72.8	8.52	100.3	6.87
		1	6.90	72.4	8.48	100.1	6.84
		2	6.89	72.1	8.45	100.5	6.83
		3	6.83	70.9	8.32	100.2	6.82
		4	6.84	70.1	8.23	100.4	6.81
		5	6.74	67.4	7.93	100.3	6.78
		6	6.65	64.1	7.55	101.0	6.75
		7	6.46	56.5	6.69	102.3	6.67
		8	6.14	40.1	4.80	101.3	6.58
		9	5.67	52.0	6.28	98.6	6.58
		9.5 (bottom)	5.21	67.5	8.24	95.6	6.68
1	5/28/02	0	4.89	54.0	6.51	103.8	6.73
		1	4.85	53.6	6.48	103.8	6.70
		2	4.87	53.5	6.48	103.8	6.68
		3	4.86	53.3	6.46	103.9	6.68
		4	4.85	53.4	6.46	103.7	6.67
		5	4.84	53.3	6.46	103.7	6.67
		6	4.82	52.8	6.41	104.1	6.68
		7	4.83	52.6	6.38	104.0	6.68
		8	4.80	52.5	6.36	104.7	6.68
		9	4.80	52.4	6.38	104.3	6.68
		10	4.76	51.5	6.26	104.3	6.68
		11 (bottom)	4.69	51.5	6.24	105.0	6.68
1	4/18/02	1	0.52	11.9	1.69	146.0	6.77
		2	0.87	14.4	1.98	145.2	6.67
		3	1.15	16.8	2.28	144.6	6.67
		4	1.34	17.7	2.41	144.2	6.65
		5	1.51	13.5	1.83	146.5	6.64
		5.5 (bottom)	1.62	14.8	1.97	146.5	6.63
1	10/1/01	0	7.23	65.8	7.61	121.1	7.28
		1	7.20	64.4	7.44	121.5	7.28
		2	7.19	64.2	7.41	121.1	7.29
		3	7.18	64.1	7.40	121.7	7.28
		4	7.17	63.8	7.36	121.1	7.28
		5	7.16	63.1	7.31	121.4	7.27
		6	7.15	62.8	7.26	121.1	7.27
		7	7.14	62.4	7.22	121.7	7.27
		8	7.00	59.0	6.83	123.1	7.26

Appendix 1, continued.

Site 1 is located about 100 m upstream of the Water Supply Dam							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(u S/cm)	pH
		9	6.46	18.0	2.11	115.1	7.00
		10 (bottom)	6.22	18.1	2.14	116.5	7.02
1	6/1/01	0	7.96	67.9	7.74	114.9	6.93
		1	7.88	67.1	7.67	115.0	6.95
		2	7.86	67.0	7.65	115.2	6.95
		3	7.06	60.7	7.06	114.7	6.93
		4	6.16	53.0	6.35	114.6	6.85
		4.75 (bottom)	6.08	51.6	6.21	114.6	6.84
1	4/10/01	1	0.21	22.1	3.10	130.1	6.64
		1.75	0.38	19.3	2.72	131.4	6.62
		2.75	0.75	17.7	2.45	131.2	6.61
		3.75	1.07	19.9	2.72	129.8	6.61
		4.75	1.34	21.0	2.85	128.8	6.61
		5.75 (bottom)	1.50	18.8	2.56	131.1	6.59
1	8/29/00	0	11.17	79.2	8.46	108.8	7.11
		1	10.50	77.6	8.44	108.8	7.13
		2	10.29	77.1	8.42	108.8	7.13
		3	9.92	72.6	8.01	108.8	7.09
		4	8.85	54.1	6.14	106.8	6.90
		5	8.19	41.2	4.72	106.3	6.77
		6	6.98	41.7	4.93	97.7	6.66
		7	6.05	18.6	2.24	109.6	6.50
		8	5.53	5.3	0.65	136.8	6.39
		9	5.23	3.4	0.45	140.0	6.45
		10 (bottom)	5.04	2.6	0.33	142.5	6.47
1	6/23/00	0	18.23	95.2	8.81	103.8	7.56
		1	17.35	93.0	8.75	102.6	7.57
		2	12.95	52.6	5.50	105.1	6.91
1	6/23/00	3	7.67	24.9	2.92	108.8	6.69
		4	5.71	17.4	2.15	114.0	6.57
		5	5.08	13.9	1.76	117.2	6.54
		6	4.60	9.9	1.25	119.4	6.52
		7	4.39	8.4	1.08	121.9	6.51
		8	4.30	6.5	0.83	122.5	6.50
		9 (bottom)	4.10	2.6	0.34	125.9	6.49
1	5/30/00	0	7.31	56.3	6.72	108.4	6.77

Appendix 1, continued.

Site 1 is located about 100 m upstream of the Water Supply Dam							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(u S/cm)	pH
		1	6.24	53.1	6.51	108.2	6.73
		2	5.79	51.9	6.40	106.8	6.71
		3	5.56	50.3	6.25	107.9	6.71
		4	5.45	49.9	6.21	107.1	6.70
		5	5.42	49.6	6.18	107.5	6.70
		6	4.81	45.1	5.73	109.3	6.68
		7 (bottom)	3.95	33.3	4.33	120.5	6.64
1	6/2/99	0	9.49	82.9	9.13	134.7	7.29
		1	9.50	81.4	8.99	134.9	7.27
		2	9.52	81.1	8.95	134.5	7.29
		3	9.48	80.7	8.92	134.7	7.30
		4	9.29	77.1	8.54	135.5	7.24
		5	7.47	54.5	6.26	133.4	7.07
		6	6.36	42.3	5.05	134.9	6.99
		7	5.81	36.3	4.39	135.6	6.93
		8	5.14	29.8	3.67	137.3	6.91
		9	4.98	28.2	3.48	137.5	6.90
		10	4.86	26.5	3.24	137.8	6.89
		11	4.79	25.5	3.16	138.4	6.88
		12 (bottom)	4.75	24.9	3.09	138.3	6.86
1	10/1/98	surface	6.27	62.7	7.49	145.1	7.60
		1	6.24	62.6	7.49	145.0	7.57
		2	6.21	62.4	7.47	144.6	7.58
		3	6.20	62.3	7.45	144.5	7.58
		4	6.14	62.9	7.54	144.8	7.60
		5	6.03	64.1	7.70	144.8	7.62
		6	5.87	64.3	7.75	144.3	7.61
		7	5.84	64.3	7.74	144.4	7.61
		8 (bottom)	5.82	64.5	7.79	144.0	7.59
1	7/28/98	surface	17.33	84.2	7.85	161.9	7.56
		1	16.83	81.2	7.67	162.0	7.54
		2	16.66	80.5	7.65	162.2	7.55
		3	14.30	45.7	4.55	157.5	7.08
		4	11.78	25.7	2.72	141.4	6.84
		5	9.93	50.7	5.51	118.6	6.97
		6 (bottom)	9.25	33.3	3.71	127.6	6.90
1	7/28/98	surface	17.21	83.6	7.84	159.6	7.64

Appendix 1, continued.

Site 1 is located about 100 m upstream of the Water Supply Dam							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(u S/cm)	pH
		1	17.14	82.9	7.80	159.8	7.63
		2	16.81	82.3	7.78	160.3	7.63
		3	14.49	46.9	4.64	157.6	7.13
		4	7.92	27.1	3.51	165.0	6.87
		5	6.68	64.7	7.63	115.2	7.03
		6	3.48	9.6	1.14	170.0	6.75
		7 (bottom)	5.23	1.0	0.12	173.0	6.81
1	3/18/98	1	0.50	N/T	1.27	176.0	6.96
		2	0.79	N/T	1.89	178.0	6.89
		3	0.89	N/T	1.71	179.0	6.87
		4	0.96	N/T	2.10	182.0	6.84
		5 (bottom)	0.96	N/T	0.47	186.0	6.75

N/T = Not Tested

Appendix 1, continued.

Site 2 is located in the middle of Water Supply Reservoir							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(*u* S/cm)	pH
2	9/30/02	0	6.94	73.1	8.55	99.9	6.89
		1	6.91	72.9	8.53	99.8	6.88
		2	6.89	72.3	8.48	99.8	6.86
		3	6.88	71.8	8.42	100.2	6.86
		4	6.84	69.3	8.13	100.4	6.84
		5	6.78	68.1	8.00	100.3	6.81
		6	6.55	58.7	6.91	100.6	6.73
		7	6.27	42.5	5.05	100.5	6.58
		8	5.88	23.2	2.80	99.0	6.46
		9	5.66	23.2	2.80	99.6	6.42
		10	5.60	16.2	1.96	99.7	6.38
		11	5.57	12.7	1.56	99.9	6.37
		12	5.54	10.7	1.27	100.3	6.37
		13	5.50	7.1	0.87	100.9	6.36
		14	5.47	4.1	0.51	101.4	6.35
		14.7 (bottom)	5.38	0.3	0.04	103.6	6.35
2	5/28/02	0	4.62	49.5	6.07	107.6	6.60
		1	4.58	49.1	5.94	108.2	6.61
		2	4.57	48.7	5.96	107.3	6.63
		3	4.58	48.4	5.92	107.2	6.62
		4	4.57	48.1	5.87	107.4	6.62
		5	4.50	47.4	5.77	108.6	6.61
		6	4.27	44.0	5.41	111.4	6.61
		7	4.32	43.6	5.35	111.2	6.60
		8	4.16	41.9	5.17	112.9	6.59
		9	3.99	38.7	4.78	115.0	6.58
		10	3.98	37.0	4.57	117.4	6.57
		11	3.88	34.5	4.31	118.4	6.56
		12	3.59	29.3	3.66	124.0	6.55
		13	3.34	22.9	2.88	131.1	6.53
		14 (bottom)	2.34	9.2	1.18	148.9	6.54
2	4/18/02	1	0.47	17.7	2.46	145.1	6.67
		2	0.84	9.3	1.32	146.0	6.62
		3	1.12	10.1	1.42	146.2	6.60
		4	1.37	14.9	2.02	144.8	6.61
		5	1.60	17.8	2.40	144.0	6.63
		6	1.81	21.1	2.83	143.0	6.64
		7	1.99	19.2	2.56	145.2	6.63
		8	1.88	3.2	0.43	157.1	6.56

Appendix 1, continued.

Site 2 is located in the middle of Water Supply Reservoir							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(u S/cm)	pH
		9	1.96	0.0	0.00	162.8	6.54
		10	1.96	0.0	0.00	173.5	6.52
		11 (bottom)	1.80	0.0	0.00	269.1	6.43
2	10/1/01	0	7.33	65.6	7.55	120.9	7.25
		1	7.30	65.7	7.55	120.3	7.25
		2	7.28	65.7	7.56	121.3	7.25
		3	7.28	65.7	7.57	120.6	7.25
		4	7.27	65.7	7.57	121.0	7.25
		5	7.26	65.7	7.57	120.8	7.25
		6	7.25	65.5	7.55	120.9	7.25
		7	7.20	65.2	7.52	121.2	7.26
		8	6.76	27.3	3.20	117.1	7.04
		9	6.55	6.4	0.74	115.0	6.98
		10	6.33	4.7	0.55	118.9	7.00
		11	6.16	6.1	0.72	116.6	7.00
		12 (bottom)	6.07	7.1	0.84	116.8	7.01
2	6/1/01	0	7.86	66.6	7.59	114.9	7.05
		1	7.76	65.9	7.55	114.7	7.10
		2	7.22	62.3	7.20	114.4	7.07
		3	6.31	54.2	6.44	114.9	7.00
		4	6.06	50.7	6.07	114.3	6.94
		5	5.94	50.0	5.99	114.6	6.93
		6	5.84	48.6	5.83	114.3	6.91
		7 (bottom)	5.68	47.7	5.73	114.3	6.88
2	4/10/01	1	0.26	20.2	2.86	130.9	6.69
		1.75	0.43	17.5	2.47	131.2	6.62
		2.75	0.82	18.1	2.51	129.7	6.62
		3.75	1.11	20.6	2.84	127.9	6.61
		4.75	1.34	23.1	3.15	127.5	6.61
		5.75	1.56	21.4	2.92	127.9	6.63
		6.75	1.82	21.9	2.97	127.4	6.62
		7 (bottom)	1.82	21.8	2.94	127.4	6.60
2	8/29/00	0	11.22	80.7	8.63	107.5	7.24
		1	10.72	79.2	8.55	107.7	7.19
		2	10.59	78.8	8.54	108.1	7.18
		3	9.70	68.5	7.58	107.9	7.07
		4	8.89	54.0	6.13	106.8	6.87
		5	8.56	44.3	5.04	106.7	6.78

Appendix 1, continued.

Site 2 is located in the middle of Water Supply Reservoir							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(*u* S/cm)	pH
		6	7.15	29.9	3.54	102.9	6.64
		7	6.04	11.5	1.42	114.2	6.50
		8	5.86	4.7	0.57	126.2	6.40
2	8/29/00	9	5.38	3.5	0.42	138.2	6.34
		10	5.17	2.7	0.34	139.9	6.37
		11	4.90	2.4	0.29	142.2	6.41
		12	4.84	2.5	0.31	142.7	6.42
		13 (bottom)	4.81	2.3	0.29	143.2	6.44
2	6/23/00	0	18.76	95.5	8.75	103.1	7.57
		1	18.43	93.3	8.61	103.0	7.61
		2	14.73	72.2	7.21	103.7	7.15
		3	8.20	23.7	2.75	108.0	6.65
		4	6.37	22.7	2.75	108.9	6.62
		5	5.69	16.7	2.07	112.1	6.58
		6	4.89	14.0	1.76	115.8	6.55
		7	4.61	10.3	1.31	119.2	6.52
		8	4.26	9.5	1.21	121.8	6.50
		9	4.07	7.4	0.96	123.9	6.51
		10	3.89	4.6	0.59	128.4	6.50
		11	3.57	2.3	0.30	134.2	6.46
		11.5 (bottom)	3.41	2.0	0.26	139.8	6.43
2	5/30/00	0	7.14	55.3	6.61	109.3	6.73
		1	6.57	53.2	6.46	108.0	6.72
		2	6.07	52.2	6.41	106.9	6.71
		3	5.65	51.0	6.31	105.7	6.71
		4	5.59	50.0	6.21	105.5	6.70
		5	5.47	48.5	6.04	106.5	6.69
		6	4.30	41.5	5.32	109.1	6.66
		7	3.89	36.8	4.78	114.7	6.64
		8	3.48	28.0	3.67	126.0	6.61
		9	3.26	21.9	2.80	133.0	6.59
		10	2.51	5.5	0.74	164.6	6.52
		11 (bottom)	2.29	3.4	0.47	179.7	6.50
2	6/2/99	0	9.74	81.0	8.86	134.2	7.47
		1	9.72	80.5	8.84	134.4	7.44
		2	9.70	80.6	8.85	134.9	7.44
		3	9.66	80.9	8.88	134.8	7.43
		4	9.66	77.9	8.56	135.1	7.40

Appendix 1, continued.

Site 2 is located in the middle of Water Supply Reservoir							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(*u* S/cm)	pH
		5	9.31	67.7	7.45	133.9	7.16
		6	7.26	46.0	5.36	133.7	7.04
		7	6.13	36.0	4.26	135.0	6.97
2	6/2/99	8	5.50	29.9	3.62	136.0	6.90
		9	5.11	26.5	3.25	137.1	6.84
		9.5 (bottom)	4.98	25.4	3.14	137.6	6.81
2	4/15/99	2	1.41	25.4	3.50	161.4	6.13
		3	1.70	24.5	3.34	160.8	6.30
		4	1.95	24.7	3.34	159.8	6.22
		5	2.12	23.3	3.13	159.8	6.23
		6	2.26	20.3	2.72	160.1	6.19
		7	2.44	17.1	2.28	160.8	6.16
		8	2.43	3.9	0.52	166.1	6.16
		9	2.42	1.7	0.21	180.6	6.17
		10	2.41	1.0	0.13	244.9	6.24
2	10/1/98	surface	6.35	60.6	7.21	144.3	7.62
		1	6.25	60.1	7.18	144.8	7.58
		2	6.24	59.7	7.11	144.3	7.57
		3	6.22	59.0	7.06	144.5	7.56
		4	6.22	58.4	6.99	144.7	7.56
		5	6.20	58.0	6.94	144.4	7.56
		6	6.20	58.0	6.95	144.4	7.57
		7	6.18	58.0	6.97	144.4	7.56
		8	6.12	59.0	7.08	144.6	7.58
		9 (bottom)	6.13	58.7	7.00	144.7	7.60
2	7/28/98	surface	17.52	87.1	8.11	161.6	7.41
		1	17.25	85.1	7.98	162.1	7.44
		2	16.86	83.3	7.92	161.2	7.46
		3	14.17	48.0	4.80	156.9	6.98
		4	11.63	28.7	3.04	142.3	6.78
		5	10.31	22.8	2.46	138.4	6.70
		6	8.26	7.3	0.82	155.2	6.65
		7	7.62	4.4	0.52	159.8	6.64
		8 (bottom)	6.78	3.7	0.44	169.1	6.63
2	3/18/98	1	0.49	N/T	1.26	176.0	7.01
		2	0.79	N/T	1.70	175.0	6.93
		3	0.94	N/T	1.58	176.0	6.85

Appendix 1, continued.

Site 2 is located in the middle of Water Supply Reservoir							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(*u* S/cm)	pH
		4	0.97	N/T	1.08	178.0	6.81
		5	0.99	N/T	0.77	182.0	6.77
		6	1.08	N/T	0.39	184.0	6.75
2	3/18/98	7	0.85	N/T	0.08	214.0	6.60
		7.8 (bottom)	0.06	N/T	0.06	281.0	6.53
2	9/25/97	surface	9.34	N/T	6.10	143.0	7.23
		1	9.23	N/T	5.76	145.0	7.10
		3	9.18	N/T	5.67	147.0	7.05
		5	9.01	N/T	4.58	147.0	6.95
		7.5 (bottom)	8.49	N/T	2.65	145.0	6.92

Appendix 1, continued.

Site 3 is located in Solo Creek Bay							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(*u* S/cm)	pH
3	9/30/02	0	7.03	71.7	8.37	100.6	6.86
		1	6.92	70.0	8.20	100.4	6.83
		2	6.82	69.2	8.12	100.4	6.82
		3	6.81	67.6	7.95	100.3	6.81
		4	6.80	68.1	7.99	100.5	6.81
		5	6.78	66.7	7.83	100.7	6.80
		6	6.72	63.8	7.51	100.3	6.78
		7	4.86	79.0	9.75	90.8	6.81
		7.75 (bottom)	4.82	79.2	9.74	90.8	6.81
3	5/28/02	0	5.18	55.6	6.68	102.6	6.72
		1	5.17	55.3	6.66	102.3	6.70
		2	5.16	54.9	6.60	102.3	6.68
		3	5.17	54.7	6.57	102.7	6.69
		4	5.17	54.6	6.55	102.2	6.69
		5	5.16	54.3	6.53	102.3	6.69
		5.75 (bottom)	5.14	53.5	6.45	102.5	6.70
3	4/18/02	1	0.50	4.3	0.65	146.9	6.68
		2	0.79	9.9	1.35	146.2	6.66
		3	1.13	12.5	1.66	145.6	6.65
		4	1.17	2.6	0.36	153.2	6.59
		4.5 (bottom)	1.26	0.3	0.04	157.3	6.58
3	4/18/02	1	0.04	10.0	1.40	174.7	6.63
		1.5 (bottom)	0.25	18.5	2.62	181.2	6.64
3	4/18/02	1	0.00	57.5	8.10	192.0	6.73
		1.8 (bottom)	0.10	47.3	6.64	196.9	6.73
3	10/1/01	0	7.24	65.1	7.51	121.6	7.28
		1	7.23	64.5	7.43	121.5	7.28
		2	7.21	64.2	7.40	121.2	7.28
		3	7.16	63.5	7.33	121.5	7.28
		4	7.09	63.0	7.29	121.2	7.29
		5 (bottom)	6.82	63.0	7.35	121.4	7.29
3	6/1/01	0	9.03	72.4	8.04	115.8	6.87
		1	8.86	71.7	8.00	115.3	6.94
		2	8.83	71.4	7.98	115.3	6.97
		3	8.66	70.2	7.86	115.4	6.97

Appendix 1, continued.

Site 3 is located in Solo Creek Bay							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(*u* S/cm)	pH
		3.5 (bottom)	8.21	65.6	7.41	115.0	6.96
3	4/13/01	1	0.03	59.8	8.38	149.7	6.79
		1.75	0.27	43.1	6.05	145.5	6.71
		2.75	0.61	25.8	3.57	139.8	6.69
3	4/13/01	1	0.04	51.7	7.28	147.7	6.69
		1.75	0.34	32.7	4.57	140.9	6.65
		2.75	0.66	19.0	2.62	135.6	6.62
		3.75	0.90	11.6	1.60	136.3	6.57
		4.75	1.09	3.9	0.53	137.0	6.53
		5.5 (bottom)	1.20	3.0	0.41	137.3	6.52
3	8/29/00	0	11.02	78.1	8.37	108.9	7.13
		1	10.23	76.2	8.34	108.5	7.11
		2	10.00	74.2	8.15	108.4	7.09
		3	9.96	73.8	8.12	108.5	7.08
		4	9.74	70.2	7.75	108.8	7.02
		5	7.55	43.6	5.09	100.3	6.80
		6	5.56	69.1	8.46	82.1	6.76
		7	5.54	14.1	1.71	112.0	6.46
		8	5.34	4.2	0.51	132.3	6.40
		9 (bottom)	5.22	3.0	0.37	138.0	6.45
3	6/23/00	0	18.34	93.8	8.67	103.6	7.48
		1	16.30	88.7	8.56	103.0	7.43
		2	10.25	33.1	3.69	107.0	6.68
		3	6.92	20.8	2.48	112.1	6.60
		4	5.80	14.1	1.74	113.4	6.55
		5	5.18	12.1	1.52	115.2	6.51
3	6/23/00	5.75 (bottom)	4.79	7.6	0.98	118.1	6.50
3	5/30/00	0	5.80	49.0	6.06	108.8	6.70
		1	5.82	48.0	5.95	108.9	6.69
		2	5.80	47.9	5.91	108.9	6.69
		3	4.72	43.0	5.50	110.9	6.67
		3.5 (bottom)	4.56	40.6	5.19	112.3	6.66
3	6/2/99	0	9.67	88.4	9.67	135.1	7.32
		1	9.60	84.4	9.29	134.8	7.32
		2	9.21	77.9	8.66	134.8	7.27

Appendix 1, continued.

Site 3 is located in Solo Creek Bay							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(*u* S/cm)	pH
		3	7.71	57.4	6.50	134.5	7.10
		4	6.93	48.1	5.59	132.5	7.02
		5	5.61	64.3	7.83	115.0	7.11
		6	5.02	69.2	8.55	110.5	7.14
		7 (bottom)	4.92	70.7	8.75	110.5	7.11
3	10/1/98	surface	6.11	71.2	8.53	144.2	7.30
		1	6.05	70.5	8.44	144.2	7.32
		2	5.98	69.4	8.36	144.2	7.34
		3	5.88	69.2	8.35	144.2	7.36
		4 (bottom)	4.93	69.5	8.59	139.4	7.36
3	7/28/98	surface	17.24	86.9	8.15	161.3	7.57
		1	16.71	80.0	7.58	161.8	7.52
		2	16.33	66.9	6.38	161.2	7.33
		3 (bottom)	14.62	58.4	5.75	150.6	7.19
3	3/18/98	1	0.47	N/T	0.31	176.0	6.93
		1.5 (bottom)					
3	9/25/97	surface	9.36	N/T	5.90	156.0	7.94
		1	9.25	N/T	5.62	156.0	7.68
		3	9.10	N/T	5.42	155.0	7.38
		4.5 (bottom)	8.96	N/T	4.30	155.0	7.13

Appendix 1, continued.

Site 7 is located in Lower Last Chance Bay							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(*u* S/cm)	pH
7	9/30/02	0	6.91	70.2	8.22	100.6	6.86
		1	6.88	69.1	8.10	100.5	6.84
		2	6.82	68.4	8.03	100.5	6.83
		3	6.72	67.3	7.92	100.6	6.83
		4	6.66	64.9	7.65	100.7	6.81
		4.75 (bottom)	6.43	56.3	6.68	101.3	6.75
7	5/28/02	0	5.09	64.0	7.72	103.5	6.76
		1	5.08	62.3	7.50	103.9	6.77
		2	5.06	61.7	7.47	103.9	6.76
		3	5.01	61.2	7.40	104.2	6.76
		4	5.00	60.5	7.31	104.1	6.76
		4.75 (bottom)	4.97	60.2	7.25	104.3	6.77
7	4/18/02	1	0.37	1.6	0.22	156.3	6.57
		2	0.66	0.7	0.04	155.6	6.56
		3	0.91	0.0	0.00	156.0	6.56
		3.5 (bottom)	0.89	0.0	0.00	172.7	6.51
7	10/1/01	0	6.98	65.1	7.57	121.8	7.28
		1	6.91	64.0	7.43	122.2	7.29
		2	6.85	63.7	7.41	121.8	7.29
		3	6.61	64.4	7.54	122.2	7.31
		4	6.51	61.6	7.23	122.5	7.28
		5 (bottom)	6.34	56.3	6.63	122.8	7.24
7	6/1/01	0	9.41	69.2	7.61	115.9	6.92
		1	9.12	68.6	7.61	115.7	6.92
		2	8.97	68.4	7.61	115.6	6.90
		3	8.73	67.1	7.51	115.8	6.91
		4 (bottom)	6.27	45.0	5.35	115.8	6.82
7	4/13/01	1	0.09	5.3	0.75	143.1	6.53
		1.75	0.29	3.7	0.54	143.6	6.52
		2.75	0.51	3.0	0.41	142.9	6.52
		3.75	0.62	2.7	0.37	154.5	6.50
		4.75 (bottom)	0.55	2.3	0.32	275.9	6.42
7	8/29/00	0	10.54	75.7	8.22	108.3	7.06
		1	10.11	72.5	7.95	108.9	7.04
		2	9.94	71.5	7.84	108.4	7.02

Appendix 1, continued.

Site 7 is located in Lower Last Chance Bay							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(*u* S/cm)	pH
		3	9.71	68.3	7.60	108.8	7.00
		4	9.30	67.1	7.50	105.9	6.95
		5 (bottom)	8.38	68.5	7.81	103.0	6.93
7	6/23/00	0	18.23	90.7	8.40	103.9	7.40
		1	16.22	82.5	7.92	103.4	7.23
		2	12.30	47.3	4.98	105.4	6.79
		3	8.07	16.9	1.96	111.1	6.64
		4	6.00	6.7	0.82	116.0	6.51
		5	5.36	4.2	0.52	119.0	6.46
7	5/30/00	0	6.80	52.3	6.30	110.7	6.75
		1	6.39	49.4	5.99	110.5	6.72
		2	4.93	41.1	5.19	110.7	6.70
		3	4.19	35.1	4.54	116.8	6.64
		4	4.10	33.4	4.31	117.5	6.63
		5 (bottom)	3.99	29.6	3.84	119.0	6.61
7	6/2/99	0	8.84	72.0	8.06	133.5	7.21
		1	8.82	70.3	7.90	133.8	7.20
		2	8.65	68.2	7.67	133.6	7.21
		3	6.21	42.5	5.09	134.9	7.01
		4	6.17	38.8	4.64	135.0	7.01
		4.5 (bottom)	6.16	37.1	4.45	134.9	7.00
7	10/1/98	surface	5.63	67.6	8.22	143.6	7.59
		1	5.52	68.0	8.29	143.9	7.57
		2	5.37	68.4	8.36	143.4	7.58
		3	5.00	68.9	8.51	143.4	7.59
		4	4.92	69.0	8.53	143.0	7.59
		5 (bottom)	4.97	66.6	8.21	143.2	7.56
7	7/28/98	surface	17.22	82.5	7.71	160.5	7.59
		1	16.82	79.7	7.54	161.2	7.57
		2	13.82	58.9	6.70	155.5	7.31
		3 (bottom)	13.22	43.1	4.40	146.3	7.20
7	9/25/97	surface	9.22	N/T	6.34	141.0	7.01
		1	8.97	N/T	5.77	141.0	7.01
		3	8.86	N/T	4.90	142.0	6.94

Appendix 1, continued.

Site 7 is located in Lower Last Chance Bay							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(*u* S/cm)	pH
		4	8.90	N/T	4.76	141.0	6.92
		4.5 (bottom)					

Appendix 1, continued.

Site 9 is located in Upper Last Chance Bay							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(*u* S/cm)	pH
9	9/30/02	0	4.78	93.7	11.58	102.7	7.00
		1	4.11	92.4	11.63	101.0	6.99
		2	3.99	91.4	11.52	101.2	6.99
		3	4.13	88.2	11.03	104.7	6.93
		4 (bottom)	4.19	55.2	6.93	136.0	6.70
9	9/17/97	0	10.90	N/T	7.60	139.0	6.97
		1	10.90	N/T	6.95	151.0	7.08
		2	10.80	N/T	7.03	142.0	7.16
		3 (bottom)	10.05	N/T	4.80	142.0	6.87

Appendix 1, continued.

Site 11 is located in Polar Bay							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(*u* S/cm)	pH
11	9/30/02	0	6.96	70.4	8.23	100.3	6.88
		1	6.94	69.9	8.19	100.5	6.84
		2	6.92	69.3	8.12	100.2	6.84
		3	6.89	68.8	8.07	100.2	6.83
		4	6.84	68.5	7.97	100.4	6.82
		5	6.71	65.5	7.71	100.5	6.80
		6	6.50	58.1	6.86	101.2	6.74
		7	6.18	68.9	8.21	102.1	6.74
		8 (bottom)	6.09	52.5	6.25	102.2	6.70
11	5/28/02	0	5.70	68.9	8.17	99.5	6.87
		1	5.69	67.0	7.95	99.9	6.83
		2	5.64	66.2	7.86	100.5	6.79
		3	5.64	66.2	7.85	100.1	6.79
		4	5.61	65.6	7.77	100.2	6.78
		5	5.61	65.5	7.78	100.5	6.79
		6	5.62	65.5	7.78	100.5	6.79
		7 (bottom)	5.61	65.3	7.75	100.6	6.79
11	4/18/02	1	0.41	3.9	0.59	154.5	6.73
		2	0.47	6.7	0.93	171.3	6.62
		3	0.82	7.7	1.06	164.1	6.60
		4	0.74	6.0	0.88	178.2	6.57
		5	1.32	4.1	0.52	191.5	6.54
		6	2.39	0.0	0.00	218.2	6.44
		6.5 (bottom)	2.58	0.0	0.00	287.5	6.38
11	10/1/01	0	7.12	63.9	7.40	122.5	7.27
		1	7.10	63.1	7.30	122.3	7.27
		2	7.08	63.1	7.30	122.0	7.28
		3	7.07	62.8	7.27	122.0	7.28
		4	7.06	62.9	7.28	122.4	7.29
		5	7.06	63.0	7.29	122.3	7.29
		6	7.00	62.8	7.29	125.5	7.28
		7	6.87	62.6	7.28	127.2	7.28
		8(bottom)	6.30	66.2	7.81	128.7	7.32
11	6/1/01	0	9.36	71.6	7.91	116.2	6.94
		1	9.22	70.7	7.80	115.7	6.91
		2	9.10	70.0	7.76	115.9	6.95
		3	9.10	69.6	7.72	115.8	6.95

Appendix 1, continued.

Site 11 is located in Polar Bay							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(u S/cm)	pH
		4	8.95	68.8	7.65	115.9	6.96
		5	6.55	56.2	6.64	116.0	6.91
		6.5 (bottom)	6.07	51.3	6.12	118.0	6.84
11	4/13/01	1	0.22	14.7	2.05	139.0	6.53
		1.75	0.21	19.2	2.71	151.5	6.54
		2.75	0.34	26.2	3.65	161.4	6.59
		3.75	0.67	23.2	3.21	154.2	6.56
		4.75	0.77	23.7	3.27	166.2	6.58
		5.75	2.10	9.6	1.29	165.9	6.50
		6.75	2.61	3.1	0.42	260.0	6.32
		7.25 (bottom)	2.47	2.4	0.32	355.1	6.30
11	8/29/00	0	10.80	75.1	8.15	108.4	7.09
		1	10.07	74.8	8.22	108.2	7.09
		2	9.84	70.9	7.84	108.2	7.07
		3	9.64	68.5	7.59	108.5	7.00
		4	9.50	76.0	8.47	105.7	7.01
		5	9.03	74.2	8.34	104.5	7.00
		6	7.15	14.9	1.75	112.2	6.68
		7	6.37	4.4	0.53	121.1	6.45
		8 (bottom)	5.87	2.6	0.32	139.8	6.45
11	6/23/00	0	18.15	93.8	8.71	103.7	7.53
		1	15.99	86.0	8.35	103.3	7.42
		2	13.45	57.6	5.88	105.3	6.95
		3	7.29	23.0	2.73	110.5	6.63
11	6/23/00	4	6.07	16.6	2.02	113.6	6.56
		5	5.39	11.8	1.48	118.0	6.52
		6	4.94	9.0	1.14	120.6	6.49
		7	4.73	6.5	0.82	123.0	6.48
		8	4.62	4.7	0.60	125.0	6.48
		8.5 (bottom)	4.52	3.6	0.45	126.7	6.43
11	5/30/00	0	6.21	51.0	6.25	109.7	6.78
		1	5.64	47.4	5.88	110.3	6.69
		2	4.80	42.7	5.40	111.9	6.70
		3	4.43	38.6	4.94	114.9	6.66
		4	4.25	37.2	4.77	116.3	6.64
		5	3.95	33.9	4.40	117.8	6.64
		6	3.81	31.6	4.10	121.5	6.63

Appendix 1, continued.

Site 11 is located in Polar Bay							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(*u* S/cm)	pH
		7	3.88	31.5	4.09	124.4	6.60
		8 (bottom)	3.30	7.4	1.05	231.6	6.35
11	6/2/99	0	8.37	66.7	7.60	134.0	7.15
		1	8.00	61.3	7.01	133.7	7.12
		2	7.44	54.7	6.34	133.9	7.13
		3	6.52	44.2	5.26	134.0	7.06
		4	6.17	40.1	4.80	135.1	7.03
		5	5.86	36.4	4.42	135.9	7.01
		6	6.58	44.5	5.26	135.1	7.03
		7 (bottom)	7.38	53.8	6.44	134.0	7.09
11	10/1/98	surface	5.80	71.9	8.69	144.1	7.57
		1	5.78	72.0	8.70	144.1	7.57
		2	5.75	72.1	8.73	143.9	7.58
		3	5.59	72.3	8.78	144.0	7.59
		4	5.57	72.5	8.82	143.3	7.60
		5	5.53	72.4	8.81	143.8	7.59
		6	5.51	72.3	8.81	143.3	7.59
		7 (bottom)	5.51	72.6	8.84	143.5	7.57
11	7/28/98	surface	17.07	82.4	7.75	160.6	7.60
		1	16.82	79.0	7.47	161.0	7.57
		2	16.15	60.8	5.84	160.0	7.23
		3	14.57	38.1	3.72	155.8	7.00
		4	12.31	15.5	1.66	152.8	6.84
		5	10.53	7.1	0.78	166.7	6.80
		5.5 (bottom)	9.78	5.0	0.56	175.8	6.83

Appendix 1, concluded.

Site 12 is located in Fish Creek Bay							
				% Saturation	Dissolved		
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity	
Number	Date	(m)	(C)	Oxygen	(mg/L)	(*u* S/cm)	pH
12	9/30/02	0	5.98	88.2	10.57	110.8	6.99
		1	5.69	86.6	10.46	111.2	6.96
		2	5.59	79.7	9.63	115.5	6.89
		3	5.59	72.1	8.73	123.3	6.77
		4	5.79	0.9	0.12	359.3	6.66
		5 (bottom)	5.17	0.0	0.00	442.3	6.78

Appendix 2. Arctic Grayling Population Estimates in the WSR

Estimates of the Arctic grayling population in the WSR and developed wetlands at the Fort Knox Mine (1995 to 2001). We used fyke-nets for the capture and recapture events, except where noted.

Year	Minimum Size of Fish in Estimate (mm)	Estimated Size of Population	95% Confidence Interval
1995[1]	150	4,358	
1996[2]	150	4,748	3,824-5,672
1996[3]	150	3,475	2,552-4,398
1998[4]	200	5,800	4,705-6,895
1999[4]	200	4,123	3,698-4,548
2000[4]	200	5,326	4,400-6,253
2001[4]	200	5,623	5,030-6,217

[1]We used estimates from the ponds and creeks for the Arctic grayling population, a confidence interval was not applicable to the data set.

[2]The 1996 estimate was made with a capture and recapture event in summer 1996.

[3]Gear type for the population estimate was a boat-mounted electroshocker with both capture and recapture events in fall 1996.

[4]The 1998 through 2001 population estimates were made using a mark event in spring of the year of the estimate, but the recapture event was in spring of the following year.

Appendix 3. Burbot Population Estimates in the WSR

Estimates of the burbot population in the WSR and developed wetlands at the Fort Knox Mine (1995 to 2002). We used hoop traps for the capture and recapture events, except where noted.

Year	Minimum Size of Fish in Estimate (mm)	Estimated Size of Population	95% Confidence Interval
1995[1]	150	876	666-1,087
1997[2]	250	622	462-782
1998[2]	300	703	499-907
1998[3]	200	3,609	2,731-4,485
1999[3]	200	4,136	3,215-5,057
2000[3]	200	3,536	2,444-4,629
2001[4]	200	3,391	2,017-4,764
2001	400	134	58-210
2002[4]	200	1,763	1,045-2,480
2002	400	131	62-199

[1]We used fyke-nets in the Polar Pond complex to make the 1995 population estimate.

[2]The 1997 and 1998 estimates were made with a capture and recapture event in May of the same year.

[3]The 1998, 1999, and 2000 population estimates were made using a mark event in spring with the recapture event occurring one year later in the spring.

[4]The 2001 and 2002 population estimates were made with capture and recapture events in the same year.

Appendix 4. Burbot Catches in the WSR

Sample Date	Gear Type	Number of Traps	Catch	Mean CPUE
5/22/96	small hoop	11	36	3.3
5/22/96	large hoop	4	6	1.5
5/23/96	small hoop	11	19	1.7
5/23/96	large hoop	4	2	0.5
5/20/97	small hoop	11	58	5.3
5/20/97	large hoop	13	24	1.8
5/21/97	small hoop	11	61	5.5
5/21/97	large hoop	17	56	3.3
5/28/97	small hoop	11	45	4.1
5/28/97	large hoop	19	42	2.2
5/29/97	small hoop	11	32	2.9
5/29/97	large hoop	20	39	2.0
5/20/98	small hoop	7	87	12.4
5/21/98	small hoop	9	61	6.8
5/21/98	large hoop	3	20	6.7
5/22/98	small hoop	9	57	6.3
5/27/98	small hoop	9	61	6.8
5/28/98	small hoop	9	67	7.4
5/29/98	small hoop	9	44	4.9
6/3/99	small hoop	17	135	7.9
6/4/99	small hoop	17	124	7.3
6/5/99	small hoop	17	136	8.0
6/7/99	small hoop	17	142	4.2
6/8/99	small hoop	17	89	5.2
5/30/01	small hoop	24	191	7.9
5/31/01	small hoop	24	105	4.4
6/1/01	small hoop	24	122	5.1
6/6/01	small hoop	30	209	7.0
6/7/01	small hoop	30	76	2.5
6/27/01	small hoop	30	98	3.3
6/28/01	small hoop	30	140	4.7

Appendix 2, concluded.

Sample Date	Gear Type	Number of Traps	Catch	Mean CPUE
6/3/02	small hoop	30	58	1.0
6/5/02	small hoop	30	58	1.0
6/6/02	small hoop	30	41	1.4
6/8/02	small hoop	30	118	2.0
6/10/02	small hoop	30	120	2.0
10/3/02	small hoop	30	69	1.2

Burbot Catch Per Unit of Effort, CPUE – number of burbot caught per trap day