Technical Report No. 05-01

Arctic Grayling and Burbot Studies at the Fort Knox Mine, 2004

by Alvin G. Ott
and William A. Morris

Last Chance Creek
Photograph by Al Ott 2001

January 2005

Alaska Department of Natural Resources
Office of Habitat Management and Permitting

Table of Contents

List of Tables

List of Figures

Acknowledgements

We thank Fairbanks Gold Mining Inc. (John Wild and Delbert Parr) for their continued support of our study to evaluate fisheries resources in the water supply reservoir and developed wetlands. Our thanks also go to Fairbanks Gold Mining Inc. for their commitment to conduct concurrent reclamation in the wetlands downstream of the tailing impoundment and in Last Chance Creek. We thank Alaska Department of Natural Resources employees Nancy Ihlenfeldt, Lisa Whitman, Kerry Howard, Laura Jacobs, and Alan Townsend for their assistance with fieldwork. Jack Winters and Delbert Parr provided constructive review of our report.

Executive Summary

Water Quality

- dissolved oxygen concentrations continue to be low in the water supply reservoir (WSR) – pages 12 to 14
- dissolved oxygen concentrations decrease with depth in both summer and winter – pages 12 to 14
- pH has shown a general decreasing trend since 1999 – page 15
- conductivity was highest in spring 1999 and very similar for the years 2000 through 2004 – page 15

Arctic Grayling

- outmigration of fish to the stilling basin appeared to be higher in summer 2003 and spring 2004 based on catches – pages 16 to 17
- Arctic grayling successfully spawned in the wetland complex in spring 2004 with peak spawning activity occurring between May 13 and 17 when water temperatures peaked from 7.9 to 13.9°C – page 18
- Arctic grayling successfully spawned in Last Chance Creek in spring 2004; this is the first year since construction of the water supply reservoir that Arctic grayling spawned in Last Chance Creek and the first time we have observed minimal aufeis in the lower portion of the creek – pages 21 to 22
- the estimated population in spring 2003 was 6,495; slight increases have occurred each year since 1999; the population remained essentially unchanged from spring 2002 to spring 2003 – page 23

Burbot

- successful spawning of burbot in the WSR continues based on catches of small burbot in the WSR and age-0 burbot in Pond F – page 29
- the estimated burbot population for fish >200 mm in summer 2003 was 1,103 – page 28

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.

During construction of the WSR dam, 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 many disturbed habitats has been rapid. Wetland development began in summer 1998. A channel connecting wetlands to the WSR was constructed in May 1999. Civil work to minimize aufeis in Last Chance Creek was done in fall 2001. Repair work on the dike separating Ponds D and E and the channel connecting the ponds was completed in summer 2002.

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

Stream sampling continued in 1995 and we estimated the Arctic grayling (*Thymallus arcticus*) and burbot (*Lota lota*) populations that would be available to colonize the WSR. In 1995, the Arctic grayling population in Fish Creek, upstream of the proposed location of the WSR dam, was estimated at 1,700 fish <150 mm, and 4,350 fish >150 mm. The number of burbot, between 150 and 331 mm, in the upper Fish Creek drainage was estimated at 876 fish.

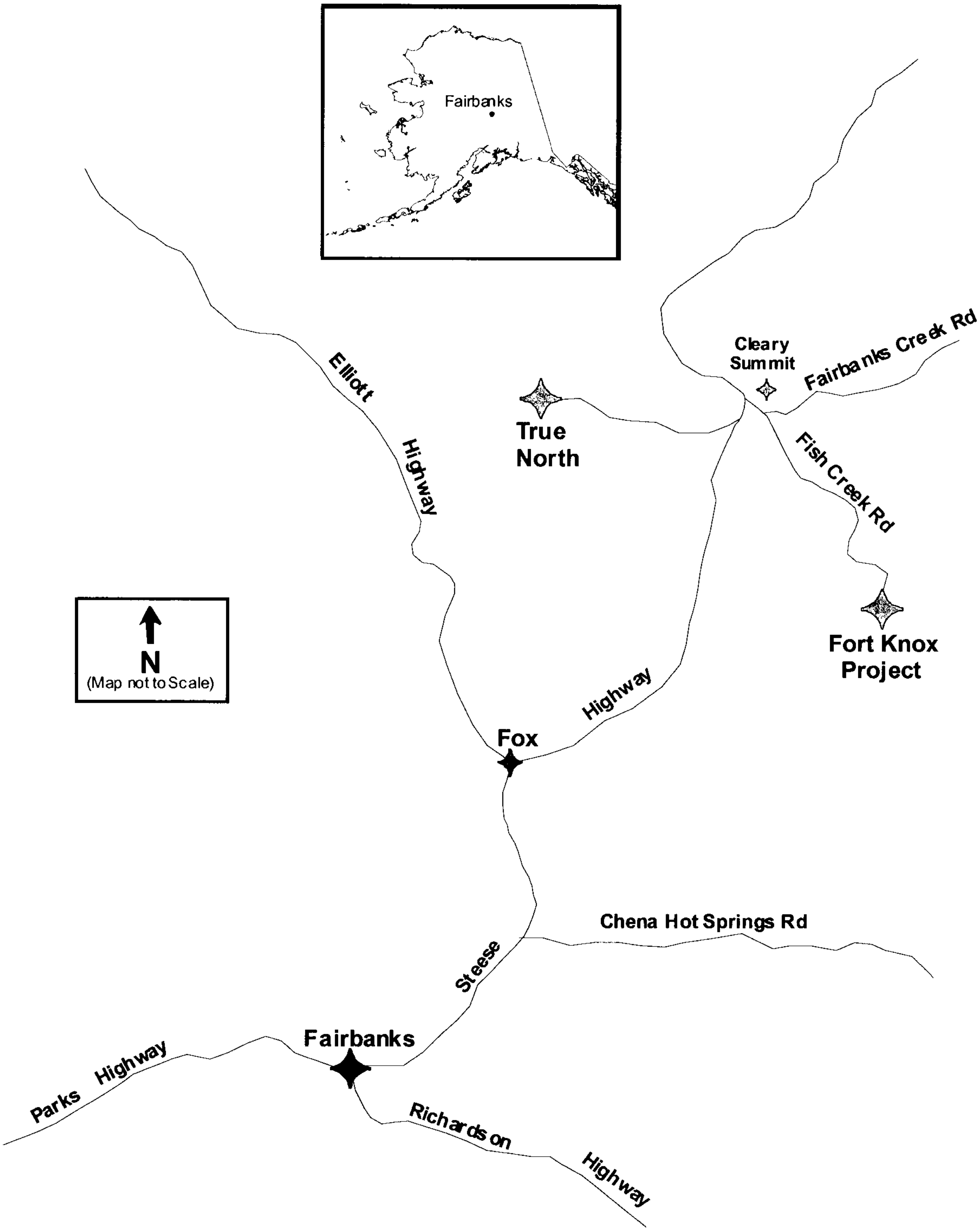


Figure 1. Fort Knox project location.

From 1996 to present, we have monitored the Arctic grayling and burbot populations in the WSR including estimates of their populations (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, Ott and Morris 2002a, Ott and Morris 2002b, Ott and Morris 2003). Water quality monitoring in the WSR began in 1997 and continues annually. Fisheries work was expanded to cover the wetlands in spring 1999 and in spring 2001 we began to capture fish in the stilling basin below the WSR spillway. Our report summarizes fish and water quality data collected during 2004 and discusses these findings in relation to previous work.

Methods

Sampling Sites

Multiple fyke-net sampling sites have been used (Figures 2 and 3) to target Arctic grayling. Changes in fyke-net locations have been made to optimize catches and to respond to water surface elevation changes in the WSR. Sites were added in the constructed wetlands after Channel #5 was constructed in spring 1999. In spring 2004, fyke-nets were fished at four stations (#16, #18, #11, and #19). Each fyke-net site was fixed in spring 2004. Sites in 2004 were not affected by the water surface elevation changes because the WSR was full and flowing over the spillway. In spring 2004, hoop traps targeting burbot were fished throughout the WSR.

Water Quality

Temperature (°C), dissolved oxygen (DO) concentration (mg/L), DO 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 DO 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). Prior to setting burbot traps, DO profiles were run at the five water quality sites to ensure adequate DO concentrations were present to support trapped burbot. If DO concentrations were low (e.g., <3 mg/L) at 5 m of depth, all hoop traps were set in less than 4 m of water. Burbot and Arctic grayling >200 mm captured during May and June were marked with a numbered Floy® internal anchor tag.

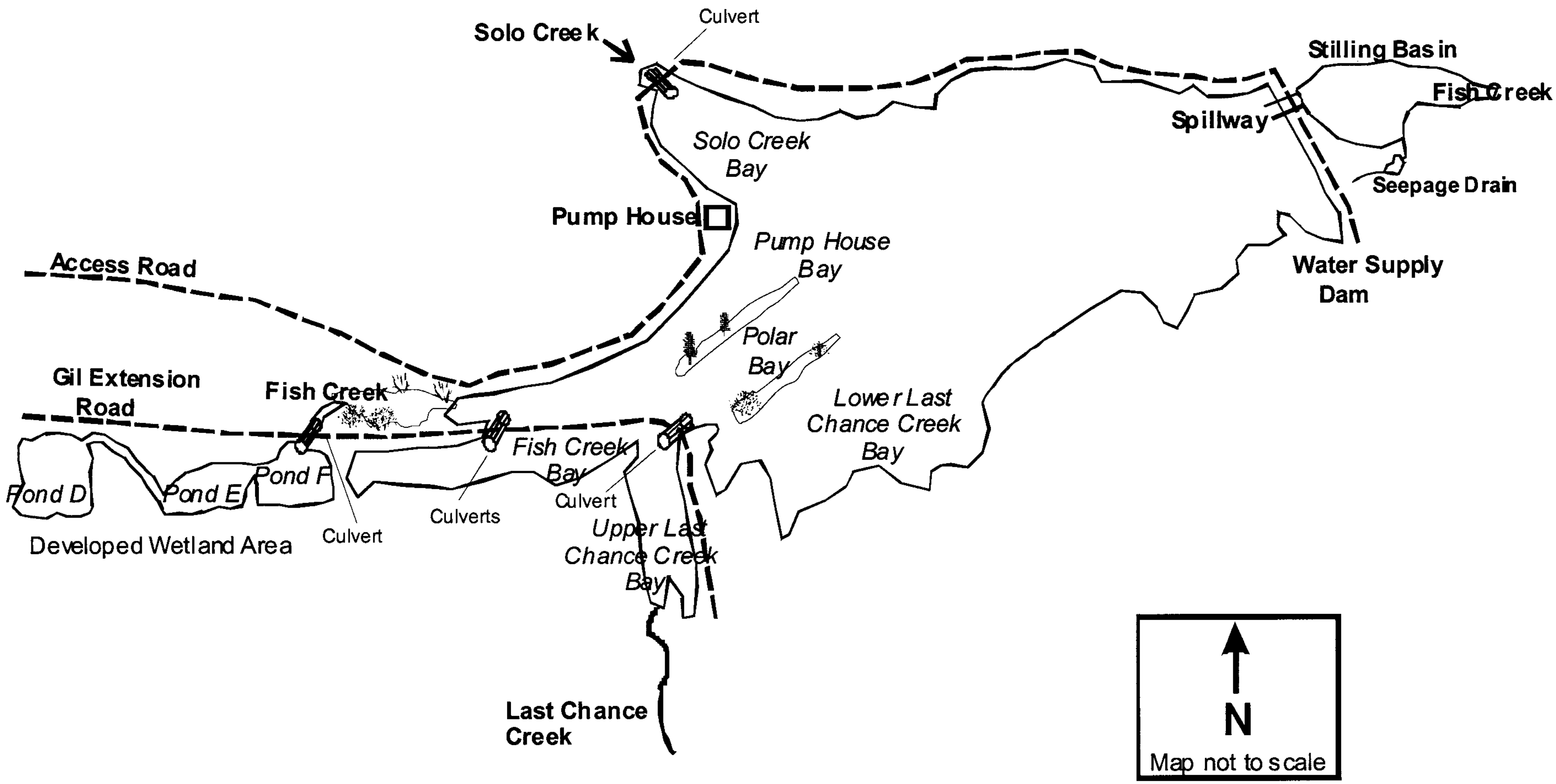


Figure 2. Sample areas in the Fort Knox WSR, stilling basin, and developed wetlands.

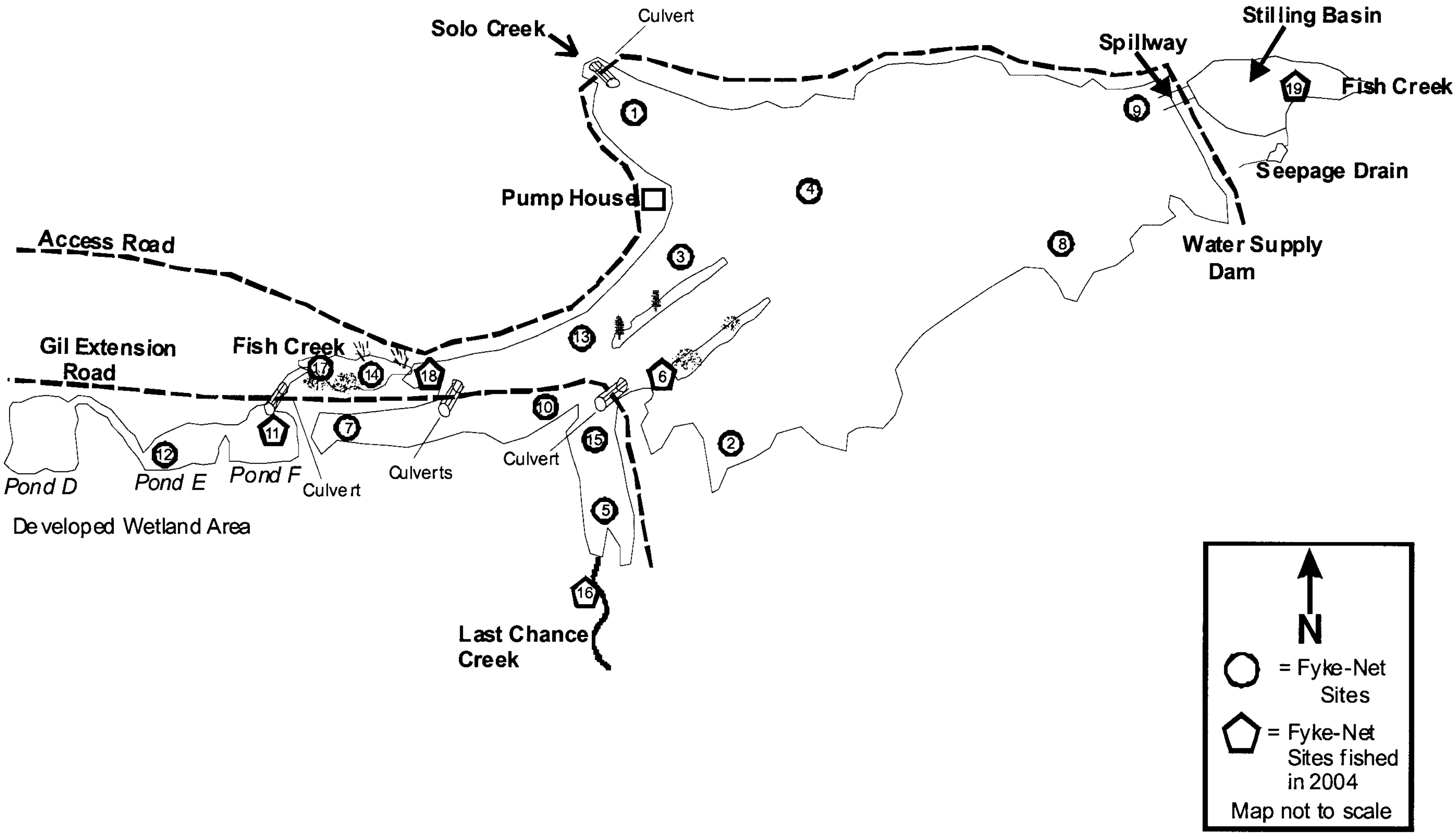


Figure 3. Fyke-net sample sites in the Fort Knox WSR, stilling basin, and developed wetlands (1996-2004).

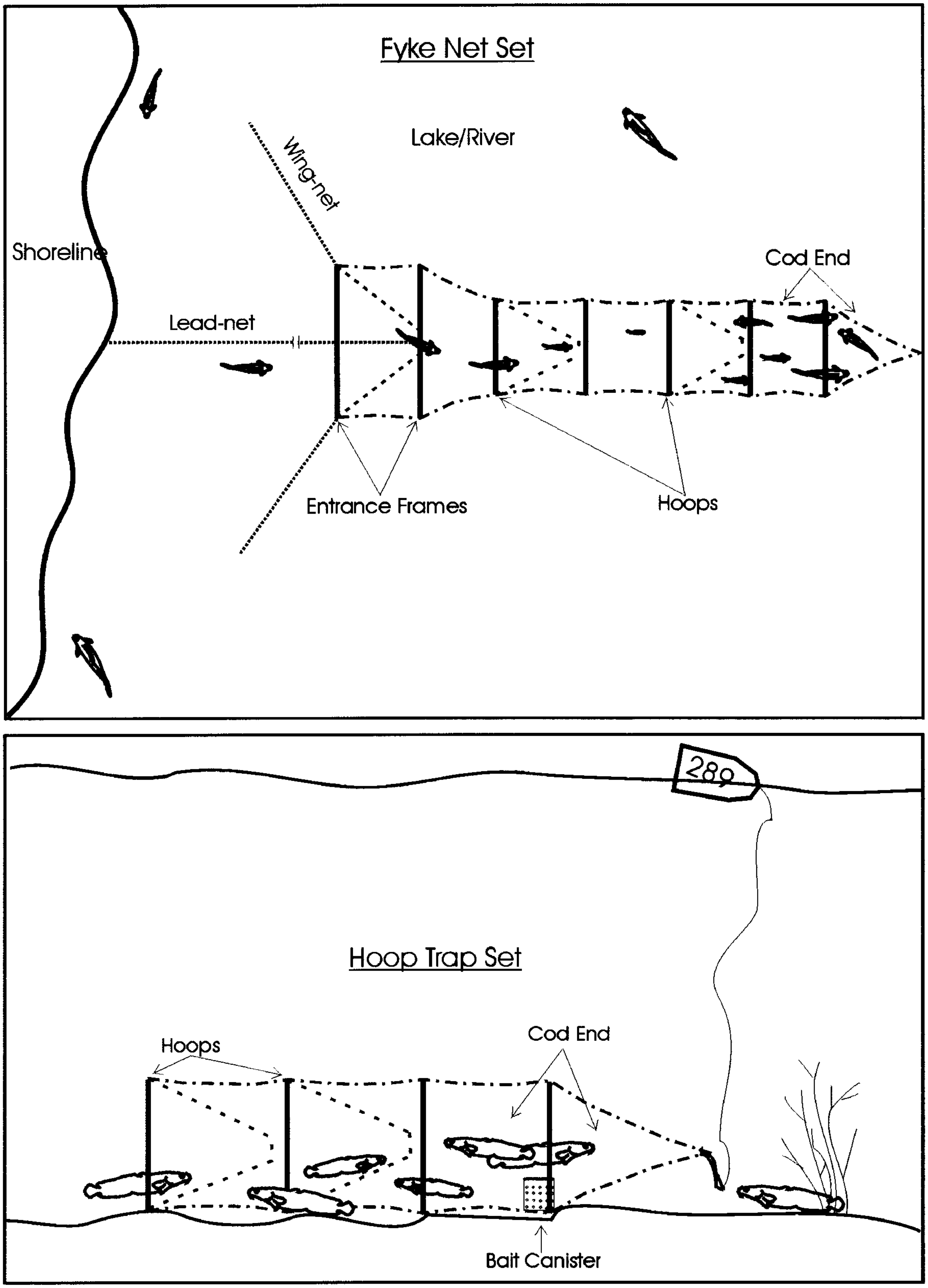


Figure 4. Diagram of fyke-net and hoop trap sets.

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. Generally, fyke-nets were checked every 24 hours.

Hoop traps baited with whitefish were used to capture burbot. In 2004, traps were fished for 72 and 96 hrs and were rebaited when 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 sites were established and sampled in the WSR beginning in fall 1997 (Figure 5). Two new sites were added in fall 2002 – both are located upstream of the Gil Causeway. Data collected at Site #1 and Site #11 are presented in Appendix 1.

Ponding of water in the WSR began in November 1995. Water levels varied greatly 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 a period of high rainfall. The WSR contains 3,363 acre-feet (1.096 billion gallons) of water.

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 was pumped from the WSR to the tailing impoundment. In summer 2001, it took until mid-summer before the WSR recharged and water flowed out the spillway. Water use during the next three winters (October through April) was minimal. Generally there was a surface discharge to Fish Creek even during the winter months.

Table 1. Winter water use from the WSR, 1997 through 2004

Year	Acre-Feet of Water Removed
1997/1998	660
1998/1999	605
1999/2000	577
2000/2001	1,464
2001/2002	320
2002/2003	337
2003/2004	279

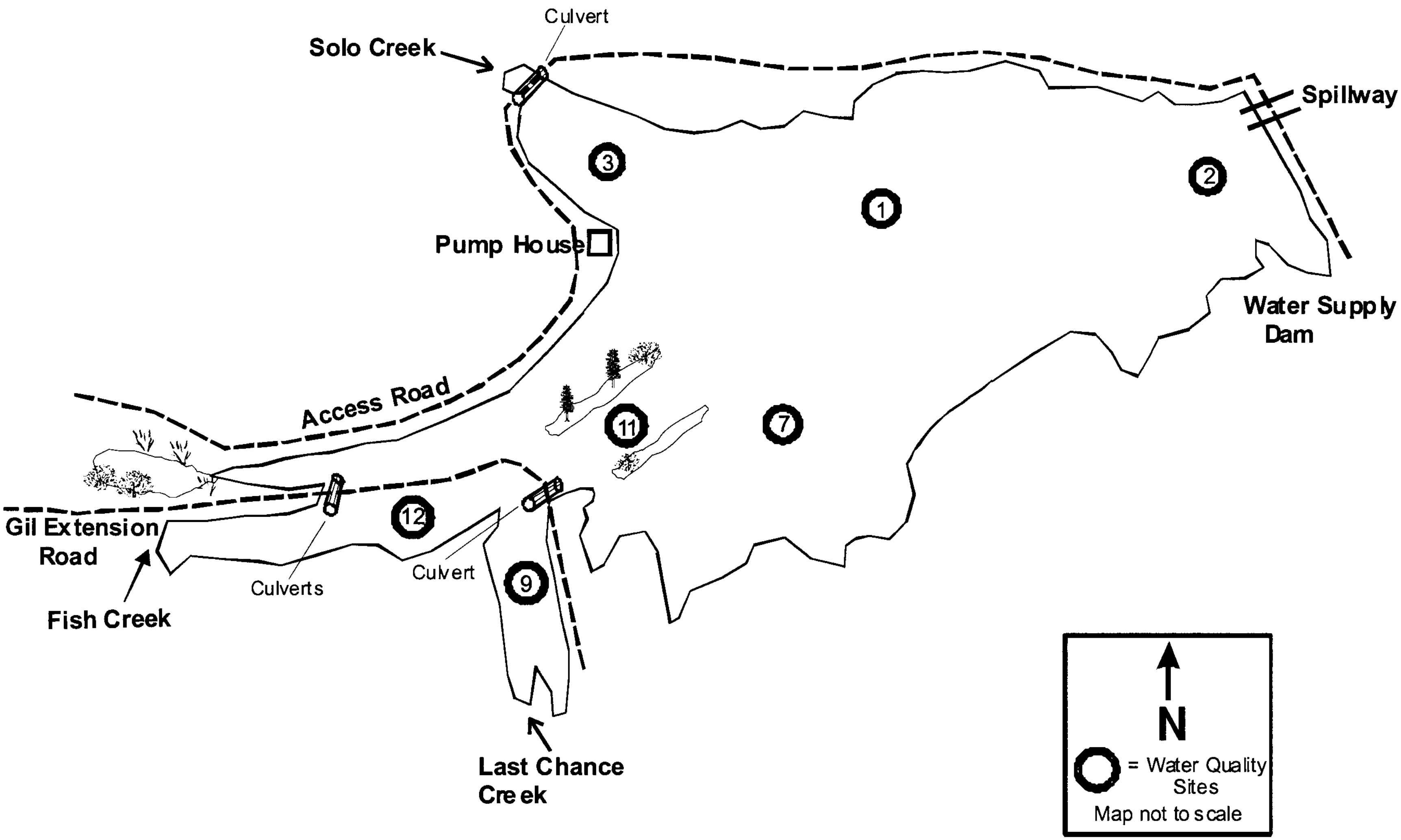


Figure 5. Water quality sample sites in the Fort Knox WSR.

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

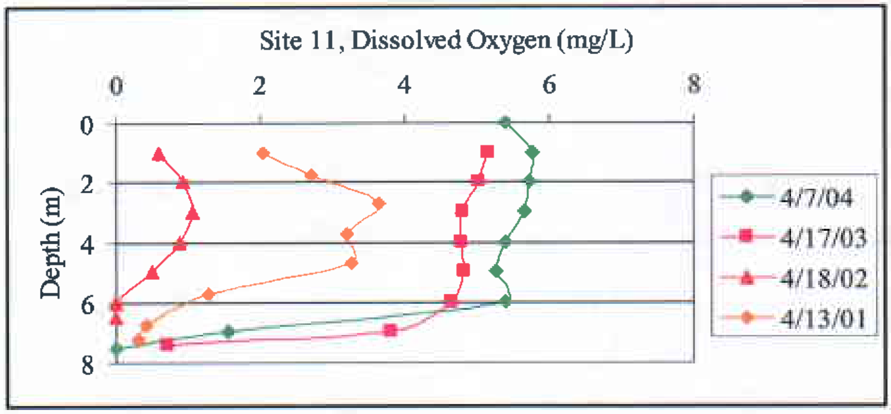
Table 2. Seepage flow rates below the WSR dam.

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
2003	1.13 to 1.78	1.36
2004	1.00 to 1.69	1.28

On April 7, 2004, water quality data were collected at Site #1 (middle of reservoir), Site #2 (located near the WSR dam), Site #3 (Solo Bay), Site #11 (Polar Bay), and Site #7 (lower Last Chance Bay). DO concentrations were lowest in lower Last Chance Bay and highest in Polar Bay.

Higher DO concentrations in Polar Bay probably are due to water flow from Last Chance Creek that enters the head of Polar Bay through a large culvert. Increased DO concentrations have been documented in Polar Bay at Site #11 over the past several years (Figure 6), most likely the result of aufeis mitigation activities in Last Chance Creek.

Civil work designed to mitigate aufeis formation in Last Chance Creek was done in the fall 2001. Material was moved in two reaches, one near the mouth and the second about 1 km upstream from the WSR. Gravel berms were constructed at both locations in an attempt to concentrate flow, prevent water from overtopping the banks during breakup, and to minimize aufeis. However, aufeis inundated the entire lower portion of Last Chance Creek in spring 2002. In spring 2003, the lower 0.5 km of the creek was free of aufeis and in spring 2004, the lower 1 km was ice free. Civil work may have helped to decrease aufeis formation in the last two winters. Decreased aufeis formation will maintain a higher flow of oxygenated water to the WSR during winter.



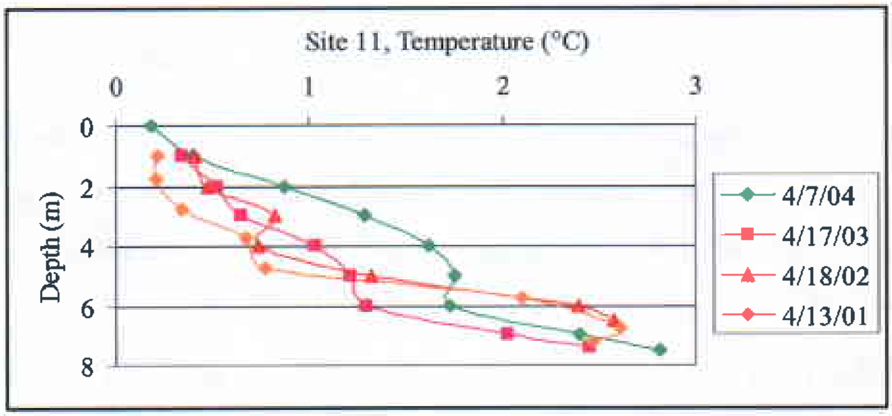
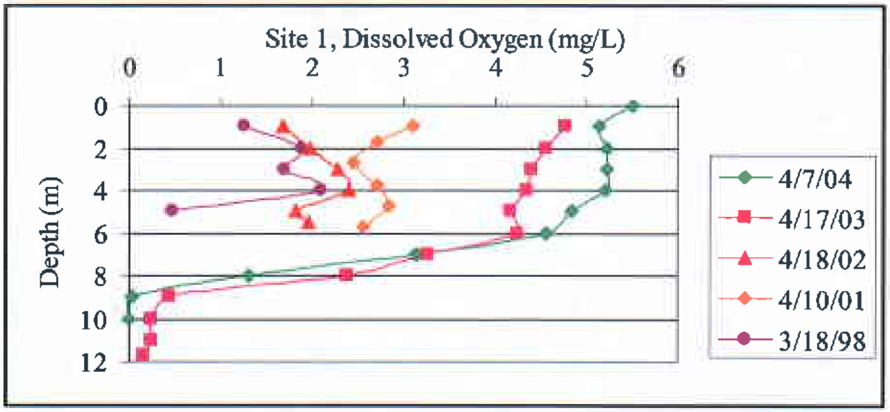


Figure 6. Dissolved oxygen concentration and temperature at Site #11 (Polar Bay) by depth in late winter (2001 through 2004).

Water quality data were collected in the WSR in early April and late May (immediately after the WSR was ice-free) in 2004. Site #1, located in the middle of the WSR, is influenced by freshwater input from Last Chance and Solo creeks. In late winter 2004, DO decreased with depth, but concentrations in the upper 6 m of water were the highest recorded to date (Figure 7).



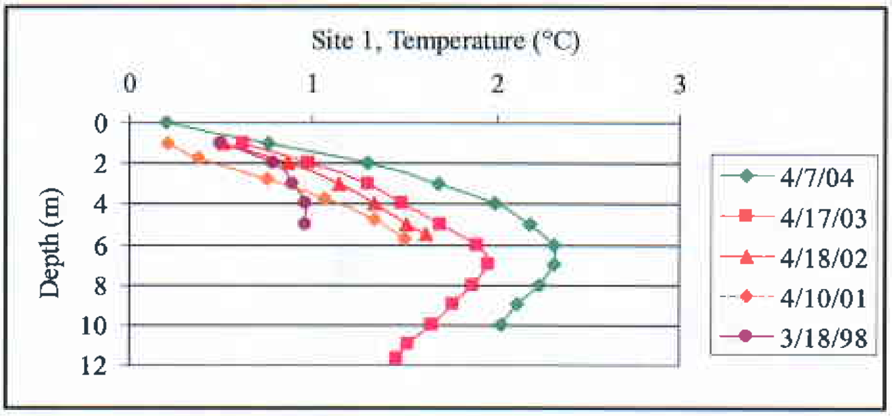
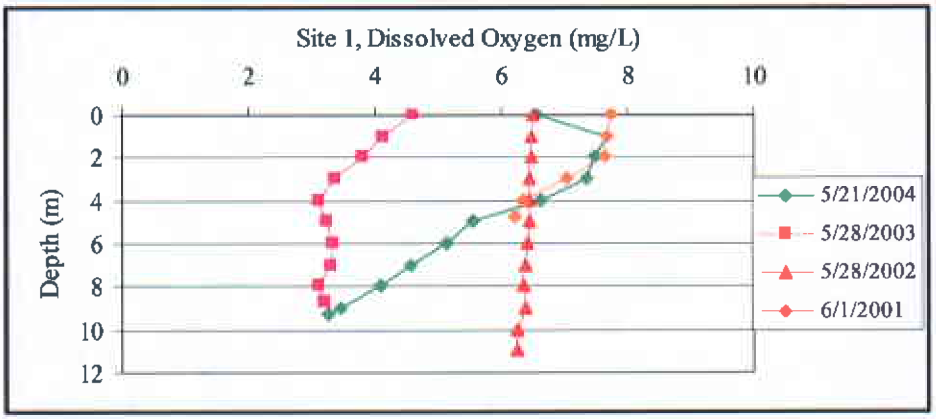


Figure 7. Dissolved oxygen concentration and temperature at Site #1 (middle of WSR) by depth in late winter 1998 and 2001 through 2004.

In early spring, just after the WSR was ice-free, DO at Site #1 decreased with depth and was similar to concentrations found in 2001 and 2002 (Figure 8). DO concentrations found in 2002 probably reflect the fact that our sample time happened to occur when waters were mixed and just prior to stratification that occurs very quickly. Trap sites for burbot in spring 2004 were set at depths <5 m to avoid low DO concentrations.



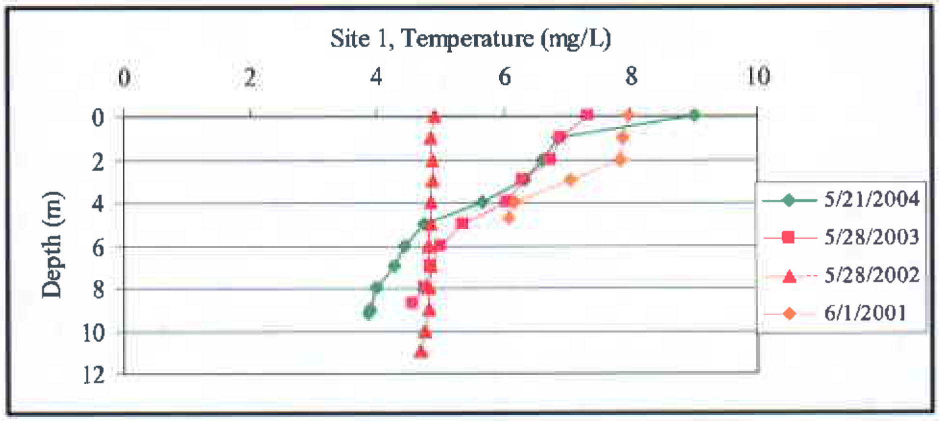


Figure 8. Dissolved oxygen concentration and temperature at Site #1 (middle of WSR) by depth in early spring 2001 through 2004.

Conductivity and pH measurements at Site #1 during early spring were compared among sample years. The general trend for pH from 1999 to 2004 has been to decrease, except for a slight increase in spring 2001 (Figure 9). Conductivity was highest in spring 1999 and very similar for the years 2000 through 2004 (Figure 10).

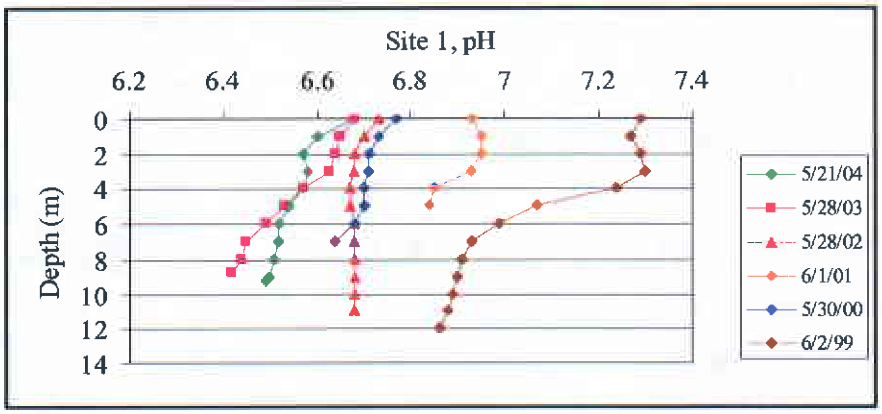


Figure 9. The pH in the WSR at Site #1 in early spring (1999 to 2004).

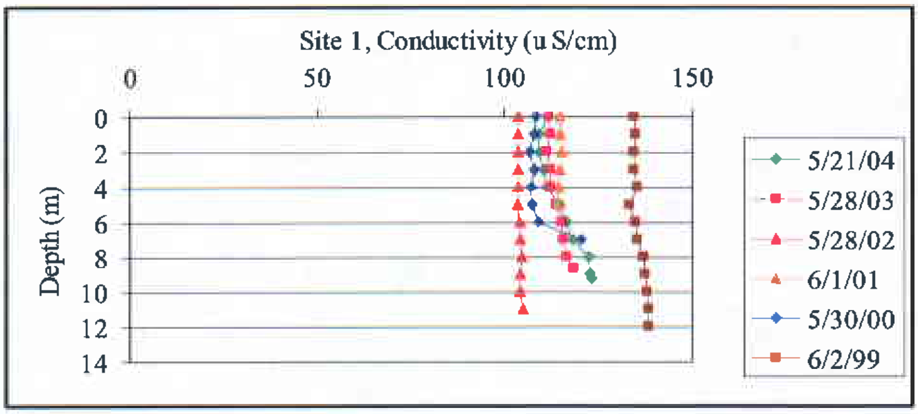
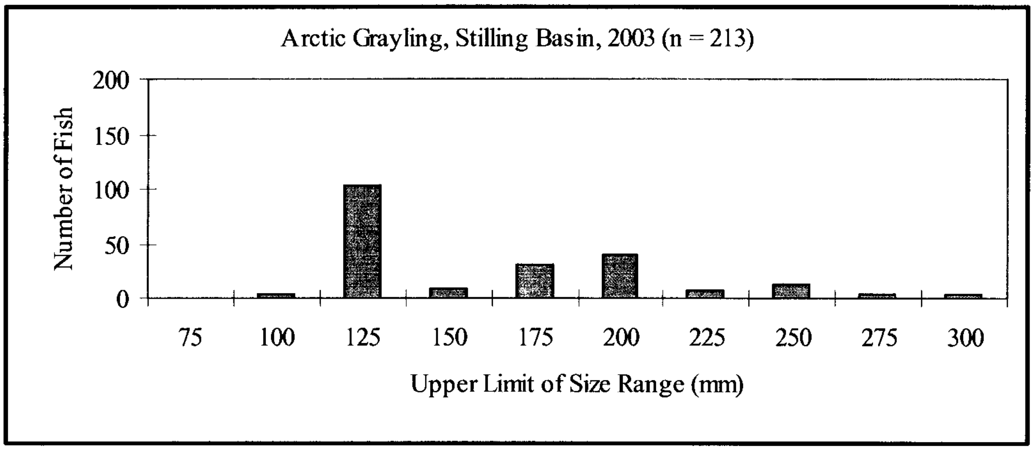


Figure 10. Conductivity in the WSR at Site #1 in early spring (1999 to 2004).

The trend in pH and conductivity appear to be related to the volume of freshwater input in the spring relative to the quantity of water used from the WSR the previous winter. In spring 1999, both pH and conductivity were higher and, as stated earlier, the WSR did not fill to full capacity until fall 1998. The WSR stratifies quickly following breakup, thus minimizing potential mixing of surface water input with waters in the WSR. The slight increase in both pH and conductivity in spring 2001 probably was the result of freshwater input that had to mix with water in the WSR because of the substantial water use during winter 2000/2001.

Stilling Basin, Arctic Grayling and Burbot

The stilling basin, located immediately downstream of the WSR spillway, is fed by groundwater, seepage flow, and by surface flow (Figure 3). In spring 2004, we sampled the stilling basin with one fyke-net for an eight-day period to gather information on fish moving into the stilling basin from the WSR. The sampling efforts in 2003 and 2004 were identical. We caught 213 Arctic grayling in spring 2003 and 500 in spring 2004. Length frequency summaries for these fish are shown in Figure 11.



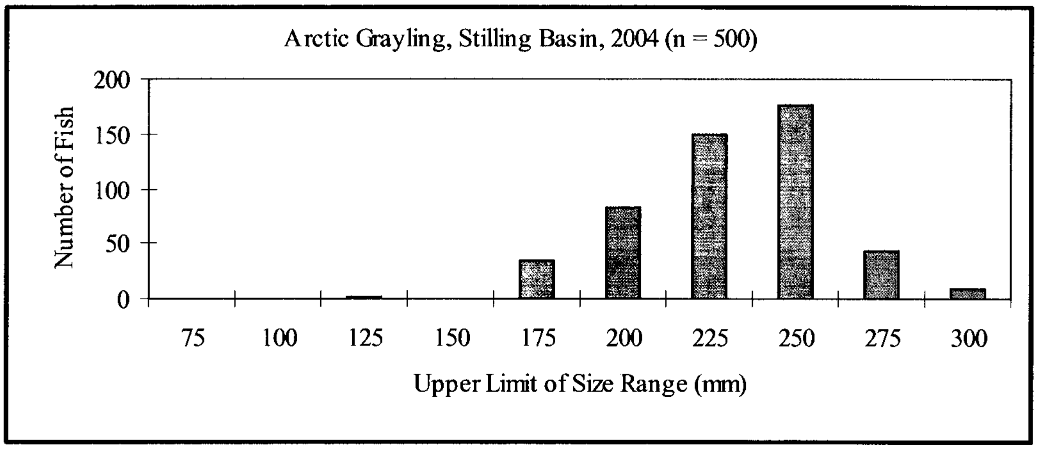


Figure 11. Length frequency distribution of Arctic grayling captured in the stilling basin below the WSR in spring 2003 and 2004.

In 2003, we caught 10 Arctic grayling that had been tagged in the WSR; in 2004 we caught 50 marked fish. The size of Arctic grayling captured in 2004 was larger than in 2003 suggesting more and larger Arctic grayling left the WSR in summer 2003 or spring 2004. Of the 50 marked fish caught in spring 2004, 10 had just been tagged or seen in the WSR in spring 2004. Lower numbers of small Arctic grayling in the 2004 catch may have been due, in part, to the larger number of burbot (36 in 2004 versus 10 in 2003) that may have preyed upon small Arctic grayling while in the net.

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. Fish were most concentrated in Lower and Upper Last Chance Creek ponds and overwintered in these flooded placer mine cuts. The Arctic grayling in these ponds were characterized as stunted: fish larger than 220 mm were rare; annual growth rate was 9 mm; and size at maturity was small (148 mm for males, 165 mm for females). Successful spawning occurred in outlets and inlets between Polar Ponds #1 and #2. Adult Arctic grayling also used Last Chance Creek for spawning, but based on visual observations success was never high. All of these ponds have been flooded by the WSR and are now referred to as Upper Last Chance and Polar bays.

Flooding of the Fish Creek valley by the WSR inundated Polar Ponds #1 and #2, thus eliminating the Arctic grayling spawning habitat associated with the pond complex. After flooding of the WSR, catches of age-0 Arctic grayling from 1996 through 1998 were very low.

Ponds C, D, E, and F were interconnected, fed by surface flow during breakup, but only by ground water during the remainder of the ice-free season. Flow through these ponds was relatively stable, and not influenced by normal rainfall events. Stable flow, warm water, stream and wetland habitats are ideal for Arctic grayling spawning and survival and growth of age-0 fish.

The near absence of age-0 Arctic grayling from spring 1996 through 1998 led to the decision to construct a channel from Pond F to the WSR. In spring 1999, FGMI constructed the outlet channel (Channel #5, Figure 2) that bypassed water that had previously exited Pond F via a perched culvert. It should be noted that the perched culvert was installed in 1995 in accordance with a Fish Habitat Permit to accommodate use of wetlands for post-mining passive water treatment. Construction of Channel #5 was done in early May 1999 and immediately upon completion, Arctic grayling entered the channel and associated wetland complex to spawn.

From spring 1999 to 2001, Arctic grayling spawned successfully in Channel #5, in the pond complexes, and in interconnecting channels. In 2002, spawning was limited to Channel #5 and Ponds E and F due to extensive aufeis (about 4 m thick) upstream in Ponds C and D that kept water temperatures in these reaches cold (< 4.0°C). Arctic grayling in spring 2003 successfully spawned throughout the wetland complex. Due to extensive aufeis in Last Chance Creek, successful spawning by Arctic grayling has not been documented since the WSR was built.

Arctic Grayling Spawning (Timing – Temperature)

In 2004, Arctic grayling were first captured on May 10 in the wetland complex and on May 13 in Last Chance Creek. Very little aufeis was present in the wetland complex. The lower 1 km of Last Chance Creek also had minimal aufeis. A chronology of observations on spawning Arctic grayling in the wetland complex is presented in Appendix 2. Peak spawning in the wetland complex occurred between May 13 and 17 as water temperatures warmed quickly (Figure 12).

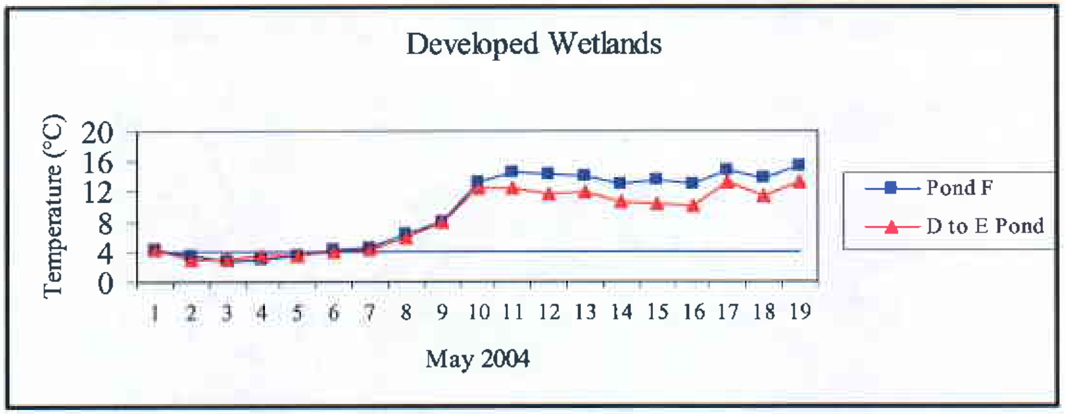


Figure 12. Peak daily water temperature in the wetland complex in spring 2004.

The gravel berm that formed Pond C washed out in 1998 leaving the stream flowing through deposited sediments. The decision was made to not reconstruct the dike, but to allow the stream to naturally develop a channel. Extensive pond type habitat exists in the wetland complex and the addition of stream habitat was thought to be beneficial for

Arctic grayling spawning. A defined stream channel has continued to develop through the old Pond C area beginning at the upstream end and proceeding downstream. Each year the amount of defined channel has increased with about 60% of the total length now considered relatively stable (Figure 13). In spring 2004, about 100 Arctic grayling spawned in the upper reaches of the stream.

Figure 13. Pond C area looking downstream in 2000 (top photo) and 2004 (bottom photo) showing changes in stream and riparian habitat.

In the lower 1 km of Last Chance Creek there was virtually no aufeis present on May 5, 2004, suggesting at least for the winter of 2003/2004 that civil work conducted in fall 2001 to minimize aufeis may be working. Water temperatures in Last Chance Creek in spring 2004 were substantially higher than in previous years (Figure 14). Adult Arctic grayling moved into Last Chance Creek from the WSR beginning on May 13, their movements peaked on May 18 and 19, and were essentially completed by May 20. Over 450 Arctic grayling, mostly adult fish, entered Last Chance Creek to spawn in spring 2004. This is the first year since the WSR was constructed that we have documented Arctic grayling spawning in Last Chance Creek. Temperature data for 2002, 2003, and 2004 clearly show that in 2002 and 2003 temperatures never warmed enough for Arctic grayling to spawn (Figure 14).

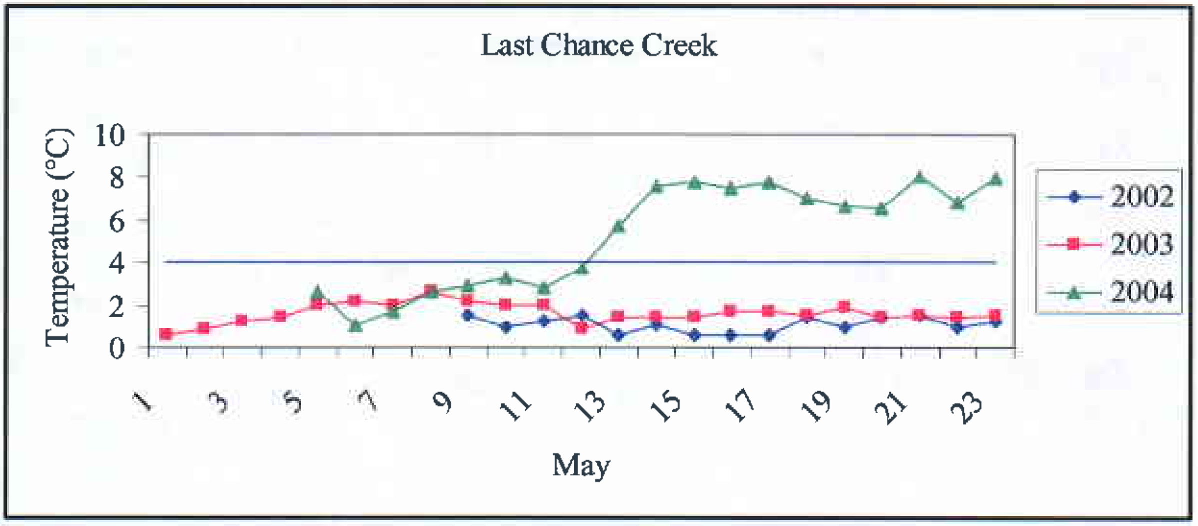


Figure 14. Peak daily water temperatures in Last Chance Creek in spring 2002 through 2004.

On June 7, 2004, we visually surveyed Last Chance Creek and the wetland complex. Age-0 Arctic grayling were not seen in Last Chance Creek, but fry were abundant along the stream margins below Pond F, between Ponds D and E, and in the upper part of Channel C. Last Chance Creek and the wetland complex were surveyed on August 10, 2004 (Table 3). Schools of several hundred age-0 Arctic grayling were seen in the lower portion of Last Chance Creek with numbers decreasing as we walked upstream. This is the first year since construction of the WSR that we have found large numbers of age-0 Arctic grayling in Last Chance Creek.

Table 3. Age-0 Arctic grayling caught in the wetland complex in summer 1999, 2002, 2003, and 2004.

Date	Number of Fish	Average Length (mm)	Range (mm)	Standard Deviation
9/1/99	21	91	76-97	5.4
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
6/25/03	20	28	21-46	7.3
7/28/03	50	59	33-75	8.4
8/9/03	65	72	58-113	11.1
8/10/04	19	68	50-82	9.7

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

We estimated the abundance of Arctic grayling in the WSR using spring 2003 as the mark event and spring 2004 as the recapture event. In spring 2004, we caught 858 Arctic grayling > 230 mm, with 198 recaptures. Our spring 2003 estimated Arctic grayling population in the WSR for fish > 200 mm was 6,495 (95% CI 5,760 to 7,231) (Figure 15, Appendix 3).

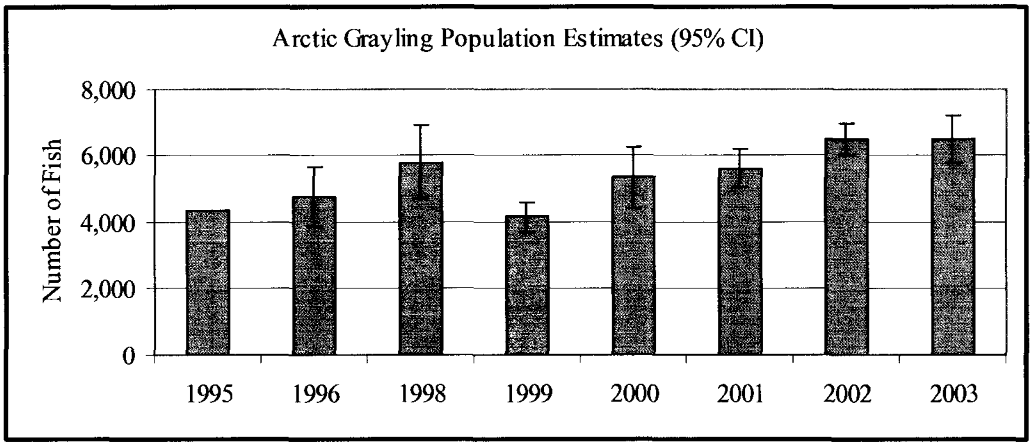


Figure 15. Estimates of the Arctic grayling population in the WSR at the Fort Knox Mine (1995-2003).

For our 2003 estimated Arctic grayling population we did not include fish that had been marked prior to 2003. Tag loss has shown a trend towards larger fish losing tags at a differentially higher rate than small fish (Ott and Morris 2002b). Therefore, our spring 2003 mark event of 1,504 fish includes only fish tagged in 2003.

We compared length frequency distributions for fish marked in spring 2003 with those recaptured in 2004 to eliminate those fish handled in 2004 that would have been too small (<200 mm) to mark in 2003. Our comparison of the length frequency diagrams indicated that fish <230 mm in spring 2004 should not be included in the population estimate (i.e., they would have been too small in 2003 to have been marked) (Figure 16). Using this approach, we reduced the number of fish seen in 2004 by 367 individuals.

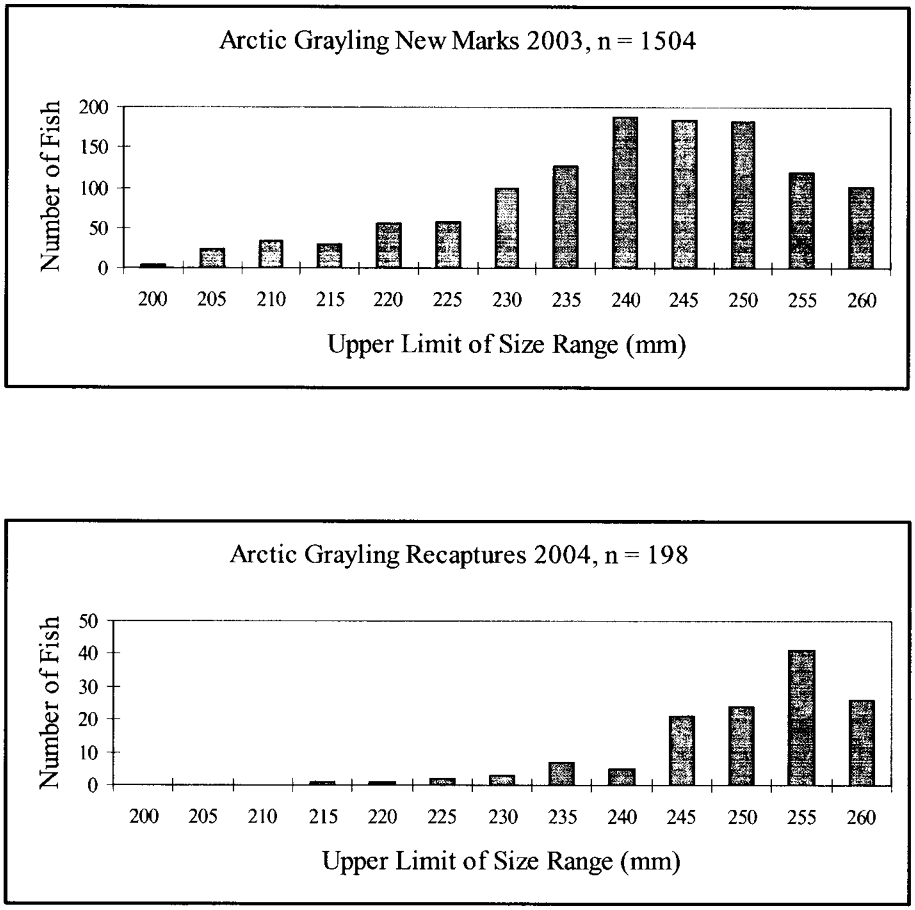
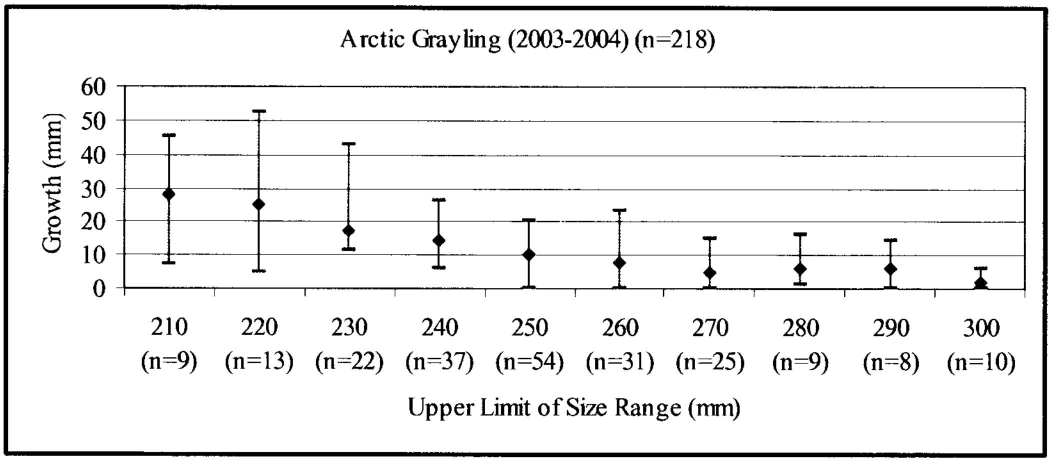


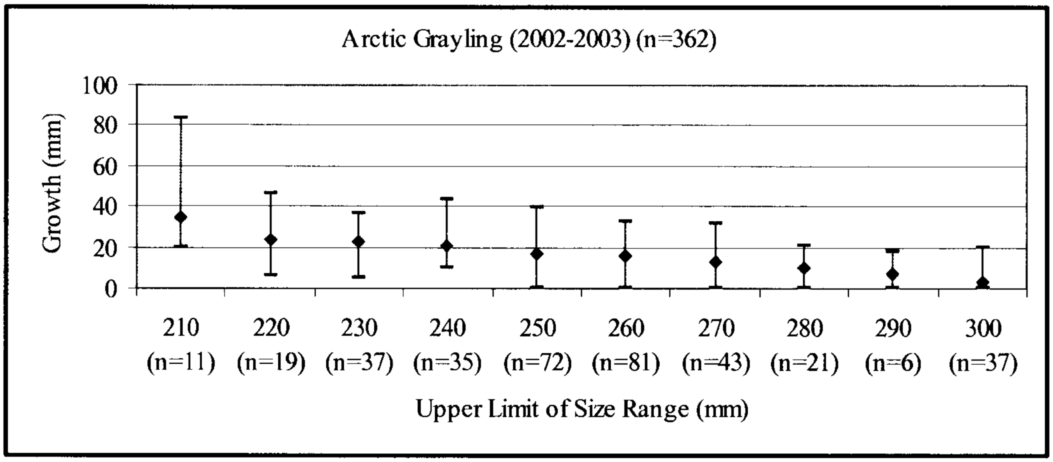
Figure 16. Length frequency distribution of Arctic grayling tagged in spring 2003 and recaptured in spring 2004 in Last Chance Creek, the WSR, and the developed wetlands.

In spring 2002, 2003, and 2004 we had sufficient recaptures to show annual growth by size (Table 4 and Figure 17). The average growth of Arctic grayling prior to the WSR was 9 mm per year. Once the WSR was flooded, annual growth rates for all marked fish from 1996 through 1998 were 41, 38, and 39 mm (Ott and Morris 2002a). Generally, annual growth rates for small Arctic grayling are still greater than prior to flooding of the WSR, but the trend appears to be for decreased growth.

Table 4. Annual growth of marked and recaptured Arctic grayling in the WSR.

Years	Upper Limit Size Range (mm)	Average Growth (mm)
2001 to 2002	210 mm	44
2001 to 2002	220 mm	33
2002 to 2003	210 mm	34
2002 to 2003	220 mm	24
2003 to 2004	210 mm	28
2003 to 2004	220 mm	25





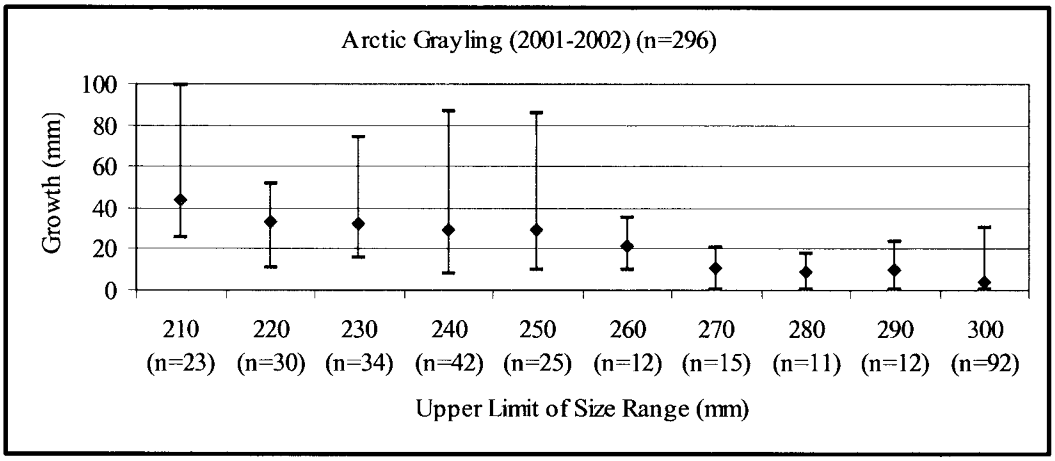


Figure 17. Maximum, minimum, and average growth for Arctic grayling > 200 mm long for 2001/2002, 2002/2003, and 2003/2004.

Length-frequency distributions for Arctic grayling collected in previous years were presented by Ott and Morris (2002b). Through 1999, little or no recruitment of small fish was seen, but after construction of the channel connecting Pond F with the WSR, substantial numbers of smaller Arctic grayling have been seen and captured. Length-frequency distribution for fish caught in spring 2004 show that recruitment of fish to the population is still occurring (Figure 18).

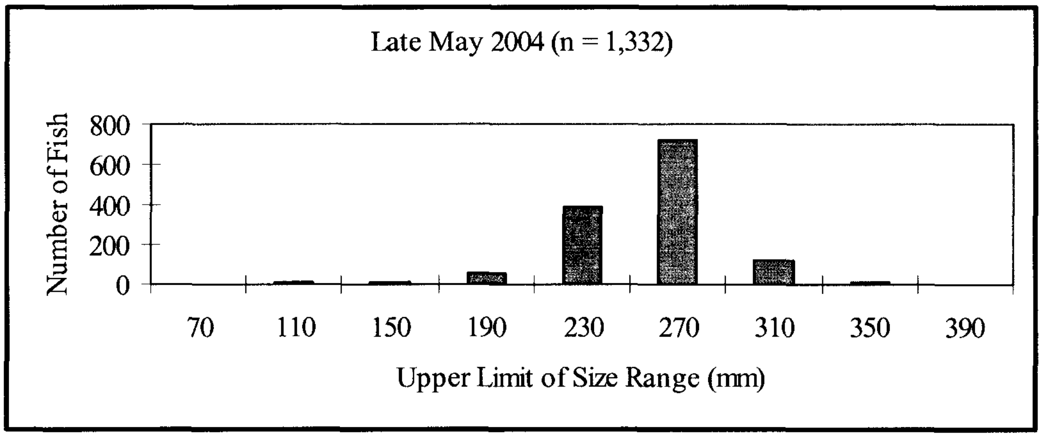


Figure 18. Length frequency distribution of Arctic grayling in the WSR, Last Chance Creek, and the developed wetlands in spring 2004.

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 the abundance of burbot (150 to 331 mm) to be 825 fish (Ott and Weber Scannell 1996). The WSR began to pond water in November 1995, flooding the ponds and creeks containing burbot.

Estimates of the burbot population in the WSR were made during the ice-free season following construction of the WSR (Figure 19 and Appendix 4). The estimated burbot population for fish >200 mm long peaked in 1999 and has decreased substantially the last several years. These data continue to indicate that fish lost in the population are smaller (i.e., <400 mm), and as noted during field sampling, those burbot between 275 and 375 mm have consistently been in poorer condition. However, burbot in this size range (275 to 375 mm) in both 2003 and 2004 appear to be in better condition. Because catches have been low in recent years, the decision was made to sample the burbot population once each year in the spring; thus, the 2004 population estimate will not be made until after the spring 2005 recapture event.

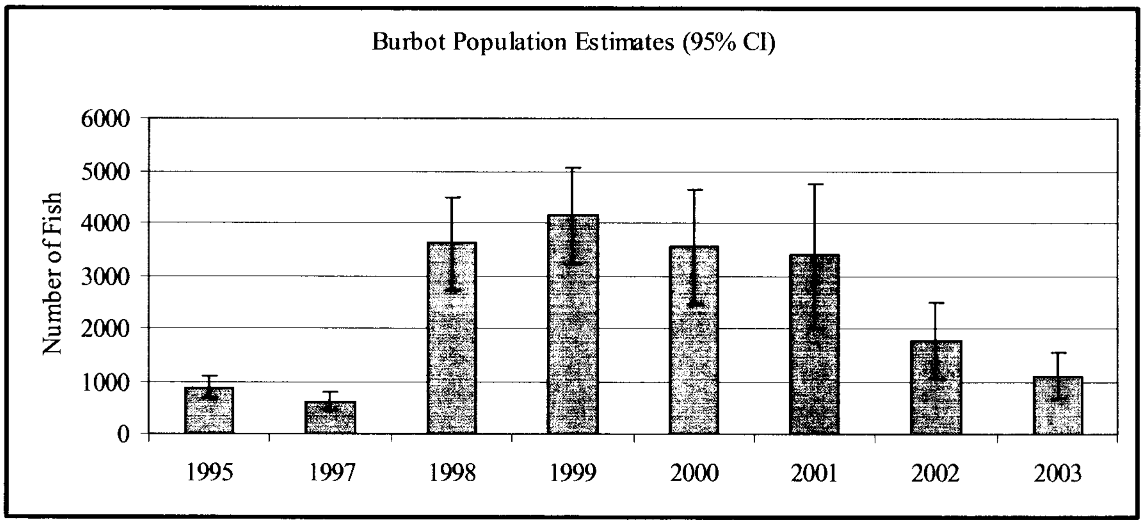


Figure 19. Estimates of the burbot population in the WSR at the Fort Knox Mine (1995 to 2003).

The estimated number of large burbot (>400 mm) was 134, 131, and 102 in 2001, 2002, and 2003. The burbot population for fish >400 mm appears to be relatively stable.

Catches of burbot in the stilling basin below the WSR indicate that very few burbot are outmigrating from the WSR. Although the catch of burbot in the stilling basin was higher in 2004 than in previous years, we still have not recaptured a burbot that was marked in the WSR. Catch per unit of effort for hoop traps fished in the WSR has been calculated annually since 1996 (Appendix 5). Catch rates decreased substantially in 2002 and remained low from 2002 through 2004 (Appendix 5).

Annual growth of burbot was tracked from 1998 to 2004. Growth by size is presented in Appendix 6 for fish caught in spring 2003 and 2004.

Length-frequency distributions for burbot captured from May 1995 to June 2002 were presented by Ott and Morris (2002). Length-frequency distributions for spring 2001 through 2004 are presented in Figure 20. Catches have declined since spring 2001, but recruitment of new fish to the population continues. In spring 2004, the most fish captured were between 226 and 300 mm long, very similar to that found in 2001 and 2002. Age-0 burbot (73, 77, and 80 mm) were captured by seine in Pond F in August, 2004.

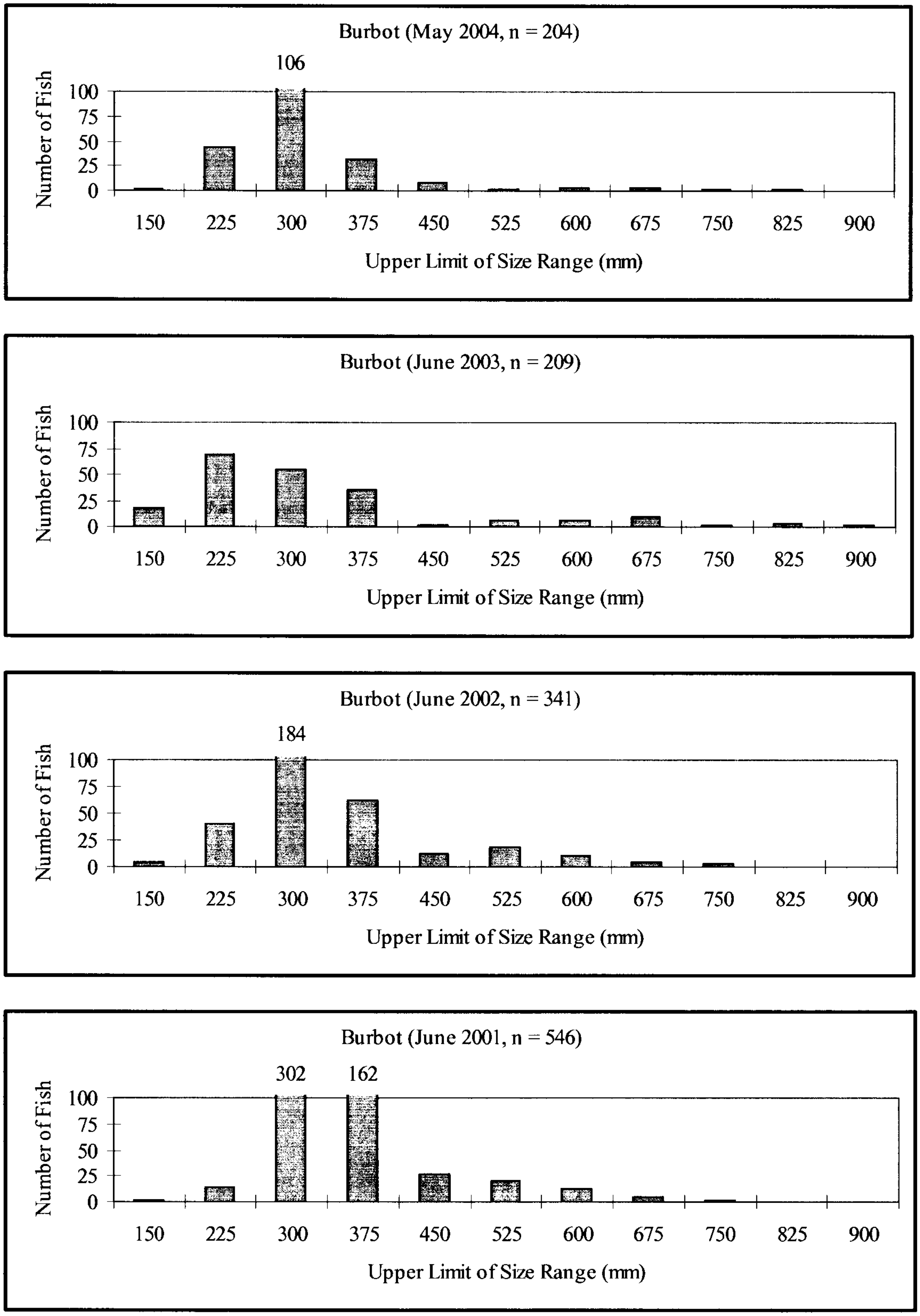


Figure 20. Length frequency distribution of burbot caught in the WSR, 2001 to 2004.

Conclusion

We predicted prior to construction of the WSR dam that opportunities existed to enhance fisheries resources, specifically the Arctic grayling population. Our goal was to reach a density of 10 to 20 Arctic grayling >200 mm per hectare of surface area (i.e., 800 to 1,600 fish >200 mm) ten years after construction. The most significant civil work completed, from a biological viewpoint, was excavation of a channel (Channel #5, Figure 2) in spring 1999 to connect the developed wetlands along the south side of the valley with the WSR. Arctic grayling spawning success in this channel and associated wetlands has been high every year from 1999 through 2004.

Progress to Date

The objectives of our continuing program to monitor fishery resources and water quality in the WSR and developed wetlands include: (a) gather data to evaluate predictions that a viable Arctic grayling population could be developed; (b) provide data on successes and failures of restoration activities that could be applied to future projects; (c) to fulfill the department's commitment to monitor the project and provide data for the environmental audits required by the State's mill site lease; (d) provide biological information needed for management decisions when the area is converted to public recreation and use at the end of mining; and (e) gather information on the fish and wildlife use of the developed wetlands and WSR to be used to assess mitigation under the U.S. Army Corps of Engineer's permit for the project.

A viable Arctic grayling population has been established in the WSR that exceeds our goal of having 800 to 1,600 Arctic grayling >200 mm. Our goal was reached by 1998 when the estimated Arctic grayling population of fish >200 mm was 5,800. Our population estimate for all subsequent years still exceeds the original objective. Many of the fish in the current population are recruitments from successful spawning in Channel #5 and the associated wetland complexe.

Predictions on the burbot population response to the flooding of the WSR were not made prior to construction. The burbot population grew rapidly following ponding of water in the WSR, reaching a high of 4,136 for fish >200 mm in 1999. Since 1999, the burbot population has decreased to an estimated 1,103 in 2003. The most dramatic decrease occurred between 2001 and 2002.

Water quality data collected have shown that flooding of ice-rich permafrost materials in the valley has created a condition in which DO concentrations are depressed with depth in both winter and summer. It has been documented that freshwater input, particularly from Solo Creek and to a lesser extent Last Chance Creek, during winter has been essential to maintaining DO concentrations in portions of the WSR that have allowed successful overwintering of both Arctic grayling and burbot.

Wildlife use of the WSR and developed wetlands generally has increased since construction of the freshwater dam and concurrent reclamation in the Fish Creek valley between the WSR and the tailing dam. Wildlife species and uses in the valley was summarized by Ott and Morris (2002b). In 2004, bald eagles (*Haliaeetus leucocephalus*), horned grebes (*Podiceps auritus*), and Pacific loons (*Gavia pacifica*) frequently were observed in the WSR. Bald eagles were observed almost every day in the spring during the spawning migration of Arctic grayling in the wetland complex.

Future Plans

We will continue to work cooperatively with FGMI to gather data on fish resources, water quality, and wildlife use of the WSR and wetland complex. We continue to discuss several projects that would potentially enhance the existing aquatic habitat at the project site. Construction of a second wetland complex along the north side of the valley that is separated from the existing functioning wetlands along the south side of the valley probably would provide spawning and rearing habitat for Arctic grayling and rearing habitat for burbot. The wetland complex along the north side of the valley would be fed by water from the tailing pond at closure. Currently, except for water flow during breakup or after heavy rains, there is no surface water flow along the north side of the Fish Creek valley. Finally, compilation of a long-term data base on the WSR and developed wetlands will aid both industry and the agencies in better decision making in the future.

Literature Cited

Chapman, D.G. 1951. Some practices of the hypergeometric distribution with applications to zoological censuses. University of California Publications in Statistics 1:131-60.

Fairbanks Gold Mining Inc. 1993. Fort Knox reclamation plan. Submitted to the Alaska Department of Natural Resources and the U.S. Army Corps of Engineers. 54 pp.

Ott, A.G. and W.A. Morris. 2003. Arctic grayling and burbot studies at the Fort Knox Mine 2003. Alaska Department of Natural Resources Tech. Rept. 03-09. Office of Habitat Management and Permitting. Juneau. 65 pp.

Ott, A.G. and W.A. Morris. 2002b. Arctic grayling and burbot studies in the Fort Knox water supply reservoir, stilling basin, and developed wetlands, 2002. Alaska Department of Fish and Game Tech. Rept. 02-06. Habitat and Restoration Division. Juneau. 65 pp.

Ott, A.G. and W.A. Morris. 2002a. Arctic grayling and burbot studies in the Fort Knox water supply reservoir and developed wetlands, 2001. Alaska Department of Fish and Game Tech. Rept. 02-1. Habitat and Restoration Division. Juneau. 46 pp.

Ott, A.G. and W.A. Morris. 2001. Arctic grayling and burbot studies in the Fort Knox water supply reservoir and developed wetlands. Alaska Department of Fish and Game Tech. Rept. 01-2. Habitat and Restoration Division. Juneau. 51 pp.

Ott, A.G. and W.A. Morris. 2000. Fish use of the Fort Knox water supply reservoir and developed wetlands. Alaska Department of Fish and Game Tech. Rept. 00-1. Habitat and Restoration Division. Juneau. 40 pp.

Ott, A.G. and W.A. Morris. 1999. Fish use of the Fort Knox water supply reservoir 1995-1998. Alaska Department of Fish and Game Tech. Rept. 99-2. Habitat and Restoration Division. Juneau. 28 pp.

Ott, A.G. and P. Weber Scannell. 1998. Fisheries use and water quality in the Fort Knox mine water supply reservoir. Alaska Department of Fish and Game Tech. Rept. 98-1. Habitat and Restoration Division. Juneau. 39 pp.

Ott, A.G. and A.H. Townsend. 1997. Fisheries use of the Fort Knox water supply reservoir 1996. Alaska Department of Fish and Game Tech. Rept. 97-2. Habitat and Restoration Division. Juneau. 69 pp.

Ott, A.G. and P. Weber Scannell. 1996. Baseline fish and aquatic habitat data for Fort Knox mine 1992 to 1995. Alaska Department of Fish and Game Tech. Rept. 96-5. Habitat and Restoration Division. Juneau. 165 pp.

Literature Cited, concluded.

Ott, A.G., P. Weber Scannell, and A.H. Townsend. 1995. Aquatic habitat and fisheries studies upper Fish Creek, 1992-1995. Alaska Department of Fish and Game Tech. Rept. 95-4. Habitat and Restoration Division. Juneau. 61 pp.

Seber, G.A.F. 1982. The estimation of animal abundance. Charles Griffin & Company LTD.

Weber Scannell, P. and A.G. Ott. 1994. Aquatic habitat of Fish Creek before development of the Fort Knox gold mine 1992-1993. Alaska Department of Fish and Game Tech. Rept. 94-5. Habitat and Restoration Division. Juneau. 79 pp.

Weber Scannell, P. and A.G. Ott. 1993. Aquatic habitat study, upper Fish Creek drainage, with an emphasis on Arctic grayling (*Thymallus arcticus*): baseline studies 1992. Alaska Department of Fish and Game Tech. Rept. 93-4. Habitat and Restoration Division. Juneau. 76 pp.

Appendix 1. Water Quality Data (Site #1) and (Site #11), WSR

Site 1 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
1	5/21/2004	0	9.01	66.6	6.56	112	6.68
		1	6.88	64.6	7.67	109.2	6.6
		2	6.6	62.6	7.48	109.3	6.57
		3	6.34	60.9	7.36	110.6	6.58
		4	5.67	54.1	6.64	111.6	6.57
		5	4.74	44.1	5.55	114.8	6.54
		6	4.42	40.4	5.13	116.6	6.52
		7	4.26	36	4.57	118.4	6.52
		8	3.98	32.1	4.11	122.7	6.51
		9	3.89	27	3.47	123.2	6.5
		9.25	3.85	25.5	3.28	123.6	6.49
1	4/7/2004	0	0.2	39.5	5.5	129	6.95
		1	0.76	37.6	5.14	128	6.82
		2	1.3	38.8	5.23	127.7	6.72
		3	1.69	38.9	5.22	126.6	6.7
		4	1.99	39.3	5.21	125.5	6.7
		5	2.19	37	4.85	124.9	6.7
		6	2.32	35	4.57	126.9	6.69
		7	2.32	24.1	3.14	133.8	6.67
		8	2.24	10.1	1.32	137.5	6.63
		9	2.12	0.2	0.03	144	6.59
		10	2.03	0	0	156.9	6.58
1	5/28/2003	0	7.33	39.6	4.59	112	6.68
		1	6.91	35.2	4.12	112.3	6.65
		2	6.75	32.3	3.8	111.4	6.64
		3	6.3	28.4	3.38	112.2	6.63
		4	6.03	25.8	3.1	112.2	6.57
		5	5.36	29.5	3.23	114.1	6.53
		6	5.01	25.7	3.32	115.1	6.49
		7	4.85	26.7	3.3	115.9	6.45
		8	4.76	25.1	3.1	116.4	6.44
		8.75	4.55	26.3	3.2	118.6	6.42

Appendix 1, Water Quality continued.

Site 1 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
1	4/17/2003	1	0.62	34.9	4.78	N/T	6.75
		2	0.98	33.8	4.57	N/T	6.74
		3	1.3	32.9	4.41	N/T	6.73
		4	1.49	32.5	4.35	N/T	6.72
		5	1.7	32.1	4.17	N/T	6.72
		6	1.9	32.2	4.24	N/T	6.73
		7	1.96	24.9	3.27	N/T	6.69
		8	1.87	18.1	2.38	N/T	6.63
		9	1.77	3.2	0.43	N/T	6.49
		10	1.65	1.8	0.24	N/T	6.56
		11	1.52	1.8	0.24	N/T	6.54
		11.7	1.46	1.1	0.16	N/T	6.26
1	9/30/2002	0	6.9	72.8	8.52	100.3	6.87
		1	6.9	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	6.75
		7	6.46	56.5	6.69	102.3	6.67
		8	6.14	40.1	4.8	101.3	6.58
		9	5.67	52	6.28	98.6	6.58
		9.5 (bottom)	5.21	67.5	8.24	95.6	6.68
1	5/28/2002	0	4.89	54	6.51	103.8	6.73
		1	4.85	53.6	6.48	103.8	6.7
		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	6.68
		8	4.8	52.5	6.36	104.7	6.68
		9	4.8	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	6.68

Appendix 1, Water Quality continued.

Site 1 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
1	4/18/2002	1	0.52	11.9	1.69	146	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	10/1/2001	0	7.23	65.8	7.61	121.1	7.28
		1	7.2	64.4	7.44	121.5	7.28
		2	7.19	64.2	7.41	121.1	7.29
		3	7.18	64.1	7.4	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	59	6.83	123.1	7.26
		9	6.46	18	2.11	115.1	7
		10 (bottom)	6.22	18.1	2.14	116.5	7.02
1	6/1/2001	0	7.96	67.9	7.74	114.9	6.93
		1	7.88	67.1	7.67	115	6.95
		2	7.86	67	7.65	115.2	6.95
		3	7.06	60.7	7.06	114.7	6.93
		4	6.16	53	6.35	114.6	6.85
		4.75 (bottom)	6.08	51.6	6.21	114.6	6.84
1	4/10/2001	1	0.21	22.1	3.1	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	2.85	128.8	6.61
		5.75 (bottom)	1.5	18.8	2.56	131.1	6.59

Appendix 1, Water Quality continued.

Site 1 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
1	8/29/2000	0	11.17	79.2	8.46	108.8	7.11
		1	10.5	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	6.9
		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	6.5
		8	5.53	5.3	0.65	136.8	6.39
		9	5.23	3.4	0.45	140	6.45
		10 (bottom)	5.04	2.6	0.33	142.5	6.47
1	6/23/2000	0	18.23	95.2	8.81	103.8	7.56
		1	17.35	93	8.75	102.6	7.57
		2	12.95	52.6	5.5	105.1	6.91
1	6/23/2000	3	7.67	24.9	2.92	108.8	6.69
		4	5.71	17.4	2.15	114	6.57
		5	5.08	13.9	1.76	117.2	6.54
		6	4.6	9.9	1.25	119.4	6.52
		7	4.39	8.4	1.08	121.9	6.51
		8	4.3	6.5	0.83	122.5	6.5
		9 (bottom)	4.1	2.6	0.34	125.9	6.49
1	5/30/2000	0	7.31	56.3	6.72	108.4	6.77
		1	6.24	53.1	6.51	108.2	6.73
		2	5.79	51.9	6.4	106.8	6.71
		3	5.56	50.3	6.25	107.9	6.71
		4	5.45	49.9	6.21	107.1	6.7
		5	5.42	49.6	6.18	107.5	6.7
		6	4.81	45.1	5.73	109.3	6.68
		7 (bottom)	3.95	33.3	4.33	120.5	6.64

Appendix 1, Water Quality continued.

Site 1 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
1	6/2/1999	0	9.49	82.9	9.13	134.7	7.29
		1	9.5	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	7.3
		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	6.9
		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	10/1/1998	surface	6.27	62.7	7.49	145.1	7.6
		1	6.24	62.6	7.49	145	7.57
		2	6.21	62.4	7.47	144.6	7.58
		3	6.2	62.3	7.45	144.5	7.58
		4	6.14	62.9	7.54	144.8	7.6
		5	6.03	64.1	7.7	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	7.59
1	7/28/1998	surface	17.33	84.2	7.85	161.9	7.56
		1	16.83	81.2	7.67	162	7.54
		2	16.66	80.5	7.65	162.2	7.55
		3	14.3	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	6.9

Appendix 1, Water Quality continued.

Site 1 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
1	7/28/1998	surface	17.21	83.6	7.84	159.6	7.64
		1	17.14	82.9	7.8	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	6.87
		5	6.68	64.7	7.63	115.2	7.03
		6	3.48	9.6	1.14	170	6.75
		7 (bottom)	5.23	1	0.12	173	6.81
1	3/18/1998	1	0.5	N/T	1.27	176	6.96
		2	0.79	N/T	1.89	178	6.89
		3	0.89	N/T	1.71	179	6.87
		4	0.96	N/T	2.1	182	6.84
		5 (bottom)	0.96	N/T	0.47	186	6.75
N/T = Not Tested							

Appendix 1, Water Quality 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	5/21/2004	0	7	63.6	7.52	111.5	6.66
		1	6.24	59	7.13	112.3	6.63
		2	6.05	57.2	6.93	114.4	6.62
		3	5.96	56.9	6.9	114.8	6.61
		4	5.92	54.8	6.67	114.6	6.67
		5	5.53	50.8	6.24	114.7	6.66
		6	4.93	46.7	5.83	115.5	6.66
		7	4.67	44.1	5.56	119.2	6.65
		8	4.16	36.5	4.66	124.4	6.63
		8.5	4.02	33.8	4.33	126.4	6.6
11	4/7/2004	0	0.18	38.6	5.4	150.4	6.72
		1	0.4	42.1	5.78	155.1	6.66
		2	0.87	42.3	5.74	151.1	6.68
		3	1.29	42.2	5.67	147.3	6.72
		4	1.62	40.6	5.41	143.3	6.75
		5	1.75	39.7	5.26	141.6	6.76
		6	1.73	40.6	5.39	156.5	6.75
		7	2.4	11.9	1.55	159.9	6.73
		7.5	2.82	0	0	172.1	6.62
11	5/28/2003	0	7.46	36.6	4.23	111.9	6.63
		1	7.25	35.9	4.16	112.7	6.64
		2	7.11	36.4	4.23	113.1	6.62
		3	7	36.5	4.27	114.3	6.59
		4	6.92	38.7	4.53	114.2	6.51
		5	6.73	34	4	115.2	6.58
		6	6.62	32.5	3.83	115.6	6.58
		7	5.7	30.1	3.63	116.8	6.54
		8	5.04	26.2	3.25	116.9	6.5
11	4/17/2003	1	0.34	37.4	5.16	N/T	
		2	0.52	36.7	5.03	N/T	
		3	0.65	36.2	4.79	N/T	
		4	1.03	35.4	4.78	N/T	
		5	1.21	35.7	4.82	N/T	
		6	1.3	34.5	4.64	N/T	
		7	2.03	29.1	3.81	N/T	
		7.4 (bottom)	2.45	5.6	0.72	N/T	

Appendix 1, Water Quality 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	9/30/2002	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	6.8
		6	6.5	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	6.7
11	5/28/2002	0	5.7	68.9	8.17	99.5	6.87
		1	5.69	67	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	4/18/2002	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	6.6
		4	0.74	6	0.88	178.2	6.57
		5	1.32	4.1	0.52	191.5	6.54
		6	2.39	0	0	218.2	6.44
		6.5 (bottom)	2.58	0	0	287.5	6.38
11	10/1/2001	0	7.12	63.9	7.4	122.5	7.27
		1	7.1	63.1	7.3	122.3	7.27
		2	7.08	63.1	7.3	122	7.28
		3	7.07	62.8	7.27	122	7.28
		4	7.06	62.9	7.28	122.4	7.29
		5	7.06	63	7.29	122.3	7.29
		6	7	62.8	7.29	125.5	7.28
		7	6.87	62.6	7.28	127.2	7.28
		8(bottom)	6.3	66.2	7.81	128.7	7.32

Appendix 1, Water Quality 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	6/1/2001	0	9.36	71.6	7.91	116.2	6.94
		1	9.22	70.7	7.8	115.7	6.91
		2	9.1	70	7.76	115.9	6.95
		3	9.1	69.6	7.72	115.8	6.95
		4	8.95	68.8	7.65	115.9	6.96
		5	6.55	56.2	6.64	116	6.91
		6.5 (bottom)	6.07	51.3	6.12	118	6.84
11	4/13/2001	1	0.22	14.7	2.05	139	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	2.1	9.6	1.29	165.9	6.5
		6.75	2.61	3.1	0.42	260	6.32
		7.25 (bottom)	2.47	2.4	0.32	355.1	6.3
11	8/29/2000	0	10.8	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
		4	9.5	76	8.47	105.7	7.01
		5	9.03	74.2	8.34	104.5	7
		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	6/23/2000	0	18.15	93.8	8.71	103.7	7.53
		1	15.99	86	8.35	103.3	7.42
		2	13.45	57.6	5.88	105.3	6.95
		3	7.29	23	2.73	110.5	6.63
11	6/23/2000	4	6.07	16.6	2.02	113.6	6.56
		5	5.39	11.8	1.48	118	6.52
		6	4.94	9	1.14	120.6	6.49
		7	4.73	6.5	0.82	123	6.48
		8	4.62	4.7	0.6	125	6.48
		8.5 (bottom)	4.52	3.6	0.45	126.7	6.43

Appendix 1, Water Quality concluded.

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	5/30/2000	0	6.21	51	6.25	109.7	6.78
		1	5.64	47.4	5.88	110.3	6.69
		2	4.8	42.7	5.4	111.9	6.7
		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	4.4	117.8	6.64
		6	3.81	31.6	4.1	121.5	6.63
		7	3.88	31.5	4.09	124.4	6.6
		8 (bottom)	3.3	7.4	1.05	231.6	6.35
11	6/2/1999	0	8.37	66.7	7.6	134	7.15
		1	8	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	7.06
		4	6.17	40.1	4.8	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	7.09
11	10/1/1998	surface	5.8	71.9	8.69	144.1	7.57
		1	5.78	72	8.7	144.1	7.57
		2	5.75	72.1	8.73	143.9	7.58
		3	5.59	72.3	8.78	144	7.59
		4	5.57	72.5	8.82	143.3	7.6
		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	7/28/1998	surface	17.07	82.4	7.75	160.6	7.6
		1	16.82	79	7.47	161	7.57
		2	16.15	60.8	5.84	160	7.23
		3	14.57	38.1	3.72	155.8	7
		4	12.31	15.5	1.66	152.8	6.84
		5	10.53	7.1	0.78	166.7	6.8
		5.5 (bottom)	9.78	5	0.56	175.8	6.83
N/T = not tested							

Appendix 2. Chronology of Arctic Grayling Spawning in the Fort Knox Developed Wetlands in Spring 2004.

Date	Description of Field Work and Arctic Graying Spawning Activity
May 5, 2004	Stowaway temperature probes placed in Pond F outlet, channel between Ponds D and E, and in Last Chance Creek
May 5, 2004	Peak water temperature 4.3°C in Pond F outlet, 4.3°C in channel between Ponds D and E, and 2.6°C in Last Chance Creek
May 5, 2004	Arctic grayling observed in Pond F outlet, no spawning activity
May 7, 2004	Peak water temperature 2.6°C in Pond F outlet, 2.9°C in channel between Ponds E and F, and 1.7°C in Last Chance Creek, cool temperature with overcast skies and high water due to rain
May 10, 2004	Peak water temperature 4.2°C in Pond F outlet, 3.9°C in channel between Ponds E and F, and 3.3°C in Last Chance Creek, several Arctic grayling in Pond F outlet and channel between Ponds E and F defending territories in known spawning areas
May 12, 2004	Peak water temperature 6.2°C in Pond F outlet, 5.7°C in channel between Ponds E and F, and 3.7°C in Last Chance Creek, some spent females caught in Pond F, 53 Arctic grayling caught in Pond F
May 13, 2004	Peak water temperature 7.9°C in Pond F outlet, 7.9°C in channel between Ponds E and F, and 5.7°C in Last Chance Creek, almost all females caught in Pond F were spent, but there still were a lot of fish spawning in Pond F outlet and channel between the ponds,
May 14, 2004	Peak water temperature 13.2°C in Pond F outlet, 12.4°C in channel between Ponds E and F, and 7.6°C in Last Chance Creek, still a lot of spawning activity in Pond F outlet and channel between ponds
May 17, 2004	Peak water temperature 13.9°C in Pond F outlet, 11.9°C in channel between Ponds E and F, and 7.8°C in Last Chance Creek, still a lot of spawning activity
May 18, 2004	Very little spawning activity observed in Pond F or in the channel connecting the ponds
May 14 to 19, 2004	Movement of ripe females and males into Last Chance Creek peaks, peak water temperatures ranging from 6.7 to 7.6°C for this time period

Appendix 3. 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 2003). 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
2002[4]	200	6,503	6,001-7,005
2003[4]	200	6,495	5,760-7,231

[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 2002 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 4. Burbot Population Estimates in the WSR

Estimates of the burbot population in the WSR and developed wetlands at the Fort Knox Mine (1995 to 2004). 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
2003[4]	200	1,103	671-1,535
2003	400	102	57-147
2004[5]			

[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, 2002, and 2003 population estimates were made with capture and recapture events in the same year.

[5]The 2004 population estimate will be made using 2004 as the mark event in spring with the recapture event occurring one year later in the spring.

Appendix 5. Burbot Catches in the WSR

Sample Date	Gear Type	Number of Traps	Catch	Mean CPUE
5/22/1996	small hoop	11	36	3.3
5/22/1996	large hoop	4	6	1.5
5/23/1996	small hoop	11	19	1.7
5/23/1996	large hoop	4	2	0.5
5/20/1997	small hoop	11	58	5.3
5/20/1997	large hoop	13	24	1.8
5/21/1997	small hoop	11	61	5.5
5/21/1997	large hoop	17	56	3.3
5/28/1997	small hoop	11	45	4.1
5/28/1997	large hoop	19	42	2.2
5/29/1997	small hoop	11	32	2.9
5/29/1997	large hoop	20	39	2.0
5/20/1998	small hoop	7	87	12.4
5/21/1998	small hoop	9	61	6.8
5/21/1998	large hoop	3	20	6.7
5/22/1998	small hoop	9	57	6.3
5/27/1998	small hoop	9	61	6.8
5/28/1998	small hoop	9	67	7.4
5/29/1998	small hoop	9	44	4.9
6/3/1999	small hoop	17	135	7.9
6/4/1999	small hoop	17	124	7.3
6/5/1999	small hoop	17	136	8.0
6/7/1999	small hoop	17	142	4.2
6/8/1999	small hoop	17	89	5.2
5/30/2001	small hoop	24	191	7.9
5/31/2001	small hoop	24	105	4.4
6/1/2001	small hoop	24	122	5.1

Appendix 5, Burbot Catches concluded.

Sample Date	Gear Type	Number of Traps	Catch	Mean CPUE
6/6/2001	small hoop	30	209	7.0
6/7/2001	small hoop	30	76	2.5
6/27/2001	small hoop	30	98	3.3
6/28/2001	small hoop	30	140	4.7
6/3/2002	small hoop	30	58	1.0
6/5/2002	small hoop	30	58	1.0
6/6/2002	small hoop	30	41	1.4
6/8/2002	small hoop	30	118	2.0
6/10/2002	small hoop	30	120	2.0
10/3/2002	small hoop	30	69	1.2
5/29/2003	small hoop	30	62	2.1
5/30/2003	small hoop	30	34	1.1
6/2/2003	small hoop	30	75	0.8
10/2/2003	small hoop	30	50	1.7
10/3/2003	small hoop	30	28	0.9
10/6/2003	small hoop	30	36	0.4
10/8/2003	small hoop	5	26	2.6
5/24/2004	small hoop	30	115	1.3
5/28/2004	small hoop	30	107	0.9

CPUE = Catch per unit of effort (24 hours)

Appendix 6. Annual Growth of Burbot

Tag Number	Color	Length (mm)	Date Captured	Site Captured	Recapture Date	Recapture Site	Length (mm)	Growth (mm)
27371	Gray	215	5/30/2003	WSR	5/24/2004	Upper WSR	250	35
27469	Gray	223	6/2/2003	WSR	5/24/2004	Upper WSR	235	12
27355	Gray	270	6/2/2003	WSR	5/28/2004	WSR	292	22
27338	Gray	287	5/29/2003	WSR	5/24/2004	WSR	295	8
27488	Gray	303	6/2/2003	WSR	5/28/2004	WSR	340	37
27157	Gray	308	5/29/2003	WSR	5/24/2004	Upper WSR	330	22
27304	Gray	315	5/29/2003	WSR	5/24/2004	WSR	335	20
27306	Gray	330	5/29/2003	WSR	5/24/2004	WSR	365	35
27479	Gray	330	6/2/2003	WSR	5/24/2004	Upper WSR	360	30
9060	Gray	330	6/2/2003	WSR	5/24/2004	Upper WSR	355	25
27350	Gray	345	6/2/2003	WSR	5/28/2004	WSR	362	17
27322	Gray	355	5/21/2003	WSR	5/24/2004	WSR	405	50
13814	Green	405	5/30/2003	WSR	5/24/2004	WSR	425	20
27085	Gray	405	5/29/2003	WSR	5/24/2004	WSR	435	30
27309	Gray	465	5/29/2003	WSR	5/28/2004	WSR	540	75
27001	Gray	520	5/29/2003	WSR	5/24/2004	WSR	570	50
31362	Blue	600	5/29/2003	WSR	5/24/2004	WSR	620	20
27267	Gray	230	6/10/2002	Upper WSR	5/8/2003	WSR	240	10
27170	Gray	270	6/8/2002	Upper WSR	5/29/2003	WSR	280	10
27157	Gray	300	6/8/2002	Upper WSR	5/29/2003	Upper WSR	308	8
27048	Gray	315	6/3/2002	WSR	5/29/2003	WSR	355	40
27121	Gray	315	6/6/2002	WSR	6/2/2003	WSR	330	15
13814	Green	382	6/6/2002	WSR	5/30/2003	WSR	405	23
27085	Gray	405	6/6/2002	WSR	5/29/2003	WSR	405	0
27124	Gray	455	6/6/2002	WSR	5/29/2003	WSR	500	45
9151	Gray	460	6/3/2002	Pond E	5/28/2003	WSR	505	45
27001	Gray	460	6/3/2002	WSR	5/29/2003	WSR	520	60
6611	OR	460	6/10/2002	Polar 2	6/2/2003	WSR	540	80
31397	BL	510	6/5/2002	WSR	6/2/2003	WSR	570	60
13909	Green	525	6/5/2002	WSR	5/29/2003	WSR	580	55
27024	Gray	546	6/3/2002	WSR	5/28/2003	WSR	605	59
5651	Yellow	546	6/3/2002	WSR	5/29/2003	WSR	650	104
31362	BL	559	6/3/2002	WSR	5/29/2003	WSR	600	41
13938	Green	559	6/3/2002	WSR	5/28/2003	WSR	600	41
31963	BL	584	6/3/2002	WSR	5/30/2003	WSR	650	66
32908	BL	610	6/3/2002	WSR	5/30/2003	WSR	675	65