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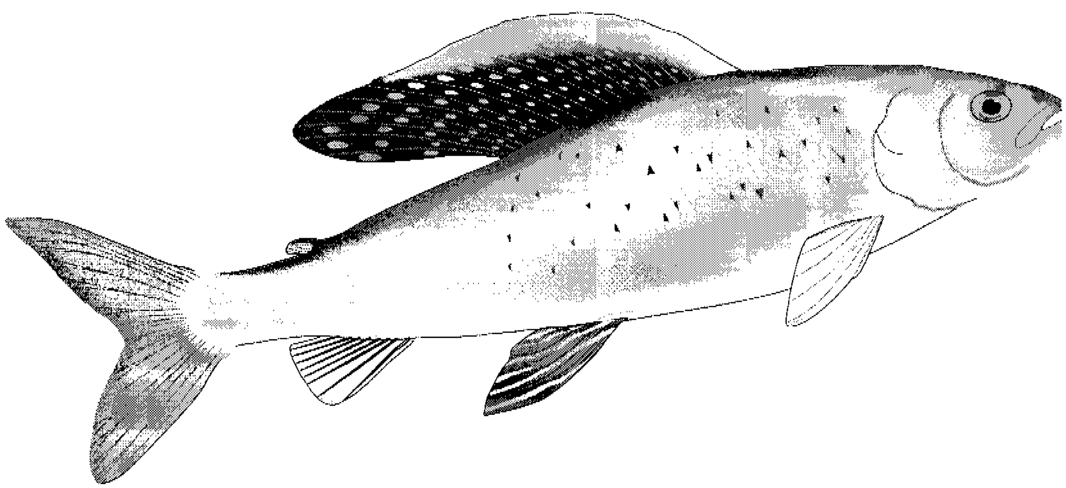
Fish Use of the Fort Knox Water Supply Reservoir 1995-1998

by Alvin G. Ott and William A. Morris



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Alaska Department of Fish and Game

Habitat and Restoration Division

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Acknowledgments

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Executive Summary

This report summarizes data collected on Arctic grayling (*Thymallus arcticus*), burbot (*Lota lota*), and water quality in the Fort Knox Gold Mine (FGMI) water supply reservoir (WSR) in 1998. Arctic grayling and burbot population data from 1995 through 1998 are presented and compared. FGMI blocked flow from three systems (Fish, Last Chance, and Solo creeks) with construction of the freshwater dam in November 1995 and began filling the WSR. Filling of the WSR caused a substantial increase in habitat, and potentially, an increase in invertebrate prey availability for resident populations of Arctic grayling and burbot. Water quality has been monitored in the reservoir in the ice and ice-free seasons from 1997 through the present. Dissolved oxygen levels in the WSR have been variable and, at times, very depressed, leading to some initial concerns for fish survival.

Populations of Arctic grayling and burbot were assessed prior to flooding of the WSR in 1995. Data collected on Arctic grayling were indicative of a stunted population; fish larger than 220 mm fork length were rare, annual growth was 9 mm, and age at maturity was small (as small as 148 mm for males, and 165 mm for females) (Ott et al. 1995). The pre-flood burbot population was estimated at 825 fish (most of which were under 300 mm fork length). After flooding, both populations changed dramatically. Arctic grayling growth rates doubled for one year, doubled the following year, and then stabilized between approximately 30-40 mm/yr, nearly quadrupling pre-flood growth rates. The population has continued to grow older with larger size classes most frequent; recruitment has been virtually non-existent. Length frequency distributions suggest the population of Arctic grayling will decline rapidly unless recruitment occurs. The burbot population also changed dramatically after flooding. Population estimates indicate that about 700 burbot over 300 mm are in the WSR; most fish in the population are under 300 mm. Length frequency distributions for burbot show the most frequently captured size classes are 150 mm, and 200 mm, with few large fish. This distribution is indicative of a rapidly increasing population.

Factors potentially limiting Arctic grayling recruitment in the WSR include burbot predation and lack of spawning habitat. Arctic grayling have been observed spawning during May both pre and post-WSR flooding. However, since flooding, gravel streambed spawning areas have been scarce. Burbot predation on grayling eggs has been inferred

by the presence of juvenile burbot at Arctic grayling spawning congregations during late May. A wetland being constructed upstream of the reservoir should be complete in fall 1999. This wetland may produce conditions favorable for Arctic grayling spawning and also may offer the potential for species segregation of young Arctic grayling and burbot. Water quality data collected also led to some concern for fish survival within the reservoir. Dissolved oxygen (DO) levels measured in fall 1997 were becoming depressed at depth; surface DO levels also were low (about 6 ppm). By March 1998, DO levels were depressed to nearly 0.0 ppm in all areas sampled. Fish survival through winter 1997/1998 appeared unlikely. However, summer 1998 sampling revealed strong populations of both Arctic grayling and burbot, with no evidence of a winter fish kill. Subsequent summer 1998 sampling revealed anomalously high DO levels in an area of the reservoir where pre-impoundment creek channels existed. It is hypothesized that an oxygenated upwelling is present in this area and allowed for the strong fish survival seen over winter 1997/1998. DO levels measured in fall 1998, indicate the WSR is well oxygenated, likely because the reservoir filled in 1998 with oxygenated water from spring and summer runoff and began to flow over the spillway. Another factor possibly affecting DO levels in 1997 may have been a massive decomposition event that may have occurred once the flooded organic matter on the WSR bed began to break-down. Results of 1998 fish and water quality analyses are presented in detail.

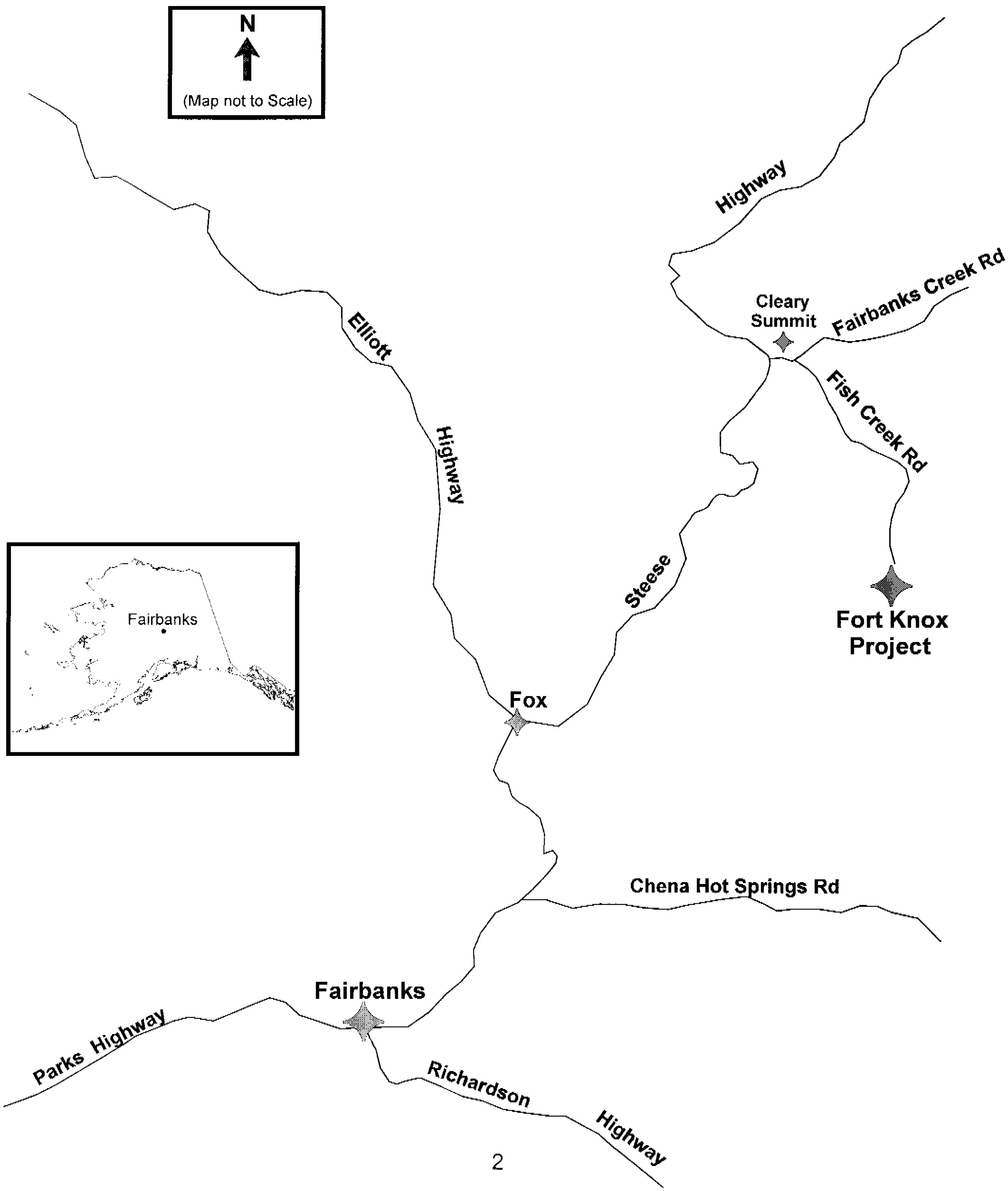
Introduction

Fairbanks Gold Mining, Inc. (FGMI) began construction of the Fort Knox hard-rock gold mine in spring 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. A summary of construction activities at the WSR was presented by Ott and Weber Scannell (1996) and Ott and Townsend (1997). Impoundment of water began in the WSR in November 1995 while spillway construction was still in progress. Construction of the WSR dam and spillway was complete by July 1996.

Water levels in the WSR had reached an elevation of 1,016.6 ft in July 1996 when pumping began to move water to the tailing impoundment. Final water surface elevation was 1,011.9 ft in November 1996, when pumping ceased. Levels continued to decrease slowly, reaching a low of 1,009.5 ft on April 25, 1997. Maximum water surface elevation after spring breakup was 1,015.3 ft on June 6, 1997, six feet below the projected maximum elevation of 1,021 ft. In late August 1997, FGMI began pumping seepage water, from below the dam, back to the WSR at a rate of approximately 800 gallons/minute. Water levels remained fairly constant throughout summer 1997 as indicated by an elevation of 1,014.3 ft on October 10, 1997. During winter 1997/1998, FGMI continued to pump seepage water back to the WSR. However, water levels continued to decrease, reaching a low of about 1005 ft in late March 1998. Substantial rainfall during summer 1998 filled the WSR; on September 29, 1998 water began to flow through the low-flow channel of the spillway at 1020.13 ft, just under the projected maximum elevation. Seepage flow below the dam remains fairly constant at a rate of 1.5 to 1.9 cfs.

Fish research was initiated in 1992 and focused on streams in and downstream of the project area (Weber Scannell and Ott 1993). In 1993, stream sampling 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

Figure 1. Fort Knox project location.



(*Thymallus arcticus*) and burbot (*Lota lota*) populations that would be available to colonize the WSR (Ott and Weber Scannell 1996). The Arctic grayling population in Fish Creek, upstream of the freshwater dam was estimated at 1,700 individuals <150 mm, and 4,350 individuals ≥150 mm. The number of burbot (150 to 331 mm) in upper Fish Creek drainage, mainly in Polar Ponds #1 and #2, was estimated at 825 fish.

In 1996, we began to monitor the use of the WSR by fish, gathering information on growth, recruitment of young-of-the-year, and catch per unit of effort (CPUE) (Ott and Weber Scannell 1996). The Arctic grayling population estimate for fish ≥150 mm in summer 1996 was 4,748 fish. Few young-of-the-year grayling were captured, however; young-of the-year burbot were abundant (Ott and Townsend 1997). In May 1997, we estimated the burbot population (fish ≥ 250 mm) at 622 fish. Young-of-the-year burbot were abundant in fall 1997, but young-of-the-year Arctic grayling were virtually absent (Ott and Weber Scannell 1998). We began water quality monitoring in the WSR in September 1997 and found anaerobic conditions in the middle of the WSR (Ott and Weber Scannell 1998). Our report summarizes fish and water quality data collected during 1998 and discusses these findings in relation to previous work.

Methods

Sampling Sites

Baseline fyke-net sampling sites in the WSR were established in 1996, and two additional sites were added in 1998 (#9 and #10) (Figures 2 and 3). In summer 1998, nets were fished at five sample sites. The general area for each net site is fixed but location varies with water level. Fyke-nets have been fished at the following sites: Fyke-net #1 (Solo Creek Bay), #2 and #6 (Last Chance Bay), #3 (Pump Bay), #4 (Polar Pond Bay), #5 and #10 (Upper Last Chance Bay), #7 (Fish Bay), #8 (Main Reservoir), and #9 (Spillway) (Figure 2).

Hoop traps (small and large) were fished throughout the WSR east of the new road as illustrated in Figure 2. Large hoop traps were only used during the May 20 to 22, 1998 sampling because smaller burbot were entangled and gilled in the netting of the large hoop traps.

Fish

Fish sampling was conducted with passive, active and observational methods in May 1998. Field sampling methods and gear included visual observations, fyke-nets, and hoop traps. On September 12 and 13, 1998, students from the University of Alaska Fairbanks used fyke-nets, minnow traps, and an electro-fishing boat to sample fish. Most of the burbot collected during May and September were measured and marked with a numbered floy-tag. A subsample of the Arctic grayling caught in May also were measured and marked with a numbered floy-tag. Some of the burbot recaptured in 1998 had been marked and injected with oxytetracycline in 1995. Twelve of these individuals were retained for age validation studies being conducted by Mr. Matt Evenson (Sport Fish Division).

A pulsed-DC (direct current) electro-fishing system mounted on a 6.1 m-long boat (Clark 1995) was used to collect fish in September 1998. Two sizes of fyke-net were also used. General net specifications were the same (wings, mesh, and center leads), however; entrance frame size varied. Entrance frames were either 0.9 m^2 or 1.2 m^2. Fyke-nets were 3.7 m long, had five hoops, a 1.8 m cod end, and 0.9 m by 7.6 m net

Figure 2. Fyke-net sample sites in the Fort Knox water supply reservoir (1996-1998).

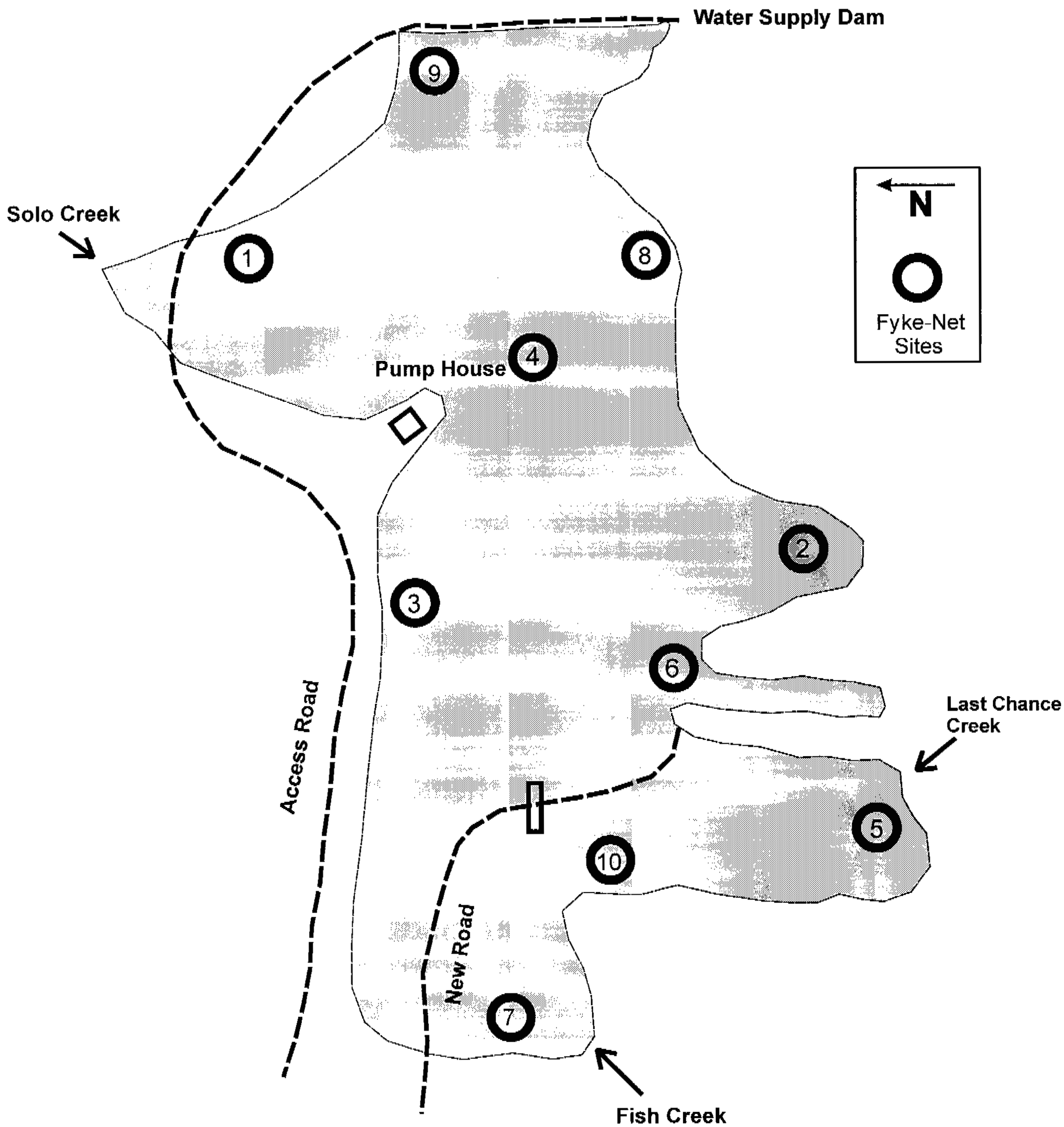
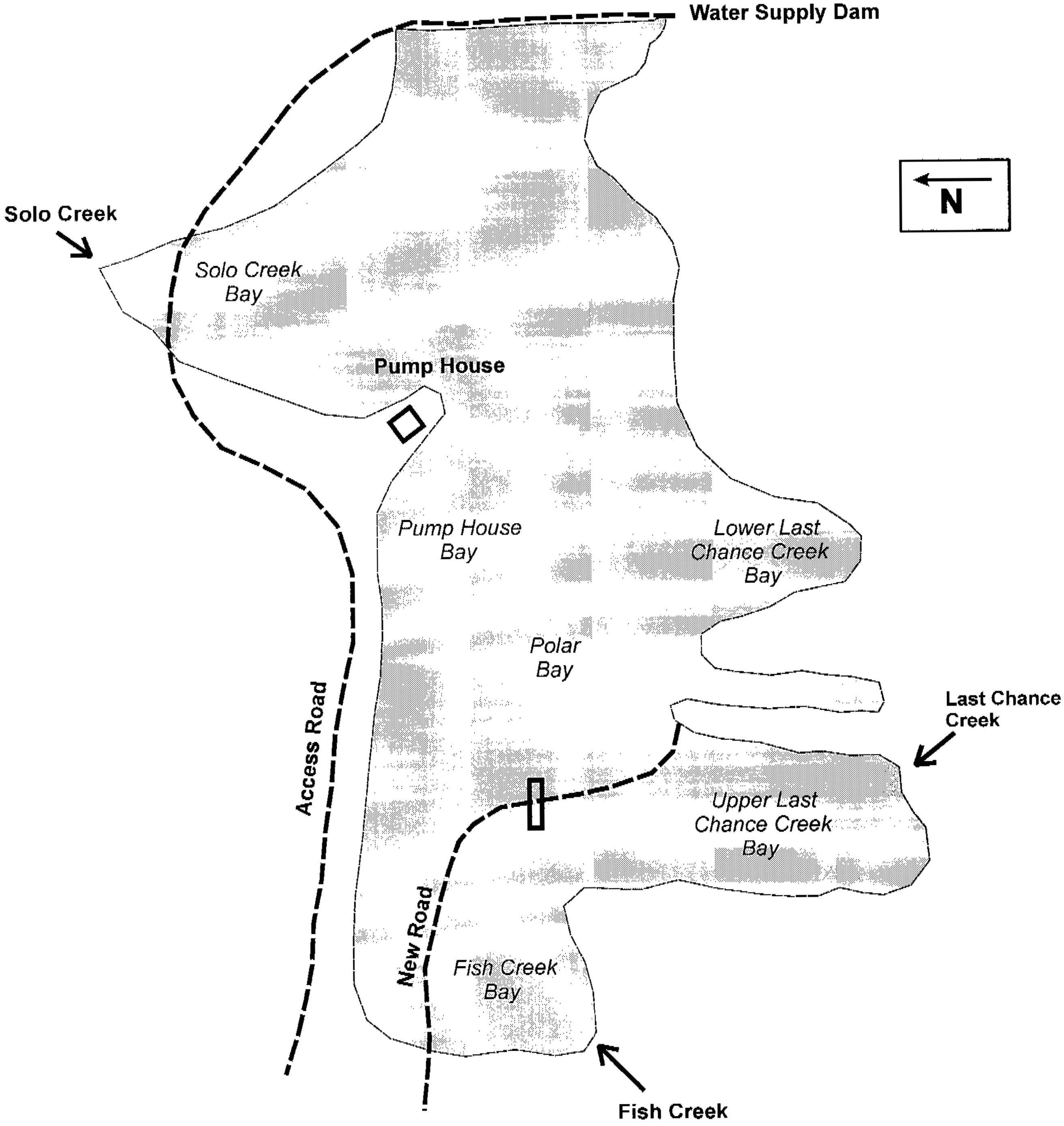


Figure 3. Sample areas in the Fort Knox water supply reservoir.



wings attached to the entrance frame. The center lead was 30.4 m and was 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, depending upon distance to deep water. Unbaited fyke-nets were fished 24 hr and either reset or removed.

We used minnow and hoop traps baited with salmon roe and fish to collect burbot in the WSR. Traps were fished 24 hr and rebaited if reset. Wire mesh minnow traps were 42 cm long, 22 cm in diameter, and had two 2.5 cm^2 openings on each end. Two sizes of hoop nets were used. Small traps were 1.6 m long with four hoops 54 cm in diameter. Netting was 8.5 mm bar mesh. The large traps were 3.05 m long with seven hoops. Hoop diameter tapered from 0.61 m at the entrance to 0.46 m at the cod end. Netting on the larger hoop traps was 25 mm bar mesh. All traps were kept stretched and open with spreader bars. Each trap had one throat and a cod end that was tied shut.

We estimated the size of the burbot population in the WSR with Chapman's modification of the Peterson mark-recapture technique (Chapman 1951). During the mark and recapture event, fish were captured with hoop nets and fyke-nets. Formulas used to estimate the population, the variance of the estimate, and the 95% confidence interval (CI) were presented in our 1996 report (Ott and Weber Scannell 1996).

Water Quality

Temperature (°C), dissolved oxygen concentration (mg/L), dissolved oxygen percent saturation (temperature and barometrically corrected), pH, conductivity (*u* S/cm), and depth (m) were measured with a Hydrolab® Minisonde® water quality multiprobe connected to a Surveyor® 4 water quality display unit. The meter was calibrated to suggested specifications prior to use in the field. The dissolved oxygen concentration was calibrated using the Winkler Titration Method (average of three measurements). Conductivity and pH were calibrated with standard solutions. Water quality measurements were made at the surface, one-meter (m) depth intervals, and at the bottom.

Results and Discussion

Fort Knox Water Supply Reservoir, Water Quality

Anaerobic conditions were found in the middle of the WSR in early September 1997 (Ott and Weber Scannell 1998). In late September 1997, in the middle of the WSR, surface dissolved oxygen was measured at 6.4 mg/L and dropped to 0.25 mg/L at the bottom. Water was mixed down to 5+ m and was stratified above or at 7 m (Ott and Weber Scannell 1998).

In March 1998, water quality data were collected at Sites 1, 2, and 3 (Figure 4). Dissolved oxygen concentrations were low, ranging from 0.06 to 2.1 mg/L (Appendix 1). Conductivity increased and pH decreased with depth at Sites 1 and 2.

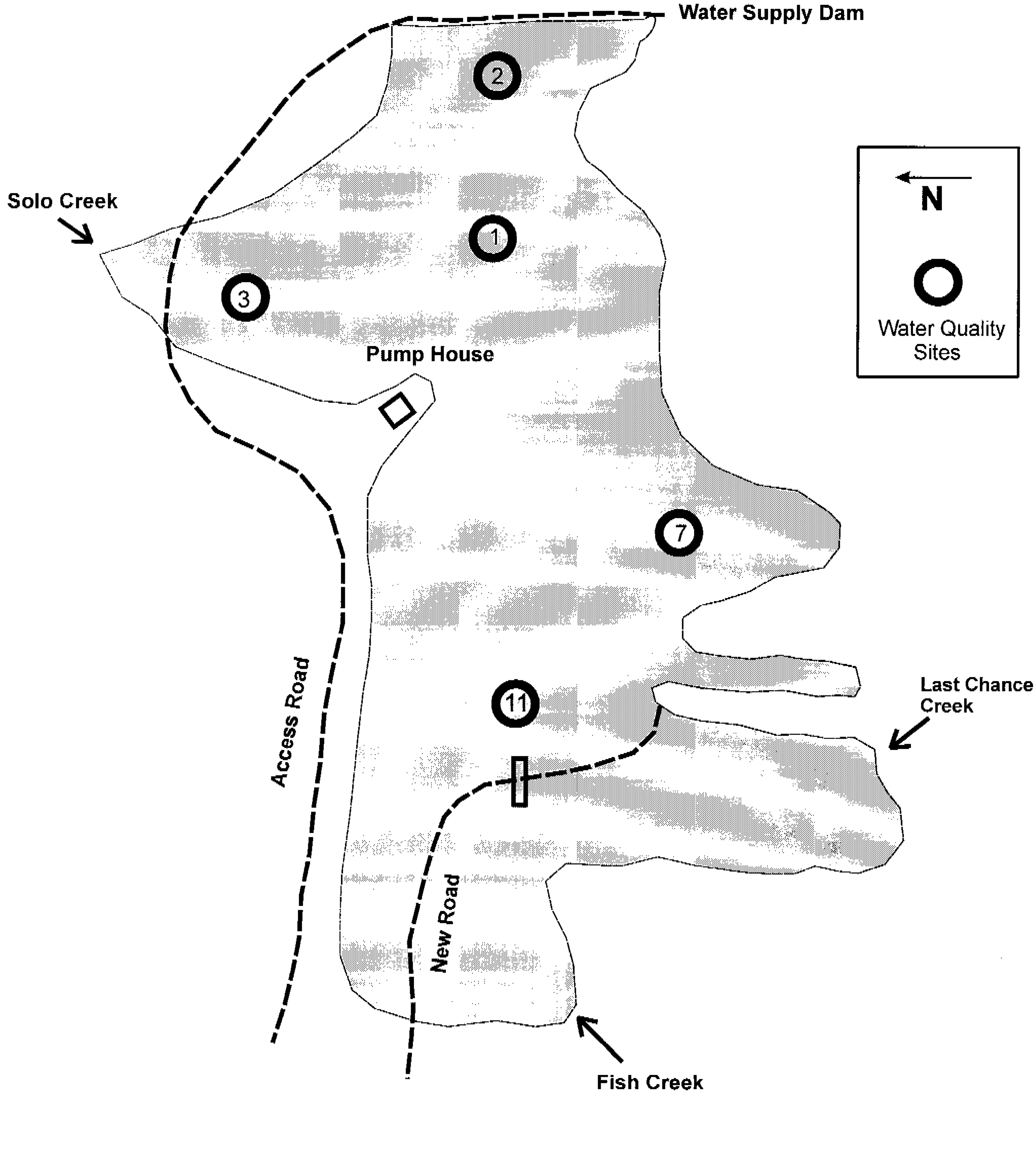
Five standardized sites were established and sampled in July and October 1998 (Figure 4). Data collected at these sites during previous sample events are presented in Appendix 1 and are discussed below.

Site #1 – Dissolved oxygen at Site #1 in March 1998 varied from 1.27 mg/L at 1 m to 0.47 mg/L at the bottom. In July 1998, dissolved oxygen concentration decreased with depth to a low of 0.12 mg/L at 7 m. Dissolved oxygen concentration at Site #1 ranged from 7.49 mg/L (surface) to 7.79 mg/L at 8 m (bottom) in October 1998

Site #2 – In September 1997 dissolved oxygen ranged from 6.10 mg/L (surface) to 2.65 mg/L at 7.5 m (bottom) and in March 1998 the dissolved oxygen varied from 1.26 mg/L to 0.06 mg/L. In July 1998, dissolved oxygen decreased with depth reaching 0.44 mg/L at the bottom. The dissolved oxygen concentration varied from 7.21 mg/L (surface) to 7.00 mg/L at 9 m (bottom) in October 1998. Oxygen depletion at the bottom of the WSR reservoir was no longer evident in October 1998.

Sites #3 (Table 3) and #7 – Water quality measurements for both sites were taken in September 1997, July 1998, and October 1998. Dissolved oxygen concentrations were similar showing some depletion with depth except in October 1998. Winter dissolved oxygen concentration in Solo Creek Bay (Site

Figure 4. Water quality sample sites in the Fort Knox water supply reservoir (1997-1998).



#3) was only 0.31 mg/L in March 1998. We found fairly uniform and well-mixed water in October 1998 with dissolved oxygen concentrations ranging from 8.35 to 8.59 mg/L at Site #3 and from 8.21 to 8.53 mg/L at Site #7.

Site #11 – This site is located in the flooded Polar #2 Bay about 100 m downstream of the culvert that carries flow from Fish and Last Chance Creeks through the newly constructed access road across the WSR (refer to Figure 3). Dissolved oxygen concentrations in July 1998 decreased with depth reaching a low of 0.56 mg/L at 5.5 m. In early October 1998 we found fairly uniform and well-mixed water, with dissolved oxygen concentrations ranging from 8.69 to 8.84 mg/L.

By late September 1998, the WSR had filled with water and an estimated 2 to 3 cfs was flowing out of the reservoir through the low-flow channel of the spillway. The outflow of surface water from the WSR is the first reported since the dam was constructed during winter 1995/1996. Due to substantial rainfall (36.7 cm [14.44 inches]) in the upper Fish Creek drainage during summer 1998, the surface water elevation rose over 2 m from spring 1998. It appears that the substantial influx of freshwater to the WSR during summer 1998 produced increased dissolved oxygen concentrations throughout the water column.

Dissolved oxygen concentration and percent saturation measurements were collected from a recently flooded gravel mine site, a man-made lake similar to the WSR, on the North Slope in late August 1998 (Hemming and Morris 1998). The dissolved oxygen concentrations ranged from 10.83 (surface) to 10.64 mg/L (7.1 m, bottom) and the percent saturation varied from 97.5 to 95.4. Dissolved oxygen concentrations in flooded North Slope gravel pits generally are high and near saturation, even during winter under ice cover (Hemming 1988, Hemming et al. 1989). Substantial decreases in dissolved oxygen concentrations in flooded mine sites on the North Slope have not been observed in over 10 years of monitoring. North Slope gravel sites generally are organic poor, and have isothermal temperature profiles and high dissolved oxygen concentrations from consistent high winds and mixing (Hemming 1988).

Development of a thermocline in the Fort Knox WSR occurs during the ice-free season. The area inundated contains vast amounts of organic material creating the potential for high biological and chemical oxygen demand. Although dissolved oxygen concentrations have increased since 1997, concentrations are lower than those found in flooded North Slope gravel pits. Sampling of the WSR will continue to document changes in water quality over time.

Fort Knox Water Supply Reservoir, Arctic Grayling

A road was reconstructed across the upper end of the WSR in mid-May 1998 to access the Gil Exploration Area. The road was designed to impound an additional 2 m of water in Upper Last Chance Creek Bay; a channel was excavated connecting Upper Last Chance Creek and Fish Creek Bays. A 1.83 m (72-inch) diameter culvert was placed in the road to provide fish passage. Water ponded in Upper Last Chance Creek Bay and began flowing through the constructed channel on May 27, 1998. On May 28, 1998, Arctic grayling were seen spawning in the shallow riffles of the outlet channel. Arctic grayling spawning activity was also observed in a shallow rocky zone near the spillway and in the Upper Last Chance Creek Bay flooded road crossing.

We fished fyke-nets at various locations in the WSR in May 1998. The highest catch occurred in Upper Last Chance Creek Bay where we caught 965 Arctic grayling (Table 1). Most of the Arctic grayling were sexually mature as evidenced by fish running eggs and milt. A net set in the newly constructed outlet channel and associated shallow pond caught 71 Arctic grayling. Presence of age 0 and 1 (<150 mm) Arctic grayling was virtually non-existent (Figure 5). During May 1998, we caught a total of 1,136 Arctic grayling $\geq$150 mm and three <150 mm.

We recaptured 121 Arctic grayling marked during the summer of 1996 in May 1998. Average annual growth for the two year period was 39 mm (SD = 10.9). Annual growth of the Arctic grayling in the WSR since 1996, even though average size of fish is increasing, has remained fairly constant at a rate much higher than pre-flooding (Figures 5 and 6). Prior to flooding of the WSR, average annual growth for Arctic grayling collected in the Last Chance Creek complex was 9 mm. Annual growth increased to 21 mm from 1995 to 1996 when the WSR was beginning to fill. During summer 1996, fish tagged in spring and recaptured in fall had an average growth of 41 mm, a substantial increase over pre-reservoir conditions.

In early September 1998, students from the University of Alaska Fairbanks sampled the WSR with fyke-nets, minnow traps, and electrofishing. Twelve Arctic grayling were caught in five fyke-nets fished 24 hr and ten Arctic grayling were captured with

Table 1. Catch of Arctic grayling in fyke-nets fished in the Fort Knox water supply reservoir (1996-1998).

Sample Date	Number of Nets	Number of Grayling (<150 mm)	Number of Grayling (>150 mm)	CPUE (AG/trap/day)
6/26/96	2	6	57	31.5
6/27/96	2	6	85	45.5
6/28/96	2	9	104	56.5
8/6/96	4	17	201	54.5
8/7/96	5	17	123	28.0
8/8/96	5	6	140	29.2
8/27/96	5	16	150	33.2
8/28/96	5	18	109	25.4
8/29/96	5	11	145	31.2
8/30/96	5	9	110	23.8
5/21/97	2	*	*	320.0
8/26/97	5	6	19	5.0
8/27/97	5	7	49	11.2
9/7/97	5	8	37	9.0
5/19/98	2	0	29	14.5
5/20/98	3	1	1002	334.0
5/27/98	2	0	3	1.5
5/28/98	3	0	30	15.0
5/29/98	3	2	72	24.7
9/13/98	5	1	11	2.4

*Arctic grayling were counted and released - measurements were not made due to the large number of fish. We did estimate that less than 10 of the 640 were small (i.e. <150 mm).

Figure 5. Length-frequency distribution of Arctic grayling caught in the water supply reservoir (1995, 1996, and 1998).

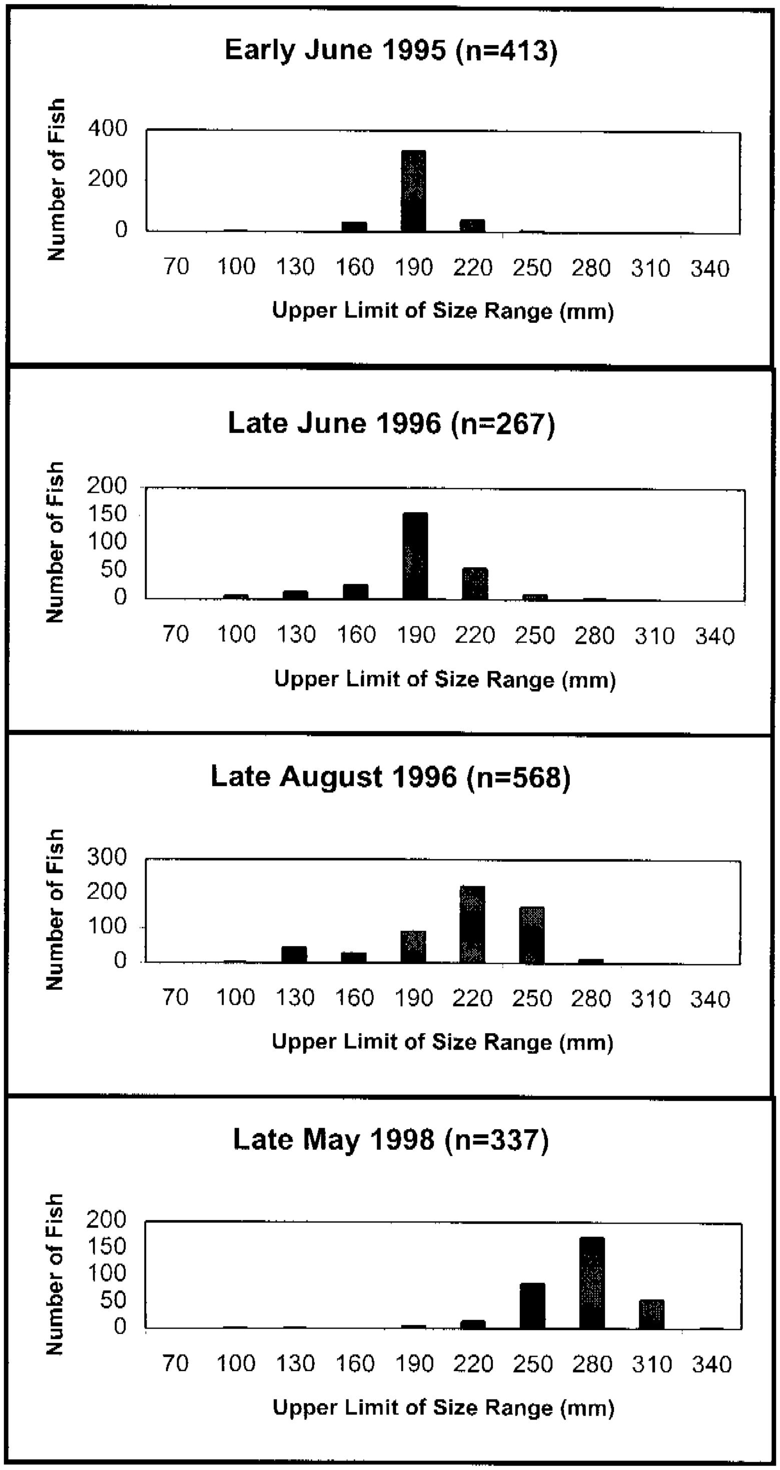
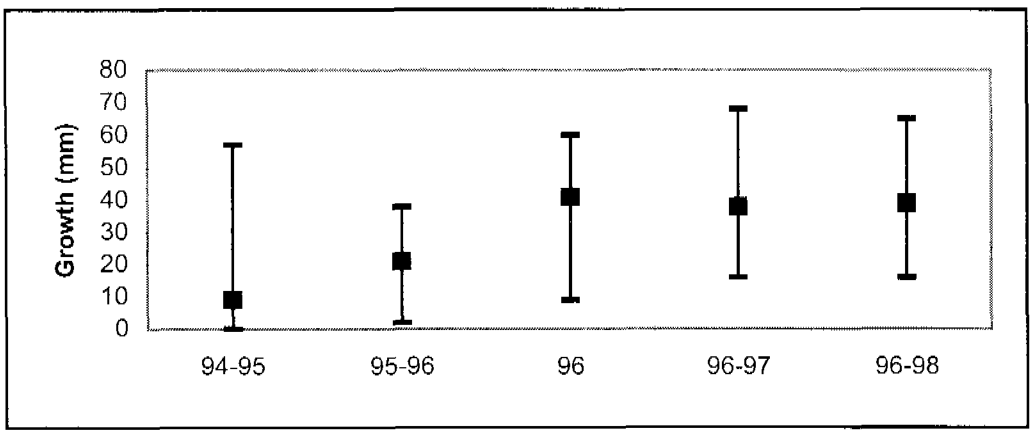


Figure 6. The minimum, maximum, and average annual growth of Arctic grayling in upper Fish Creek and the Fort Knox water supply reservoir from 1994 to 1998.



electrofishing. Only one Arctic grayling in fyke-net catches was <150 mm and two of the ten fish caught by electrofishing were <150 mm. No young-of-the-year Arctic grayling were captured during the September 1998 sampling event.

Catches of Arctic grayling in spring 1998 were similar to those reported in 1997. In both years, we had extremely high catches in spring, probably due to the fact that the nets were fished at a time when adult fish were actively moving along the shoreline to find suitable spawning habitat. Three tributaries to the WSR exist: Solo Creek which was not used for spawning before construction due to cold water temperatures in this north-facing permafrost drainage; Fish Creek where a barrier has been built to keep fish from the constructed wetland complex; and Last Chance Creek where aufeis forced the creek out of the channel and over a 2 m high waterfall. Arctic grayling did not have access to stream spawning habitats in 1996, 1997, or 1998 and we have seen little evidence of young-of-the-year survival. Length frequency distributions suggest the population of Arctic grayling will decline rapidly unless recruitment occurs.

Fort Knox Water Supply Reservoir, Burbot

Burbot use of the Lower Last Chance Creek Pond and Polar Ponds #1 and #2 was reported by Ott and Weber Scannell (1996). In May 1995, we conducted a mark/recapture experiment and estimated the burbot population (150 to 331 mm) at about 825 fish (Ott and Weber Scannell 1996). Flooding of the water supply reservoir began in November 1995, isolating burbot upstream of the dam. Burbot sampling continued in summer 1996, to obtain data on recruitment and growth of young-of-the-year burbot (Ott and Townsend 1997).

In late May 1997, we again conducted a mark/recapture population estimate for burbot. We marked 189 burbot captured with hoop nets and minnow traps on May 21 and 22, 1997. Sixteen of the burbot ranged in size from 145 to 181 mm and the remaining 173 were between 287 and 605 mm. We recaptured 125 burbot on May 28 and 29, 1997. Of the 125 fish, eight were small (147 to 195 mm) and the rest ranged from 273 to 612 mm. Thirty-two of the fish seen during the recapture event had been marked on May 21 or 22. None of the recaptured fish was less than 250 mm. Our 1997 spring population estimate for burbot ≥250 mm was 622 (95% confidence interval 462 to 782) with an unknown number less than 250 mm.

In spring 1998, 203 burbot were captured and unmarked fish were marked with a numbered floy-tag (154 were ≥300 and 49 were between 200 and 299 mm). We conducted the recapture event one week later, capturing 126 burbot >300 mm, of which, 27 were marked the previous week. We also captured 49 burbot between 200 and 299 mm, none of which were previously marked. Our population estimate for burbot ≥300 mm was 703 (95% confidence interval 499 to 907) with an unknown number less than 300 mm.

Burbot estimates in the WSR for 1995, 1997, and 1998 were 825, 622, and 703 fish, respectively. The 1995 estimate included burbot >150 mm, the 1997 and 1998 estimates were for burbot ≥250 and ≥300 mm, respectively. Assuming the population sampled is the same group of fish, survival of these fish has been extremely high since the original population estimate was made in 1995.

Catch per unit of effort for small and large hoop traps fished in the WSR have been collected each year since 1996 (Table 2). Generally, catch rates have increased each year due to recruitment of small burbot. Fyke-net catch per unit of effort for burbot has varied (Table 3). In general, catches of burbot <250 mm in the fyke-nets has increased relative to burbot ≥250 mm.

Length frequency for burbot collected from May 1995 to May 1998 is shown in Figure 7. Substantial recruitment of small size classes of burbot is apparent (Figure 7).

Winter growth rates for seven burbot (average size 350 mm, SD = 6.9) tagged in September 1997 and recaptured in May 1998 averaged 20 mm (SD = 8.3). A number of burbot caught in May 1997 were recaptured in May 1998. Burbot ranging in length from 300 to 324 mm (n = 24) when tagged averaged 40 mm (SD = 16.8) growth (Table 4). Fish from 376 to 399 mm (n = 7) when tagged grew an average of 66 mm (SD = 20.0). Average annual growth rate was highest (average 77 mm, SD = 19.0) for fish which ranged from 400 to 499 mm (n = 7) at tagging. General observations made during the spring 1998 sampling were that both the smaller burbot (<250 mm) and larger burbot (>375) were in better condition than previous years. Higher growth rates for the larger burbot may be related to the fact that these fish have converted mainly to eating other fish. The near total absence of Arctic grayling less than 200 mm probably is related in part to predation by burbot.

Table 2. Catch of burbot in the water supply reservoir in 1996, 1997, and 1998 using hoop nets.

Sample Date	Gear Type	Number of Traps	Catch (Total)	Mean CPUE[1] (BB/trap/day)
May 22, 96	small hoop	11	36	3.3
May 22, 96	large hoop	4	6	1.5
May 23, 96	small hoop	11	19	1.7
May 23, 96	large hoop	4	2	0.5
May 20, 97	small hoop	11	58	5.3
May 20, 97	large hoop	13	24	1.8
May 21, 97	small hoop	11	61	5.5
May 21, 97	large hoop	17	56	3.3
May 28, 97	small hoop	11	45	4.1
May 28, 97	large hoop	19	42	2.2
May 29, 97	small hoop	11	32	2.9
May 29, 97	large hoop	20	39	2.0
May 20, 98	small hoop	7	87	12.4
May 21, 98	small hoop	9	61	6.8
May 21, 98	large hoop	3	20	6.7
May 22, 98	small hoop	9	57	6.3
May 27, 98	small hoop	9	61	6.8
May 28, 98	small hoop	9	67	7.4
May 29, 98	small hoop	9	44	4.9

[1]CPUE = catch per unit of effort

Table 3. Catch of burbot in unbaited fyke-nets fished in the Fort Knox water supply reservoir (1996 to 1998).

Sample Date	Number of Nets	Number of Burbot (<250 mm)	Number of Burbot ($\geq$250 mm)	CPUE (BB/trap/day)
6/5/96	1	0	4	4.0
6/26/96	2	0	1	0.5
6/27/96	2	0	0	0.0
6/28/96	2	0	1	0.5
8/6/96	4	2	14	4.0
8/7/96	5	11	12	4.6
8/8/96	5	9	18	5.4
8/16/96	1	8	1	9.0
8/27/96	5	8	19	5.4
8/28/96	5	3	20	4.6
8/29/96	5	5	21	5.2
8/30/96	5	1	22	4.6
5/21/97	2	12	0	6.0
8/26/97	5	36	35	14.2
8/27/97	5	46	33	13.8
9/7/97	5	42	53	19.0
5/19/98	2	37	16	26.5
5/20/98	3	22	7	9.7
5/27/98	2	8	1	4.5
5/28/98	3	12	1	4.3
5/29/98	3	12	1	4.3

Figure 7. Length-frequency distribution of burbot caught in the water supply reservoir (1995-1998).

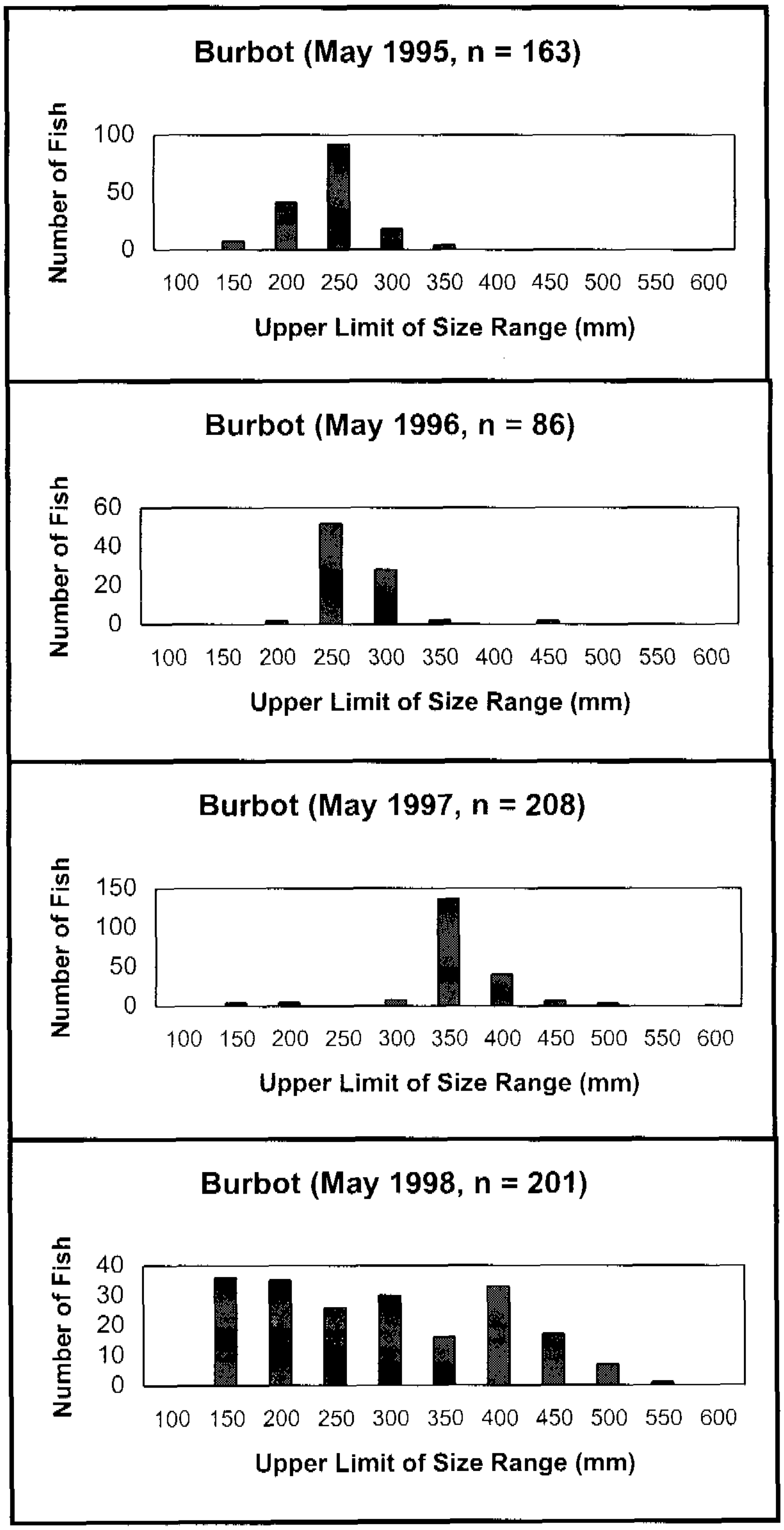


Table 4. Growth of burbot tagged in May 1997 and recaptured in May 1998 using fyke-nets and hoop traps.

Length at Mark (mm)	Sample Size	Average Growth (mm)	Standard Deviation
300-324	24	40	16.8
325-349	25	45	13.9
350-374	12	44	16.7
375-399	7	66	20.0
400-500	7	77	19.0

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Appendix 1 - Water Quality Water Supply Reservoir

Site Number	Date	Depth (m)	Temperature (C)	% Saturation Dissolved Oxygen	Dissolved Oxygen (mg/L)	Conductivity (*u* S/cm)	pH
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
		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
		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

N/T = not tested

Appendix 1 (continued).

Site Number	Date	Depth (m)	Temperature (C)	% Saturation Dissolved Oxygen	Dissolved Oxygen (mg/L)	Conductivity (*u* S/cm)	pH
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
		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

Appendix 1 (continued).

Site Number	Date	Depth (m)	Temperature (C)	% Saturation Dissolved Oxygen	Dissolved Oxygen (mg/L)	Conductivity (u S/cm)	pH
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 Number	Date	Depth (m)	Temperature (C)	% Saturation Dissolved Oxygen	Dissolved Oxygen (mg/L)	Conductivity (*u* S/cm)	pH
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
		4	8.90	N/T	4.76	141.0	6.92
		4.5 (bottom)					

Appendix 1 (concluded).

Site Number	Date	Depth (m)	Temperature (C)	% Saturation Dissolved Oxygen	Dissolved Oxygen (mg/L)	Conductivity (u S/cm)	pH
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