Technical Report No. 13-05

Arctic Grayling and Burbot Studies at the Fort Knox Mine, 2013

by Alvin G. Ott, William A. Morris, Heather L. Scannell, and Parker T. Bradley

Pond F Outlet, 400 mm Male Arctic Grayling, May 2013
Photograph by Alvin G. Ott

December 2013

Alaska Department of Fish and Game
Division of Habitat

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ARCTIC GRAYLING AND BURBOT STUDIES AT THE FORT KNOX MINE, 2013

By

Alvin G. Ott, William A. Morris, Heather L. Scannell, and Parker T. Bradley

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Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in reports by the Divisions of Habitat, Sport Fish and of Commercial Fisheries. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

Weights and measures (metric)	
centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)	
cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature	
day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry	
all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General	
Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	\$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)	
fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

Mathematics, statistics	
all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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Acknowledgements

We thank Fairbanks Gold Mining Inc. (FGMI) (Delbert Parr and Dave Stewart) for their continued support of our work to monitor fish and wildlife resources in the Water Supply Reservoir, tributaries, and developed wetlands. Delbert Parr and Dave Stewart (FGMI) provided constructive review of our report.

Executive Summary

Water Quality

●Winter dissolved oxygen decreased with depth in the WSR, but in deeper areas there was a mid-column increase in DO that probably exists because of input water from Last Chance and Solo creeks (pages 7 to 9)

Arctic Grayling Stilling Basin

●Forty nine Arctic grayling were caught in the stilling basin. Four of these fish had been marked in the stilling basin in late July 2011 (page 10)

Arctic Grayling Water Supply Reservoir

●Arctic grayling spawning was late in the wetland complex due to prolonger cold weather and an extended breakup. The only spawning observed was in the Pond D outlet and the upper part of Channel C (pages 12 and 13)

●Arctic grayling fry were numerous in the upper portion of Channel C with few fish present in the remainder of the wetland complex (page 13)

●The spring 2012 population estimate for Arctic grayling $\geq$ 200 mm long was 7,404 fish (page 15)

●Recruitment of small Arctic grayling was observed in spring 2013 – 67 new fish were captured and marked between 200 and 225 mm in length (page 15)

●Average annual growth of Arctic grayling in the WSR decreased from 2010 to 2012 as compared with 2009 as the population increased (page 16)

●Data on population size and average growth of fish $\leq$ 250 and > 250 mm indicates an inverse relationship between population size and average growth (page 17)

Burbot Water Supply Reservoir

●We caught 96 burbot in the WSR and developed wetlands that ranged from 89 to 697 mm long - 24 of those fish were larger than 400 mm and 7 of those had been tagged in 2012 (page 18)

●The estimated population of large burbot ($\geq$ 400 mm) in the WSR was 193 for spring 2012 (page 19)

Introduction

Fairbanks Gold Mining Incorporated (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, Alaska (Figure 1). The project includes an open-pit mine, mill, tailing impoundment, water supply reservoir (WSR), and related facilities. Construction of the WSR dam and spillway was completed in July 1996. In 2007, permits were issued for the construction, operation, and closure of a valley fill heap leach facility located in Walter Creek upstream of the tailing pond. Ore was processed through the mill and added to the Walter Creek valley fill heap leach in 2013. Exploration drilling continued at the Gil Prospect located 13 km east of Fort Knox.

Figure 1. Aerial photograph of the Fort Knox Gold Mine water supply reservoir, tailing facility, and pit – water supply reservoir in lower part of photo and the tailing dam and impoundment in the upper Fish Creek valley, photograph provided by FGMI.

A chronology of events for 2011, 2012, and 2013 with emphasis on biological factors, is presented in Appendix 1. The chronology for previous years (1992 to 2010) can be found in Technical Report No. 10-5 titled "Arctic grayling and burbot studies at the Fort Knox Mine, 2010" (Ott and Morris, 2010).

Rehabilitation, to the extent practicable, has been concurrent with mining activities and natural revegetation of some disturbed habitats has been rapid. Wetland construction between the tailing dam and WSR began in summer 1998. A channel connecting wetlands along the south side of the Fish Creek valley was built in spring 1999 (Figure 2).

Figure 2. Channel from wetlands to WSR in 2000 (top photo) and in 2010 (bottom photo).

In-channel excavation, drainage rock placement, and channel reconstruction work to mitigate aufeis in Last Chance Creek was conducted in fall 2001 and again in fall 2008. Repair work on dikes separating Ponds D and E and the channel connecting the ponds was completed in summer 2002. Buell and Moody (2005) provided recommendations for additional work to enhance fish and wildlife habitats between the tailing dam and WSR.

Fish research prior to construction of the Fort Knox mine and related facilities began in 1992 and water quality sampling started in summer 1997. Technical Reports (Weber Scannell and Ott 1993, Weber Scannell and Ott 1994, Ott et al. 1995, 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, b, Ott and Morris 2003, Ott and Morris 2005a, b, Ott and Morris 2006, Ott and Morris 2007, Ott and Morris 2009a, b, Ott and Morris 2010, Ott and Morris 2011, Ott et al. 2012) summarizing field work can be found on the Alaska Department of Fish and Game, Division of Habitat's Web Page:

http://www.adfg.alaska.gov/index.cfm?adfg=habitat_publications.main.

Populations of Arctic grayling (*Thymallus arcticus*) and burbot (*Lota lota*) exist in the WSR, and both Arctic grayling and burbot inhabit the stilling basin below the WSR. Arctic grayling spawning occurs predominantly in the wetland complex between the WSR and the tailing dam. Burbot spawning as documented by using radio telemetry likely occurs in Solo Bay where Solo Creek enters the WSR. Recruitment of Arctic grayling to the stilling basin is from the WSR, but no tagged burbot from the WSR have been caught in the stilling basin. Our report summarizes fish and water quality data collected during 2013 and discusses these findings in relation to previous work.

Methods

Water Quality

In 2013, water quality sampling was conducted in late April when the WSR was ice covered. Temperature (^{o} C), dissolved oxygen (DO) concentration (mg/L), DO percent saturation (barometrically corrected), pH, specific conductance (*u* S/cm), oxidation reduction potential (ORP), and depth (m) were measured with a Hydrolab® Minisonde®5 water quality multiprobe connected to a Surveyor® 4 digital display unit. The multiprobe sensors were calibrated to suggested specifications prior to use. The LDO sensor was calibrated using a saturated air method. Conductivity, ORP, and pH sensors were calibrated with fresh standard solutions. Winter water quality measurements were made at 1 m depth intervals from the surface to the bottom.

Fish

Fish sampling methods included visual observations, fyke nets, angling, and hoop traps. One fyke net sampling site in the developed wetlands located just upstream of the WSR was used in spring 2013 (Figure 3). The fyke net was set on May 20, because at this time, this was the only site with enough free water to set a fyke net. The net was pulled on May 30, 2013; water levels in the WSR had risen to the point where ponded water existed around the fyke net. Arctic grayling were sampled by angling in the stilling basin and burbot were captured using baited hoop traps.

Arctic grayling were measured to fork length (nearest mm), inspected for tags and spawning condition, and released. Burbot were measured (total length), inspected for tags, and released. Arctic grayling and burbot $\geq$ 200 mm were marked with a numbered Floy® T-bar internal anchor tag. Arctic grayling and burbot abundance was estimated using Chapman's modification of the Lincoln-Petersen two-sample mark-recapture model (Chapman 1951) and variance was estimated (Seber 1982).

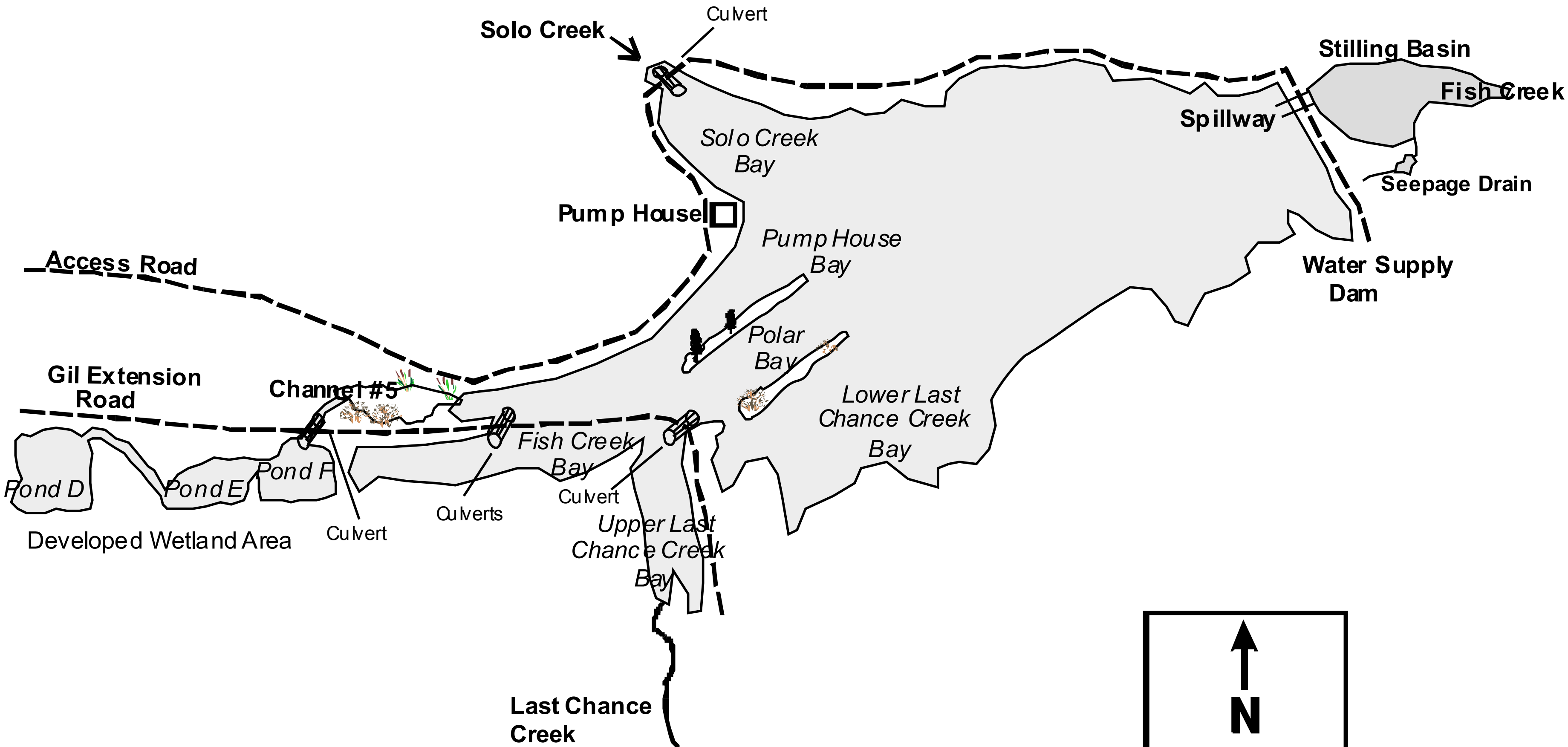

Figure 3. Sample areas in the Fort Knox WSR, stilling basin, and developed wetlands.

Results and Discussion

Water Supply Reservoir, Water Quality

Ponding of water for the WSR began in November 1995. Water surface elevation varied in 1996 and 1997 due to water use and winter seepage below the freshwater dam. The WSR reached the projected maximum water surface elevation of 1,021 feet on September 29, 1998, after a major rainfall event. When full, the WSR contains about 3,363 acre-feet (1.1 billion gallons) of water.

Water levels have remained fairly constant since 1998, except in the winter of 2000/2001, 2007/2008, 2009/2010, and 2012/2013 when large amounts were removed (Table 1). On May 5, 2013, there was no surface flow over the spillway, but by May 27, 2013, water was flowing over the spillway. Winter water use in 2012/2013 was 1,837 acre-feet (over 50% of the water available).

Table 1. Winter water use from the WSR, 1997 to 2012 (October 1 to April 30).

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
2004/2005	716
2005/2006	659
2006/2007	299
2007/2008	1,176
2008/2009	817
2009/2010	1,167
2010/2011	187
2011/2012	59
2012/2013	1,837

On September 9, 2013, flashboards had been placed in the low flow channel and water was not flowing over the spillway. Water levels were about 15 cm (6 inches) higher in the WSR. Based on discussions with FGMI, anticipated winter water use (2013 – 2014) will be high because of additional water needs for the valley heap leach. Another inspection was made on October 22, 2013, the flashboards had been removed and water was flowing in the low flow channel of the spillway.

Seepage flow through the WSR was monitored continuously by FGMI and has remained relatively constant over the last 15 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
2005	0.97 to 2.35	1.49
2006	1.30 to 2.35	1.44
2007	1.13 to 1.78	1.32
2008	n/a	n/a
2009	1.06 to 3.55	1.53
2010	1.06 to 1.78	1.38
2011[1]	1.25	1.25
2012	1.06 to 2.18	1.41
2013	0.94 to 1.60	1.17

[1]Average flow rate

Water quality data were collected prior to breakup in April 2013 (Appendix 2). Average ice thickness on the WSR was about 1 m. The water surface elevation was at the ice surface across the reservoir with the exception of Last Chance and Fish Creek bays each of which had 0.15 to 0.2 m of overflow. Water temperature ranged from 0.29 to about 2.2°C and generally increased with depth, minor cooling trends were observed at depths greater than 8 m. Those portions of the WSR with greatest depth generally were the warmest. DO concentration decreased with depth at most sites; however, a mid-column layer of higher DO water was observed at Solo Bay and Sites #1 and #2 (Figure 4). DO concentration remained above 3 mg/L at Site #2 down to 7 m and remained above 3 mg/L at Site #1 between 3 and 7 m. The remaining sites, including Solo Bay, exhibited depressed DO below 3 mg/L. Temperature specific DO saturation followed the same pattern as DO concentration in the deepest area of the reservoir, Site #2, exhibiting saturations of around 30% from below the ice to about 6 m.

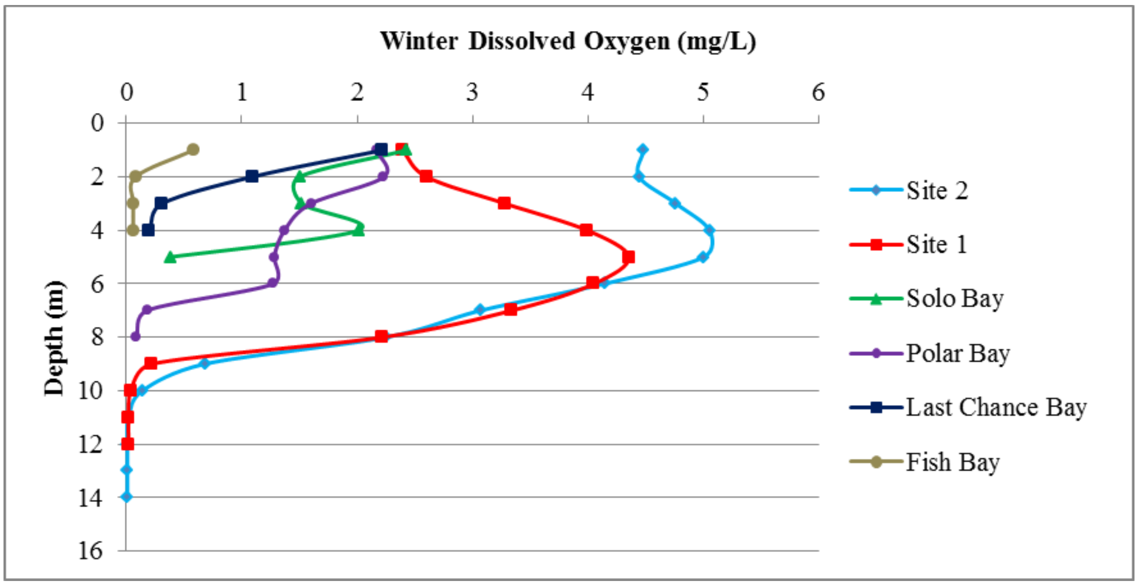

Figure 4. Dissolved oxygen concentrations by depth in the WSR in April 2013.

Specific conductance was similar throughout most of the waterbody and increased with depth. Polar Bay exhibited higher specific conductance by depth. ORP was similar at most sites, but highest in Polar and Last Chance bays. Although nearly constant with depth in the upper layers at each site, ORP dropped dramatically once the layer of rapid DO decline was reached.

Average winter water column DO at Site #2 (located about 100 m upstream of the dam) is shown in Figure 5. In late winter 2013, the average water column DO was 2.28 mg/L.

Discharge from Last Chance, Solo, and Fish creeks, likely explains the layers of mid-column increased DO. It is likely that discharge into the WSR from these creeks is the sole reason for adequate DO concentrations for fish survival in any given year. Last Chance Creek waters enter the WSR through Polar Bay, when winter discharge is present. Review of specific conductance data indeed suggest that water in Polar Bay is different than water found in the rest of the WSR. Solo Creek may have had less influence given the overall low DO concentration observed in Solo Bay; however, the DO spike at 4 m in Solo Bay does suggest some input.

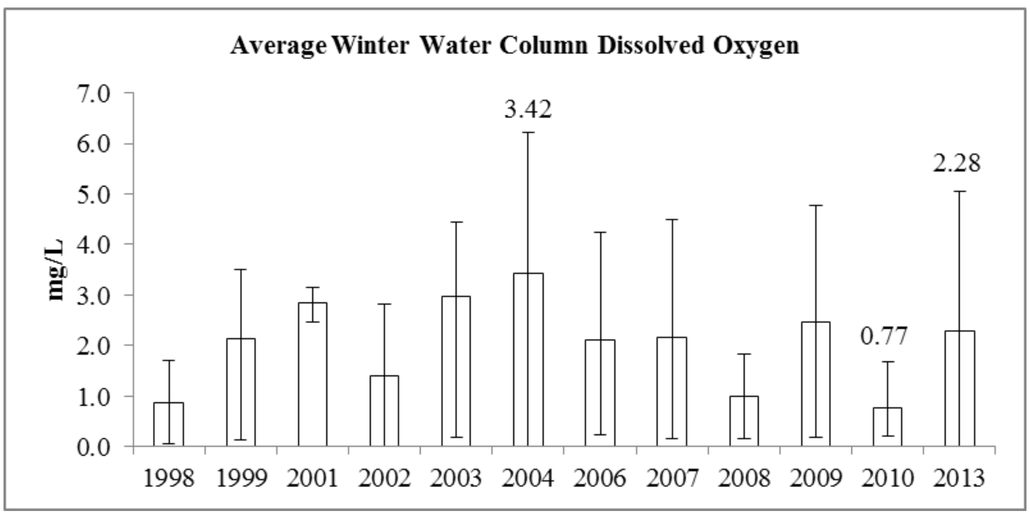

Figure 5. Average water column dissolved oxygen concentration in late winter at Site #2.

Stilling Basin, Arctic Grayling and Burbot

The stilling basin, located immediately downstream of the WSR spillway, is fed by groundwater, seepage flow, and surface flow. The narrow notch in the spillway was designed to accommodate surface water discharge from the WSR during winter without forming aufeis. Aufeis in the spillway has never been observed since it was constructed. In spring 2013, water was not flowing over the spillway (Figure 6).

Figure 6. Spillway, looking downstream, at the Fort Knox freshwater dam in spring 2013.

Arctic Grayling

Limited Arctic grayling sampling using angling was conducted in spring 2013. We fished for 35 min on May 20 and for 90 min on May 22, catching 49 Arctic grayling ranging from 153 to 285 mm fork length. Both ripe males and females were caught. Five recaptures were seen with four of these fish marked previously in late July 2011. Growth of these fish ranged from 20 to 26 mm.

The length frequency distribution for Arctic grayling caught in the stilling basin is presented in Figure 7. Multiple age classes were present in our sample.

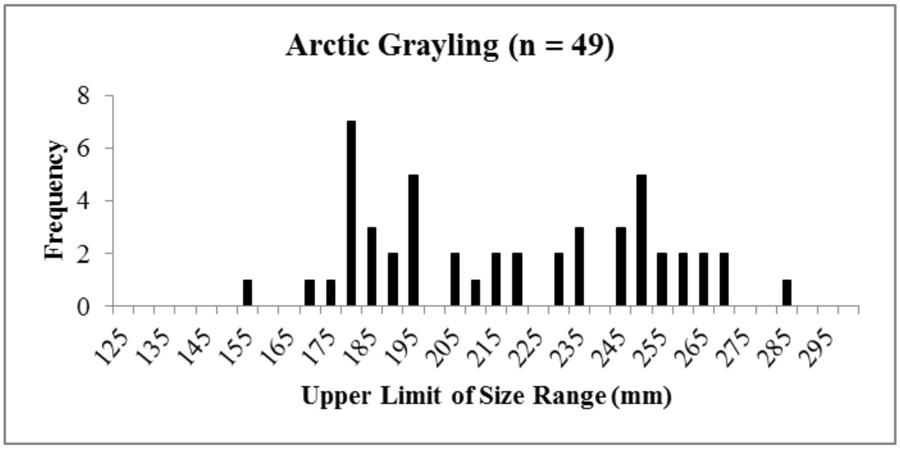

Figure 7. Length frequency distribution of Arctic grayling in the stilling basin in spring 2013.

Water Supply Reservoir, Arctic Grayling

Arctic grayling were found throughout the Fish Creek drainage prior to construction of the WSR. Fish were concentrated in flooded mine cuts in Last Chance Creek. The population appeared stunted: fish larger than 220 mm were rare; average annual growth was 9 mm; and size at maturity was small (148 mm for males, 165 mm for females). Successful spawning was limited to inlets and outlets of the flooded mine cuts and upper Last Chance Creek. Flooding of the WSR inundated the inlets and outlets of mine cuts, thus eliminating the spawning habitat. Since flooding of the WSR, aufeis in Last Chance Creek has been substantial. Since 1998, we have only observed successful spawning by Arctic grayling in Last Chance Creek in 2004 and 2005.

Very few fry were captured or observed from 1996 through 1998 in the WSR and Last Chance Creek (less than 10 were observed). In spring 1999, FGMI constructed an outlet channel (Channel #5) to connect the developed wetland complex with the WSR (Figure 3). Channel #5 was constructed to bypass a perched pipe and provide fish access to potential spawning and rearing habitat in the wetland complex. Arctic grayling have successfully spawned in the wetland complex every year since 1999 and have used most of the wetland complex in many years. However, substantial aufeis and resultant cold water temperatures in the wetland complex, in addition to beaver dams, limited availability of, and access to, spawning habitats in 2002, 2006, and 2007.

Arctic Grayling Spawning (Timing, Temperature, and Fry Presence)

In spring 2013, we fished one fyke net in the developed wetlands just upstream of the WSR. The fyke net was set on May 20 and was fished until May 30. Beavers had rebuilt multiple dams in the wetland complex and FGMI personnel removed (notched) the beaver dams to allow fish access to the upper portion of the wetland complex. Aufeis was minimal and similar to that seen in spring 2012.

Cold weather in spring 2013 resulted in a late breakup. Water temperatures at the fyke net location in Pond F outlet first reached > 4^{o}C on May 29, 2013 (Figure 8). In the three previous years, water temperatures exceeded 4^{o}C between May 9 and May 15 (Figure 8).

In spring 2013, the water was turbid in the wetland complex from Pond D downstream and observations of active spawning were not possible due to poor visibility. However, on June 3, 2013, we did observe Arctic grayling spawning at Pond D outlet and in the headwaters of Channel C. By June 5, 2013, spawning was complete - no adult Arctic grayling were seen.

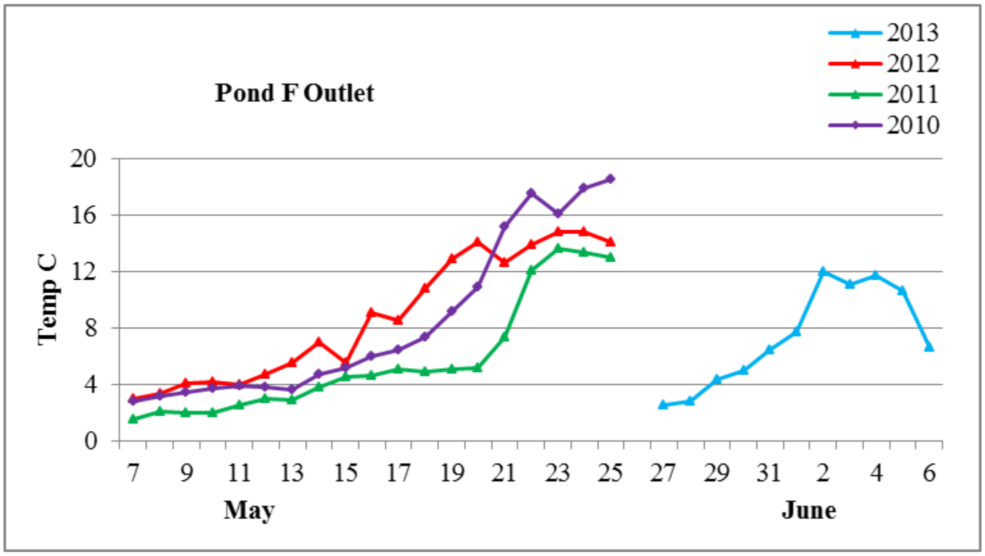

Figure 8. Peak daily water temperatures in Pond F outlet channel.

Observation of Arctic grayling fry distribution and relative abundance on June 25, 2013, revealed low numbers of fry (< 10) in the lower wetlands (Pond D downstream), high numbers of fry in the upper portion of Channel C (hundreds), and overall size of fry was small (15 to 20 mm). Most of the successful spawning in 2013, based on the presence of fry, occurred in the upper part of Channel C. On September 3, 2013, there were a number of Arctic grayling fry observed in Ponds D, E, and F. Beaver dams had been rebuilt and FGMI responded by removing beavers and their dams, allowing Arctic grayling fry to leave the wetland complex for overwintering habitat in the WSR.

Arctic Grayling Catches and Metrics

We first captured Arctic grayling on May 21, 2013, in a fyke net in Pond F outlet channel just upstream of the WSR. Some Arctic grayling had already entered the wetland complex when sampling began. The catch per trap day increased with time, peaked on May 25 and 26, and then decreased at the end of the sample period (Figure 9).

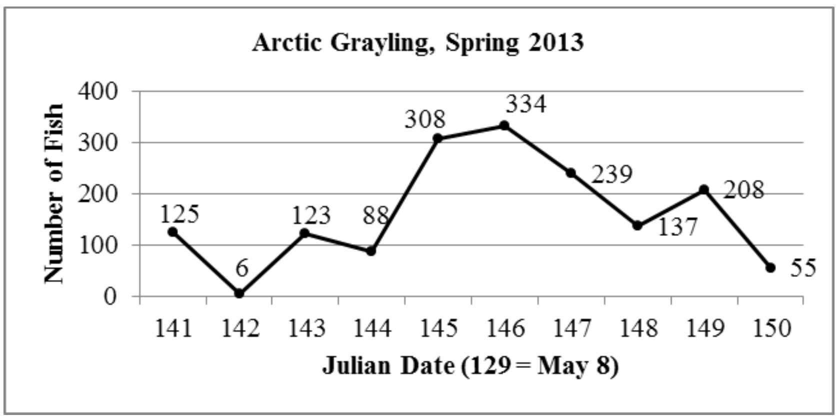

Figure 9. Catch per unit of effort (fish per net day) for Arctic grayling in spring 2013 in the wetland complex.

The abundance of Arctic grayling was estimated in the WSR using spring 2012 as the mark event and spring 2013 as the recapture event. In spring 2012, there were 1,593 marks when newly tagged and recaptured fish were combined. In spring 2013, 1,532 Arctic grayling $\geq$ 225 mm were captured, and of those, 329 were recaptures. For the 2012 estimated Arctic grayling population, length frequency distributions from 2012 and 2013 were compared to eliminate those fish handled in 2013 that would have been too small (< 200 mm) to mark in spring 2012. We reduced the total number of marked fish handled in spring 2013 by 67 fish that were $\leq$ 225 mm long, yielding a total of 1,532 fish handled in 2013 for use in estimating the 2012 population.

The spring 2012 population estimate for Arctic grayling ≥ 200 mm long was 7,404 fish (95% CI 6,775 to 8,033) (Figure 10 and Appendix 3). There was no substantial change in the Arctic grayling population from 2011 to 2012.

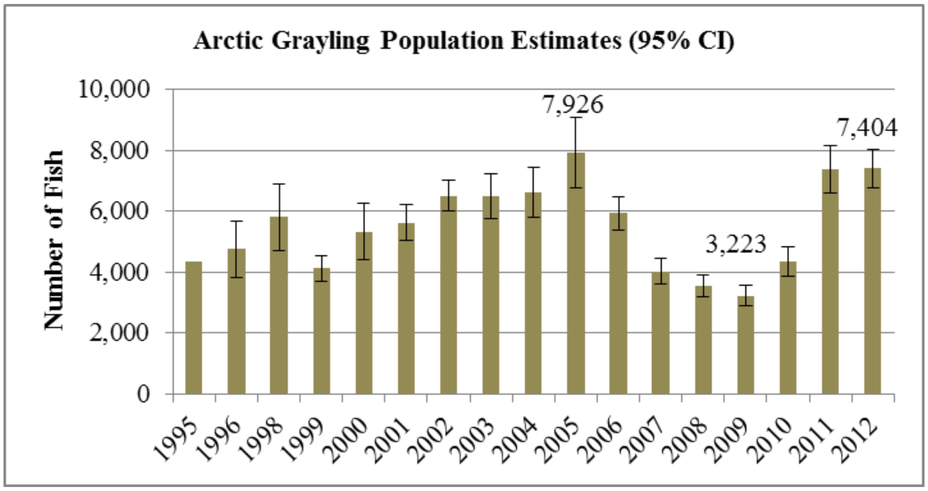

Figure 10. Estimates of the Arctic grayling population in the WSR.

Substantial recruitment of fish ≥ 200 mm was observed in springs 2010, 2011, 2012, and again in 2013 (Figure 11). We captured 67 fish between 200 and 225 mm long that we marked in spring 2013 that would have been less than 200 mm long in spring 2012. The structure of the population is similar in 2012 and 2013.

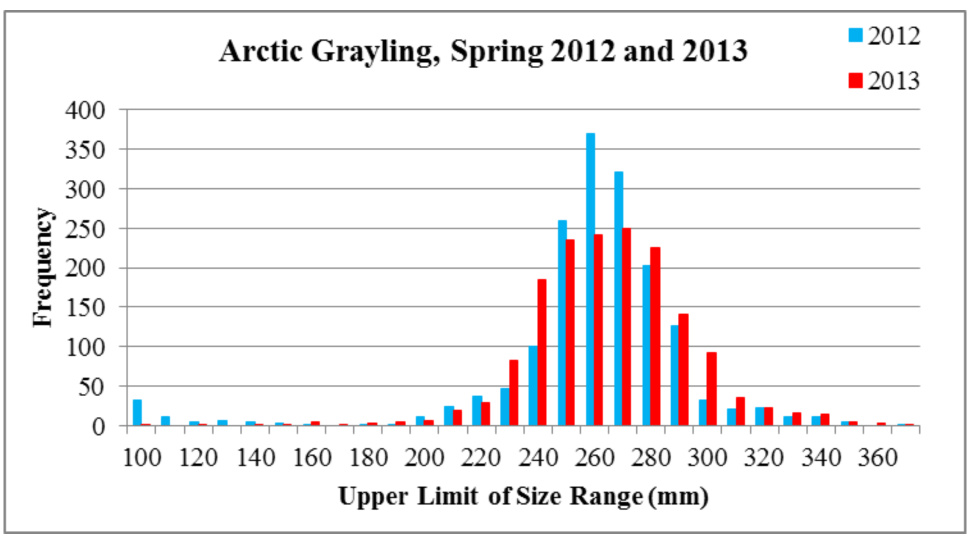

Figure 11. Length frequency distribution of Arctic grayling in wetlands in spring 2012 and 2013 (n = 1,668 and 1,623).

The fyke net was set and began fishing before the major portion of fish entered the wetland complex. Similar to previous years, large Arctic grayling ($\geq$ 250 mm) dominated the catch and were more abundant than the smaller fish (200 to < 250 mm) (Figure 12). Ninety five percent of the fish > 200 mm were mature (854 males and 668 females). Catches of fish < 200 mm were low (0 to 10 per net day) and several of these were ripe males.

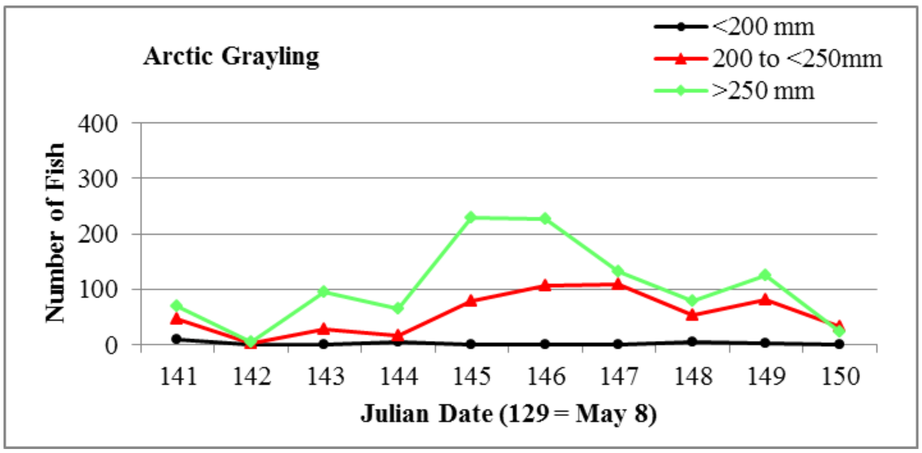

Figure 12. Arctic grayling catch by size group from May 21 through May 30, 2013.

Average growth of Arctic grayling prior to development of the WSR ranged from 3 to 17 mm per year (Appendix 4). After the WSR was flooded in 1995, annual growth for marked fish increased substantially. Growth rates decreased in 2010, 2011, and 2012 compared with 2009 (Figure 13).

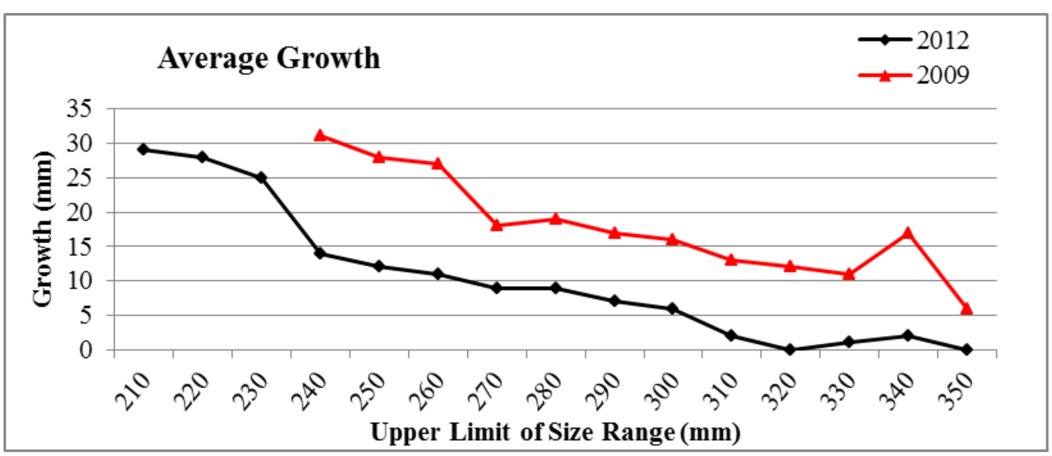

Figure 13. Growth of marked Arctic grayling in the WSR in 2009 and 2012.

An inverse relationship between growth rates and the Arctic grayling population size was observed. Annual growth rates of marked fish peaked in 2001, and then decreased slowly each year through 2004. Growth rates were increasing as the fish population was decreasing in the WSR. Since 2004, growth rates of individual fish have increased, with highest growth seen in summer 2008, as the population continued to decrease. However, growth rates in summer 2009 dropped slightly and probably reflect the large increase in recruitment of new fish to the population. Growth rates in 2010, 2011, and 2012 continued to be lower than in summer 2009.

Average growth of Arctic grayling grouped by the ≤ 250 mm and > 250 mm size classes for all sample years where population estimates were made is presented in Figure 14. Growth rates for both the smaller (≤ 250 mm) and larger (> 250 mm) cohorts of fish are higher when the population is lower. One possible explanation for the increased growth might be the assumption that with a lower overall population there is increased food availability for individuals as competition is reduced. These data would indicate that at the higher populations there is not adequate food to maintain the higher growth rates. Further, these data suggest that maintaining the population of fish > 200 mm at around 3,000 to 4,000 individuals might be ideal to produce a stable population with higher average growth rates.

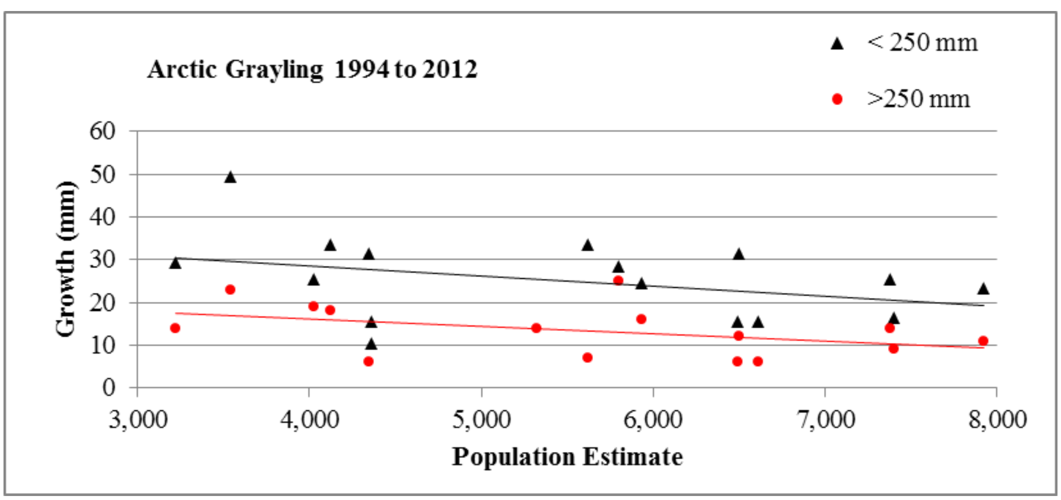

Figure 14. Growth of marked Arctic grayling in the WSR versus the estimated population of fish. Linear trendlines are shown for each group of fish.

Water Supply Reservoir, Burbot

Burbot were captured in spring 2013 in fyke nets fished in the developed wetlands and in hoop traps fished in the WSR. Most of the burbot were captured in hoop traps (86 out of 96 fish). Burbot ranged in size from 89 to 697 mm, and 24 of the burbot were ≥ 400 mm (Figure 15).

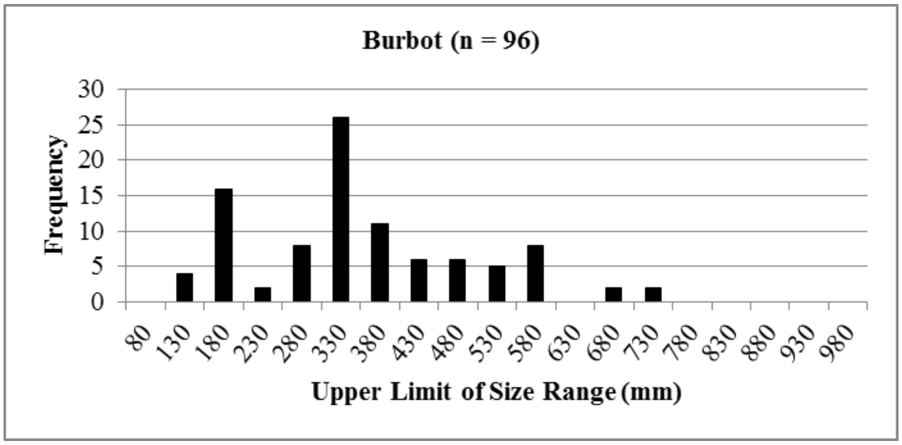

Figure 15. Length frequency of burbot in the developed wetlands and WSR in spring 2013.

The catch per unit of effort for hoop traps (number of burbot per hoop trap/24 hrs) fished in the WSR remains low as compared with higher catches that occurred following the flooding of the reservoir (Figure 16). Catches of smaller burbot were highest in 1998 (7.2 fish/day), but decreased quickly and have steadily declined since 2002.

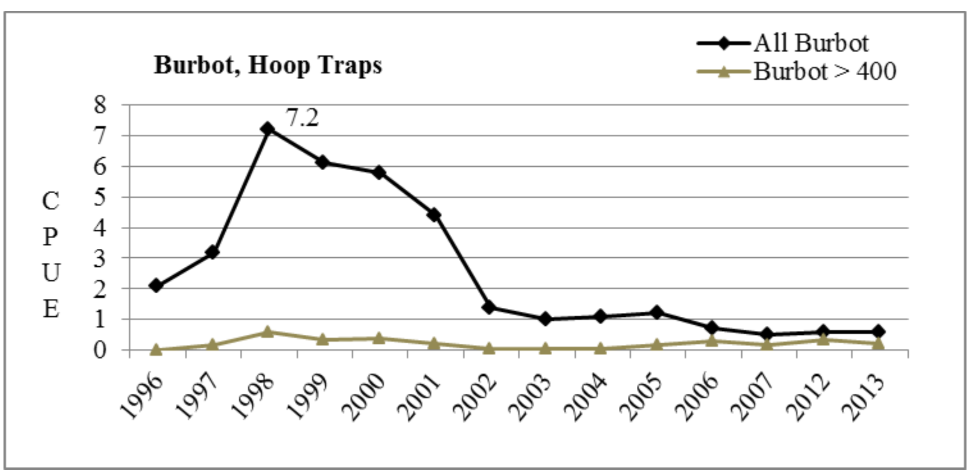

Figure 16. Catch per unit of effort (fish/trap day) of burbot in the WSR from 1996 to 2012.

In spring 2012, we marked or recaptured 61 burbot $\geq$ 400 mm. We caught 24 burbot $\geq$ 400 mm with seven recaptured fish seen in spring 2013. Our estimated population of large burbot for spring 2012 was 193 (Figure 17). Growth rates of six large burbot averaged 49 mm per year but were highly variable and ranged from 25 to 85 mm.

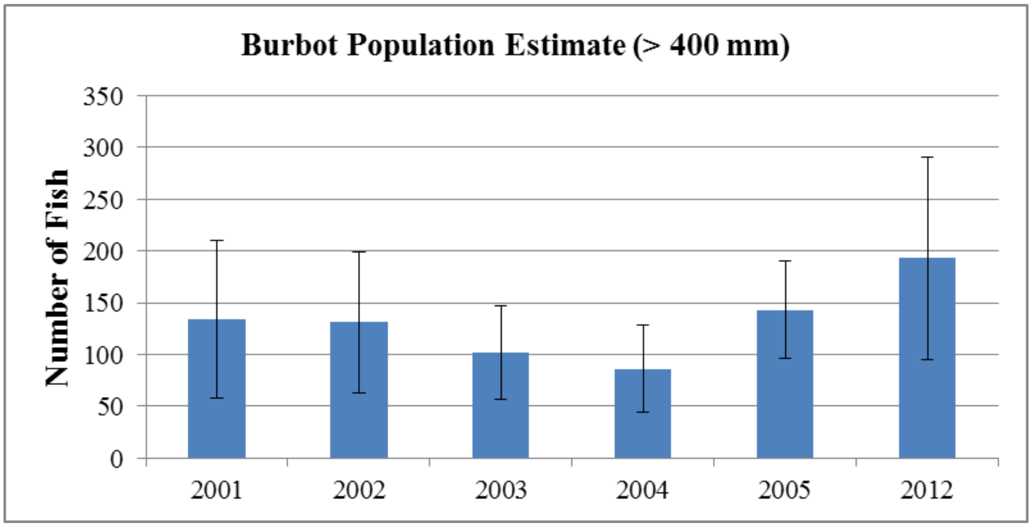

Figure 17. Burbot population estimates in the WSR.

Conclusion

Self-sustaining populations of Arctic grayling and burbot have been established in the Fort Knox WSR. The post-mining goal for the Arctic grayling population was set at 800 to 1,600 fish $\geq$ 200 mm (FGMI 1993). Our spring 2012 estimated population for Arctic grayling $\geq$ 200 mm was 7,404 fish. Except for the 2005 Arctic grayling estimate, this is the highest population estimate made since the fresh water pond was built. A goal for the burbot population was not set prior to construction, but a small self-sustaining population exists.

We plan to continue to work cooperatively with FGMI to collect data on fish resources and water quality in the WSR and to implement rehabilitation projects designed to increase fish and aquatic habitat values and terrestrial habitats. Active management of beaver populations within the developed wetlands and WSR appears to remain a critical component to the productive capacity of the wetland complex for Arctic grayling. During summer 2013, FGMI breached multiple beaver dams in the spring and again in the fall. Some of the beavers in the wetland complex were removed in the fall of 2013.

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Appendix 1. A Summary of Mine Development with Emphasis on Biological Factors

2011

●on February 9, 2011, ADF&G provided input to ADNR on the environmental audit to be conducted in summer 2011. We identified several possible fish and wildlife enhancement projects originally recommended by Buell and Moody (2005).

●on March 4, 2011, the ACOE issued a permit (POA-1992-574-M19) authorizing construction of the modified dam raise and expansion of the Tailing Storage Facility (TSF).

●in April and May several Plan of Operations amendments were issued by ADNR for work associated with the TSF, waste rock dumps, powerline, topsoil storage, and dewatering.

●on May 2, 2011, ADF&G provided input to ADNR on the reclamation and closure plan for Fort Knox. Emphasis was on maintaining the existing developed wetland complex downstream of the TSF.

●our spring sample event for Arctic grayling and burbot ran from May 9 to 24. We caught 1,194 Arctic grayling and 117 burbot in a fyke net set in the WSR.

●the estimated spring 2010 Arctic grayling population was 4,346 fish > 200 mm long and was an increase from the 2009 estimate of 3,223. Recruitment of new fish in spring 2011 was strong with 198 new fish < 230 mm marked.

●Arctic grayling spawned in the wetland complex from Pond D downstream. Beavers had not rebuilt the dams in the wetland complex.

●a constructed osprey nesting platform adjacent to the main pump house in the WSR was occupied in spring 2011 – one chick was seen in August. An active raven nest was observed on the rock cut near the freshwater dam.

●water began flowing over the spillway on May 27, water had not reached the spillway since winter 2009/2010.

●on June 2, 2011, ADF&G provided written comments on the Ft. Knox and True North environmental audit proposals.

●on July 19, 2011, FGMI pumped about 10,440 gallons of water from the "801 Pond" downstream – environmental staff were notified and pumping was immediately stopped – water from the "801 Pond" is supposed to be pumped back into sump below the TSF

●on August 4, 2011, ADNR informed us of planned changes at Fort Knox including expansion of the heap leach facility from 160 to 300 million tons, the need for a ADEC permit to discharge non-contact water, and the long-term need for a permit and water treatment plant for closure.

Appendix 1 (continued).

2011

●on September 13, 2011, ADNR approved the drilling of two monitoring wells in the headwaters of Victoria Creek. The purpose of these monitoring wells is to ensure water in Victoria Creek is not impacted by the increased elevation of tailings in the Pearl Creek drainage.

●on September 28, 2011, we met with FGMI to discuss plans to discharge non-contact water from the Fort Knox pit to the WSR.

2012

●our spring sample event (Arctic grayling and burbot) began on May 7 and ended on May 30. The estimated spring 2011 Arctic grayling population was 7,378 fish $\geq$ 200 mm long which was an increase of 3,032 from the 2010 estimate. Recruitment of new fish in spring 2012 was strong with 111 new fish < 230 mm marked.

●we caught 140 burbot (175 to 950 mm long) in spring 2012 in hoop traps and fyke nets.

●Arctic grayling spawned throughout the wetland complex, including the upper portion of Channel C, in spring 2012. Beavers had not rebuilt the dams in the wetland complex.

●a constructed osprey nesting platform adjacent to the main pump house in the WSR was occupied in spring 2012.

●water was flowing over the spillway when we began sampling in the spring of 2012 – water was still overflowing in late October.

●on July 13, 2012, ADF&G provided input to ADEC on the APDES draft permit for discharge of non-contact water. The discharge point has been changed to the old Fish Creek channel just downstream of Ponds A and B. The ADEC permit was issued on August 15, 2012.

●on September 27, 2012, ADF&G confirmed that a culvert in the road down the Fish Creek valley had been removed. In our trip report to FGMI, we recommended some additional civil work to ensure that the discharge water stays on the north side of the valley.

2013

●on April 25, 2013, water quality data (temperature, dissolved oxygen, etc.) were collected in the WSR under ice cover.

●our spring sample event (Arctic grayling and burbot) began on May 20 and ended on June 10. The estimated spring 2012 Arctic grayling population was 7,404 fish $\geq$200 mm long. Recruitment of new fish in spring 2013 was strong with 114 new fish <230 mm marked.

Appendix 1 (concluded).

2013

- ●we caught 96 burbot (89 to 697 mm long) in spring 2013 in hoop traps and fyke nets.
- ●Arctic grayling spawned throughout the wetland complex, including the upper portion of Channel C, in spring 2013. Beavers had rebuilt the dams in the wetland complex, but the dams were notched to allow fish passage.
- ●a constructed osprey nesting platform adjacent to the main pump house in the WSR was occupied in spring 2013.
- ●water was not flowing over the spillway when we began sampling, but by May 27 water had begun to flow out of the WSR and over the spillway
- ●on June 25, 2013, we observed Arctic grayling fry (numerous) in the upper portion of Channel C, very few fry were observed in Pond F and the Pond F outlet.

Appendix 2. Water Quality, April 2013

Site 2 is located about 100 m upstream of the Water Supply Dam								
				% Saturation	Dissolved			
Site		Depth	Temperature	Dissolved	Oxygen	Conductivity		
Number	Date	(m)	(C)	Oxygen	(mg/L)	(*u* S/cm)	pH	ORP
2	4/25/2013	1	0.49	32.1	4.48	145.5	5.96	285
		2	0.71	32	4.44	144.1	6.16	289
		3	1.11	34.7	4.76	143.3	6.15	293
		4	1.39	37.1	5.05	142.8	6.32	296
		5	1.69	37	5	142.9	6.34	296
		6	1.87	30.8	4.14	143.7	6.3	300
		7	2.01	22.9	3.07	146.3	6.3	303
		8	2.2	16.9	2.25	150.9	6.29	304
		9	2.11	5.1	0.68	185.6	6.26	305
		10	1.99	1.1	0.14	173	6.24	303
		11	2.06	0.2	0.02	179.1	6.23	304
		12	1.93	0.1	0.01	222.7	6.13	216
		13	2.03	0.1	0.01	223	6.11	217
		14	2.05	0.1	0.01	227.6	6.12	205
Site 1 is located in the middle of the Water Supply Reservoir								
1	4/25/2013	1	-0.08	16.9	2.39	148.1	5.91	281
		2	0.44	18.6	2.6	146.4	6.36	283
		3	0.78	23.7	3.28	145.6	6.3	287
		4	1.17	29.1	3.99	144.7	6.4	290
		5	1.47	32	4.35	144.5	6.28	292
		6	1.69	30	4.05	144.6	6.29	294
		7	1.82	24.8	3.34	147.3	6.29	295
		8	1.88	16.5	2.22	153.4	6.28	296
		9	1.89	1.6	0.22	164.4	6.26	279
		10	1.78	0.3	0.04	178.3	6.16	247
		11	1.65	0.2	0.02	199.2	6.14	210
		12	1.55	0.1	0.02	444.7	6.02	172
Site 3 is located in Solo Bay								
3	4/25/2013	1	-0.14	17.1	2.43	145.5		248
		2	0.47	10.8	1.5	149		278
		3	0.79	11	1.52	150.1		282
		4	1.14	14.7	2.01	149.3		285
		5	1.3	2.8	0.38	155.8		270

Appendix 2 (concluded)

Site Number	Date	Depth (m)	Temperature (C)	% Saturation Dissolved Oxygen	Dissolved Oxygen (mg/L)	Conductivity (u S/cm)	pH	ORP
Site 11 is located in Polar Bay								
11	4/25/2013	1	-0.22	15.2	2.17	150.9	5.56	328
		2	0.21	15.9	2.23	161.7	5.77	331
		3	0.14	11.4	1.6	191.9	4.5	333
		4	0.38	9.8	1.37	192.6	3	333
		5	0.55	9.2	1.28	191.1	4.1	333
		6	0.92	9.2	1.27	187.6	2.55	334
		7	1.78	1.4	0.18	209.8		337
		7.3	2.19	0.6	0.09	236.2		331
Site 7 is located in lower Last Chance Bay								
7	4/25/2013	1	-0.19	15.6	2.22	80.6	4.9	356
		2	0.01	7.7	1.09	93.2	5.28	357
		3	0.17	2.2	0.31	110.5	5.44	357
		4	0.67	1.5	0.2	123.5	5.24	320

NOTE: The pH meter malfunctioned at Sites 3 and 11.

Appendix 3. Arctic Grayling Population Estimates in the WSR.

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
2004[4]	200	6,614	5,808-7,420
2005[4]	200	7,926	6,759-9,094
2006[4]	200	5,930	5,382-6,478
2007[4]	200	4,027	3,620-4,433
2008[4]	200	3,545	3,191-3,900
2009[4]	200	3,223	2,896-3,550
2010[4]	200	4,346	3,870-4,823
2011[4]	200	7,378	6,616-8,141
2012[4]	200	7,404	6,775-8,033

[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 2012 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. Arctic Grayling Growth in the WSR.

2012 to 2013 growth grayling (n=239)			
Upper Limit (mm) and Sample Size	Average (mm)	Maximum (mm)	Minimum (mm)
210 (n=5)	29	34	21
220 (n=7)	28	34	16
230 (n=6)	25	34	15
240 (n=18)	14	24	0
250 (n=42)	12	25	4
260 (n=80)	11	43	0
270 (n=74)	9	17	0
280 (n=43)	9	24	0
290 (n=31)	7	20	2
300 (n=6)	6	11	2
310 (n=6)	2	9	0
320 (n=5)	0	2	0
330 (n=3)	1	3	0
340 (n=2)	2	2	2
350 (n=1)	0	0	0

	≤ 250 mm	>250 mm			
Upper Limit (mm) and Sample Size	Average (mm)	Average (mm)	Year	Population Size	Fish > 250 mm
210 to 250 (n=15)	10		1994	4,358	
210 to 250 (n=3)	15		1995	4,358	
210 to 250 (n=9)	28	25	1998	5,800	1998 (n=22)
210 to 250 (n=10)	33	18	1999	4,123	1999 (n=131)
210 to 250 (n=0)		14	2000	5,326	2000 (n=47)
210 to 250 (n=154)	33	7	2001	5,623	2001 (n=142)
210 to 250 (n=119)	31	12	2002	6,503	2002 (n=188)
210 to 250 (n=135)	15	6	2003	6,495	2003 (n=83)
210 to 250 (n=135)	15	6	2004	6,614	2004 (n=76)
210 to 250 (n=81)	23	11	2005	7,926	2005 (n=51)
210 to 250 (n=144)	24	16	2006	5,930	2006 (n=130)
210 to 250 (n=27)	25	19	2007	4,027	2007 (n=178)
210 to 250 (n=29)	49	23	2008	3,545	2008 (n=180)
210 to 250 (n=5)	29	14	2009	3,223	2009 (n=209)
210 to 250 (n=48)	31	6	2010	4,346	2010 (n=148)
200 to 250 (n=124)	25	14	2011	7,378	2011 (n=115)