Technical Report No. 17-10

Fish and Water Quality Monitoring at the Fort Knox Mine, 2017

by

Alvin G. Ott and Parker T. Bradley

December 2017

Alaska Department of Fish and Game Division of Habitat

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Habitat, Sport Fish, and Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, Technical Reports and Special Publications. 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)

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

TECHNICAL REPORT NO. 17-10

FISH AND WATER QUALITY MONITORING AT THE FORT KNOX MINE, 2017

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December, 2017

Cover: Fyke Net in the Developed Wetlands, May 1, 2017. Drone Photograph by Parker T. Bradley

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Acknowledgements

We thank Fairbanks Gold Mining Inc. (FGMI) (Bartly Kleven, Mark Huffington, Jennifer Pyecha, 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. Audra Brase provided a considerable number of suggestions and edits to this report.

Executive Summary

Water Quality

●Dissolved oxygen (DO) concentrations were measured in mid-April 2017 and for the third consecutive year DO concentrations were some of the highest seen since sampling began in 1998. Higher DO concentrations appear to be directly related to the discharge of non-contact mine water to the water supply reservoir (WSR).

Arctic Grayling in the Water Supply Reservoir

●Sampling for Arctic Graying was conducted from May 1-18, 2017 as the fish moved from the WSR to the developed wetlands. Spawning began around May 11 when peak water temperatures reached 3.9 ºC and by May 16, 96% of the females handled were spent. Ripe females continued to enter the wetland complex from the WSR at the close of the sampling event.

●Substantial recruitment of Arctic grayling was observed in spring 2017, 406 fish between 200 and 245 mm FL were newly captured and tagged.

●The spring 2016 population estimate for Arctic grayling $\geq$ 200 mm FL was 4,396 fish (95% CI 3,912 to 4,880 fish).

Burbot in the Water Supply Reservoir

●Sampling for burbot was conducted during the Arctic grayling sampling event (May 1-18, 2017) and again from September 26 to October 2. During the two sampling events, 120 burbot were captured in the developed wetlands and WSR. These fish ranged in size from 135 to 900 mm TL. Thirty five of the captured burbot were ≥ 400 mm TL and eight had been previously captured in the 2016 sampling events.

●The spring/fall 2016 population estimate of burbot ($\geq$ 400 mm TL) was 119 fish (95% CI 65-173).

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, tailings 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 tailings pond. In 2017, ore continued to be processed through the mill as well as through the Walter Creek valley fill heap leach. Exploration drilling continued in the vicinity of the existing open pit.

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

Rehabilitation of the disturbed habitats has been concurrent with mining activities, to the extent practicable, and natural revegetation of some areas has been rapid (Figure 2).

Figure 2. Pond F outlet channel in 2000 (left photo) and in 2010 (right photo).

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 in certain years when large amounts are removed (Table 1). In late April 2017 there was surface flow over the spillway (Figure 3). No removal of water during winter (October 1 to April 30) occurred in 2016/2017.

Figure 3. Spillway in water supply reservoir in late April, 2017.

In spring 2015, FGMI initiated a discharge of non-contact water from dewatering wells around the open pit. The discharge was authorized by a permit issued by the Alaska Department of

Environmental Conservation. The discharge began in mid-March and has been continuous except for periodic shutdowns. The discharge water appears to increase the dissolved oxygen concentrations in the WSR in late winter. From October 1, 2016 to April 30, 2017, the total discharge was 477.5 acre feet of water from Outfall 001.

Table 1. Winter (October 1 to April 30) water use from the WSR, 1997 to 2017.

Year (October 1 to April 30)		Acre-Feet of Water Removed		Percent of Water Removed
1997/1998		660		19.6
1998/1999		605		18.0
1999/2000		577		17.2
2000/2001		1,464		43.5
2001/2002		320		9.5
2002/2003		337		10.0
2003/2004		279		8.3
2004/2005		716		21.3
2005/2006		659		19.6
2006/2007		299		8.9
2007/2008		1,176		35.0
2008/2009		817		24.3
2009/2010		1,167		34.7
2010/2011		187		5.6
2011/2012		59		1.8
2012/2013		1,837		54.6
2013/2014		1,399		41.6
2014/2015		104		3.1
2015/2016		0		0
2016/2017		0		0

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 tailings 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.

Fish monitoring has been performed annually at the Fort Knox mine and related facilities since 1992 and water quality sampling since 1997. This report summarizes fish and water quality data collected during 2017 and discusses these findings in relation to previous work. A chronology of events from 2011 to 2017 with emphasis on biological factors is presented in Appendix 1. The chronology for previous years (1992 to 2010) can be found in ADF&G Technical Report No. 10-5, *Arctic grayling and burbot studies at the Fort Knox Mine, 2010* (Ott and Morris, 2010). A references section following the literature cited section in this report contains a listing of all ADF&G/ADNR technical reports for Fort Knox.

Methods

Water Quality

In 2017, water quality sampling was conducted on April 12 and 19 when the WSR was ice covered (Figure 4). Temperature (^oC), 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.

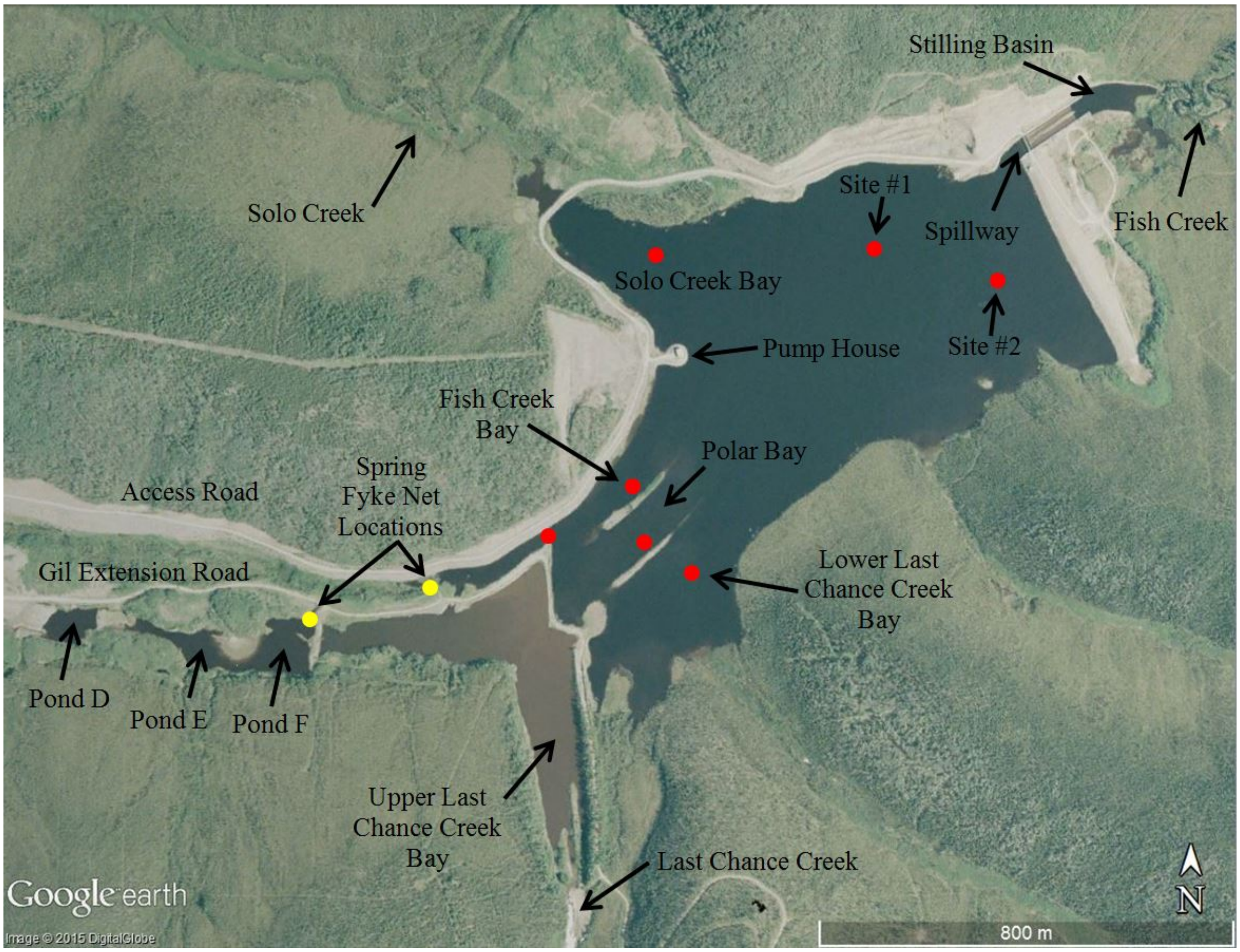


Figure 4. Map of Fort Knox Water Supply Reservoir water quality sample sites, April 12 and 19, 2017 and spring 2017 fyke net sites.

Fish

Fish sampling methods included visual observations, fyke nets, angling, and hoop traps. Two fyke nets were set in the developed wetlands (Figure 4). On May 1, 2017, a fyke net was set in the lower end of the Fish Creek channel. A second fyke net was set in Pond F outlet on May 5. Fyke nets were checked every day to every other day until both nets were pulled on May 18. Initially, fish from both nets were counted and processed. However, when catches increased in the lower net, fish from the upper net were released.

Burbot were caught in the fyke nets and in hoop traps baited with herring in the WSR. Seventeen hoop traps were used to capture burbot in the fall (September 26 to October 2, 2017).

Arctic grayling were measured to fork length (nearest mm), inspected for tags and spawning condition, and released. Burbot were measured to total length (nearest mm), inspected for tags, and released. Un-tagged Arctic grayling ≥ 200 mm and burbot ≥ 300 mm were marked with a numbered Floy® T-bar internal anchor tag. Abundance of Arctic grayling and burbot was estimated using Chapman's modification of the Lincoln-Petersen two-sample mark-recapture model (Chapman 1951) and variance was estimated (Seber 1982).

On May 12, Arctic grayling from the lower fyke net were retained for gamete samples. Fifteen females were sampled and eggs retained and eight of the females were sacrificed for selenium analyses. Sperm samples were collected from 10 males. Gamete samples from male and female fish were kept in separate sample containers. Gamete samples were transported back to Fairbanks where the sperm was checked for motility, the eggs dry fertilized, and the eggs allowed to water harden before transport from Fairbanks to a facility in Canada. This work was done as part of a larger study assessing effects of various selenium concentrations in Arctic grayling ovaries on fry development. Selenium concentrations are low in ovaries from Arctic grayling at Ft. Knox (Ott et al. 2016). These data will be compared to other regions of the state that have higher concentrations. This work was done in collaboration with Owl Ridge Natural Resources, Inc.

Results and Discussion

Water Supply Reservoir, Water Quality

Water quality data were collected prior to breakup on April 12 and 19, 2017 (Appendix 2). All sites were done on April 12 and Solo Bay was redone on April 19. 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 Site 2, which had a couple of inches of overflow. Water temperature ranged from 0.11 ºC to 2.02 ºC and steadily increased with depth (Figure 5).

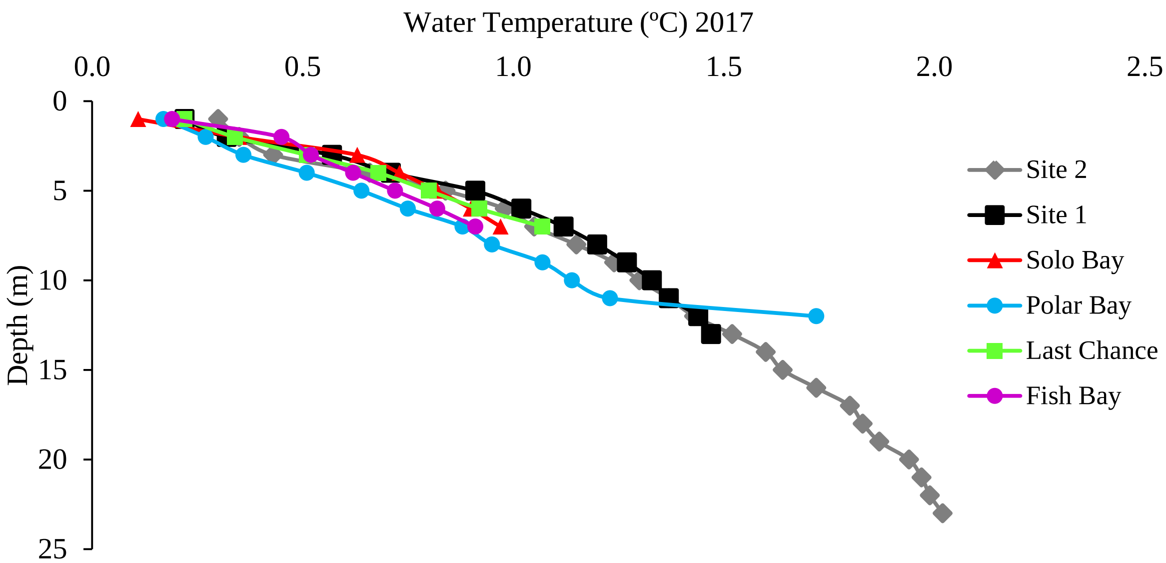


Figure 5. WSR water temperature profiles, April 2017.

Dissolved oxygen concentrations at all sites were higher relative to other years prior to discharge, particularly in the top two meters at Fish Creek Bay (Figure 6). Fish Bay had the highest DO concentration for the third year in a row averaging 7.38 mg/L followed by Polar Bay at 5.99 mg/L. Similar results for DO were found in 2015 and 2016, and it was determined the elevated DO concentrations were likely a result of the non-contact groundwater discharge that began in March 2015. This discharge continued for the duration of winter 2015/2016, and also the winter of 2016/2017, except for one week in late February/early March 2017 resulting in DO concentrations slightly higher than April 2015 values, particularly at depth. For example, at Site 2 in 2015, DO concentrations above 4 mg/L were maintained to about 7 m in depth while in 2016 and 2017, DO above 4 mg/L was maintained to 12 m and 14 m in depth, respectively. At all locations, DO generally decreased with depth. Temperature specific DO saturation followed the same pattern as DO concentrations with exceptionally high levels in the Fish Bay near where Fish Creek enters the upper WSR (Figure 7).

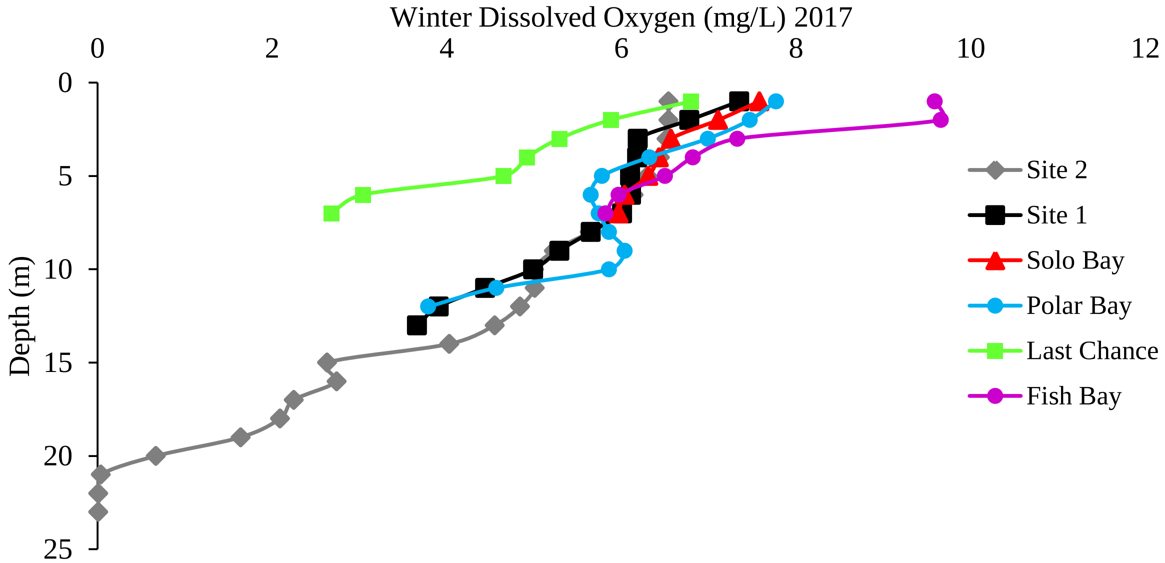


Figure 6. WSR dissolved oxygen (mg/L) profiles, April 2017.

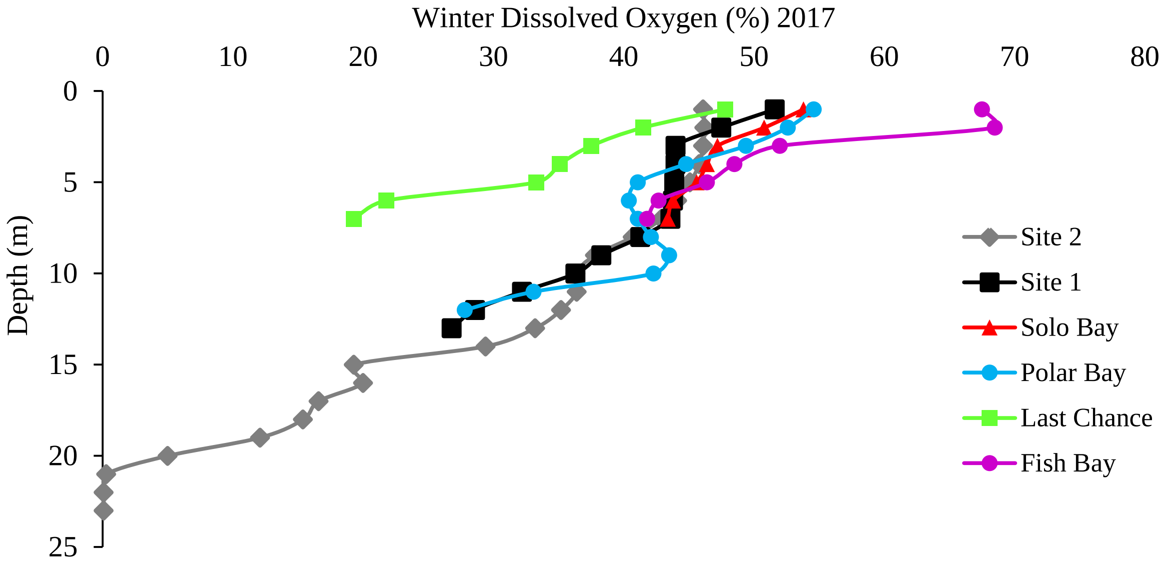


Figure 7. WSR dissolved oxygen percent saturation (%) profiles, April 2017.

The DO concentrations in late winter of 2015, 2016, and 2017 were much higher than those recorded in 2013 (Figure 8). The increase in DO concentrations probably is due to the discharge of non-contact water to the Fish Creek valley upstream of the WSR (Figure 9).

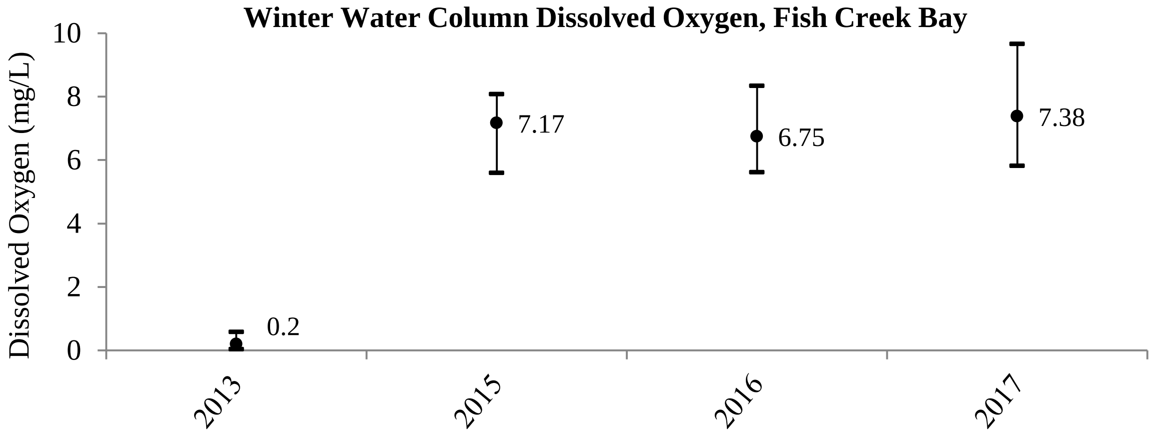
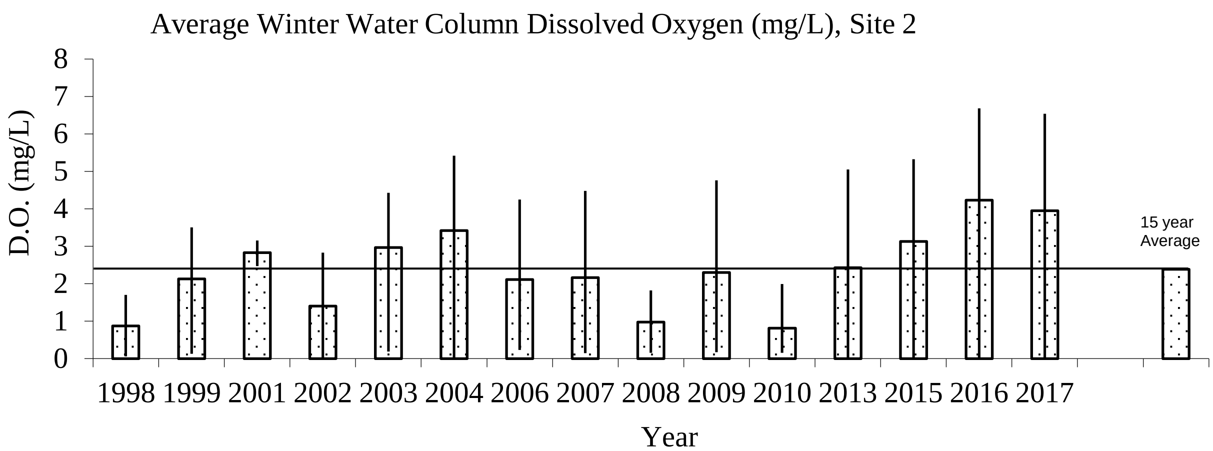


Figure 8. Winter water column dissolved oxygen.

Figure 9. Discharge point for non-contact water from dewatering wells around the Fort Knox open pit.

Average winter water column DO at Site 2 was above the 15 year running average for the third year in a row and the second highest on record, behind 2016 (Figure 10). This is likely a result of the continual discharge of non-contact ground water into the Fish Creek Valley about 1.6 km upstream from Pond F outlet.



Error bars are below ice maximum and minimum water column D.O.

Figure 10. Average, maximum, and minimum late winter water column DO concentrations at Site 2 in the WSR, 1998-2017 (excluding 2000, 2011, 2012, and 2014).

At all sites, pH initially increased with depth before stabilizing or slightly decreasing (Figure 11).

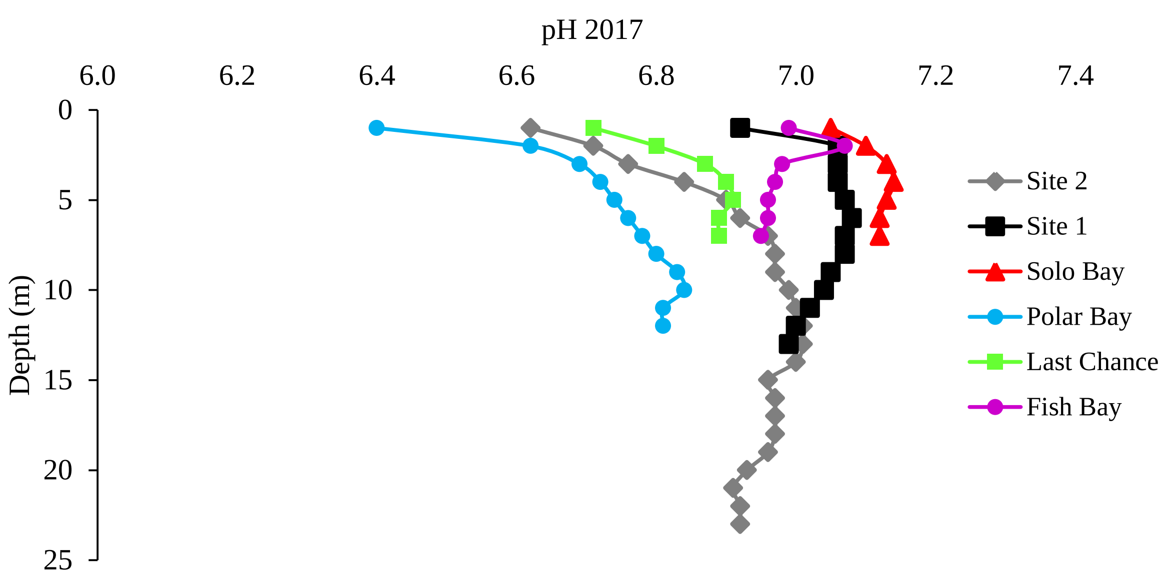


Figure 11. WSR pH profiles, April 2017.

Specific conductance was similar among the sites throughout most of the reservoir (Figure 12). Values were relatively similar throughout the water column, except for site 2 where values began to increase below 13 m.

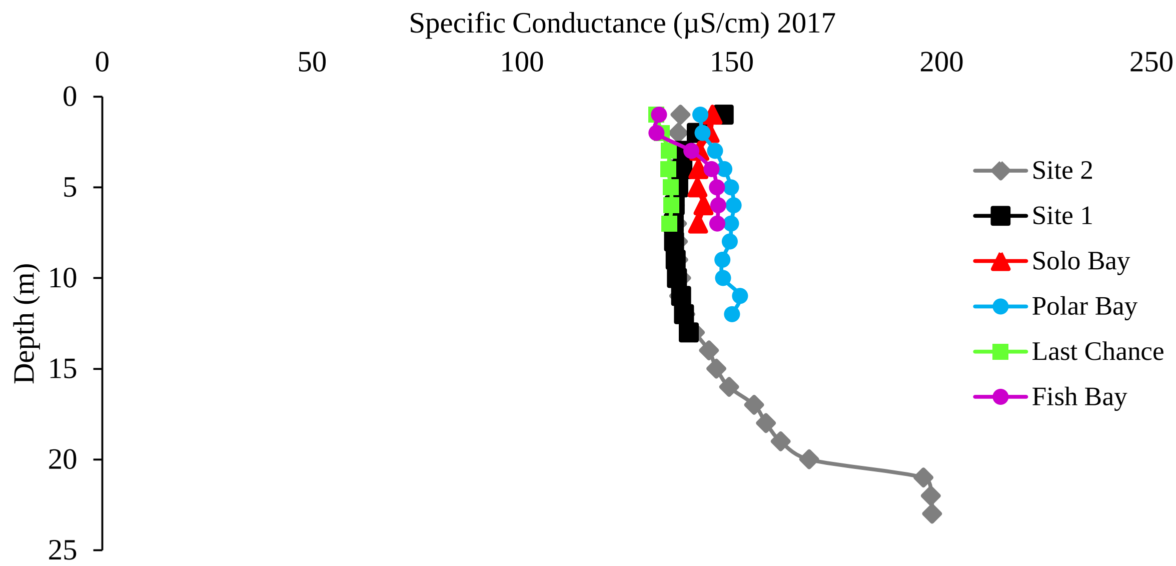


Figure 12. WSR specific conductance (µS/cm) profiles, April 2017.

Oxidation reduction potential was highest in Last Chance and Polar Bay, and lowest at Solo Bay (Figure 13). Values were fairly uniform throughout the water column, except for Site 2, where ORP began to decrease below 19 m as water became anoxic.

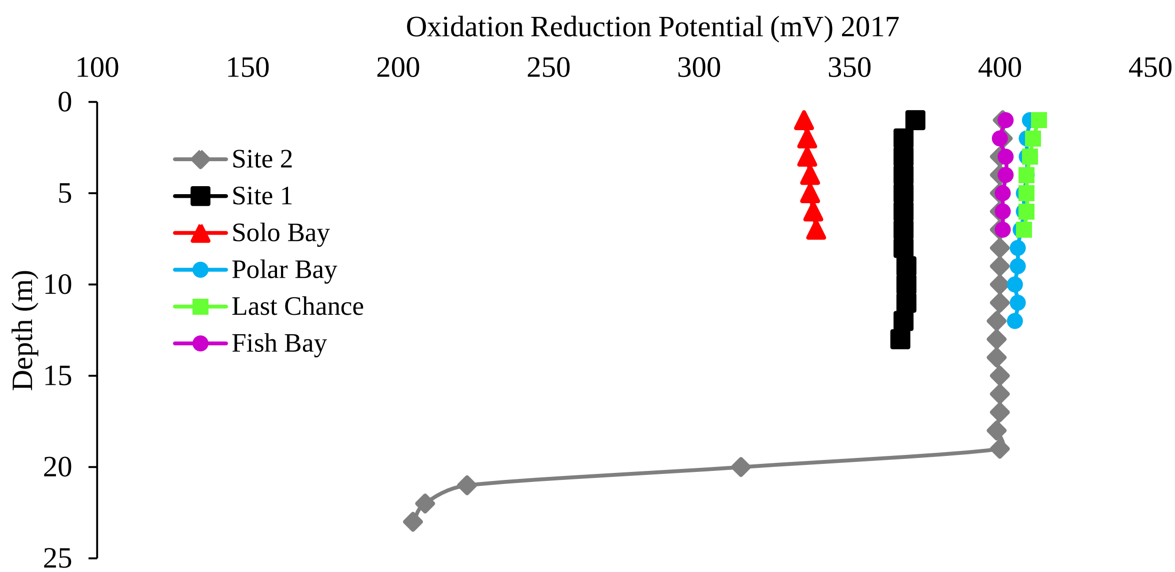


Figure 13. WSR oxidation reduction potential (mV) profiles, April 2017.

At some point this winter, the non-contact groundwater discharge began crossing the access road down the middle of the Fish Creek valley and flowed into the wetland complex. At the point of crossing, there was substantial ice build-up over the road, along with a large hole in the ice over the road. While there was standing water in the road, we did not observe any flowing water. It appeared that the non-contact groundwater discharge had changed course and rather than flowing across the road at this location, it was currently crossing the road at another location, going subsurface, or was perhaps flowing back in the old Fish Creek channel. Later in the spring, we determined that flow was back into the Fish Creek channel.

Stilling Basin, Arctic Grayling

The stilling basin, located immediately downstream of the WSR spillway is fed by groundwater, seepage flow, and surface flow. A 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 2017, water was flowing over the spillway. Fish sampling in the stilling basin was not conducted during summer 2017.

Water Supply Reservoir, Arctic Grayling

Arctic grayling were found throughout the Fish Creek drainage prior to construction of the WSR. However, 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 this spawning habitat. Since flooding of the WSR, aufeis in Last Chance Creek has been substantial. Since 1998, successful spawning by Arctic grayling in Last Chance Creek has only been observed in 2004 and 2005.

Very few fry were captured or observed (< 10 fish) from 1996 through 1998 in the WSR and Last Chance Creek. In spring 1999, FGMI constructed an outlet channel to connect the developed wetland complex with the WSR (Figure 14). The outlet channel was constructed to bypass a perched pipe and provide fish access to potential spawning and rearing habitat in the wetland complex.

Figure 14. Pond F outlet channel in 2000 (left photo) and in 2010 (right photo).

Arctic grayling have successfully spawned in the wetland complex every year since 1999. However, in 2002, 2006, and 2007, substantial aufeis and resultant cold water temperatures in the wetland complex, in addition to beaver dams, limited the availability of, and access to, spawning habitat. In recent years, aufeis buildup has been relatively minor and more effective beaver management has been implemented.

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

In 2017, aufeis in the wetland complex was minimal and while beaver dams in Pond D outlet and in the lower wetland complex had been rebuilt, they were breached to allow fish passage. Arctic grayling had access to the wetland complex (Ponds E and F), but access was blocked by a natural barrier that had formed in the channel connecting Ponds D and E (Figure 15).

Figure 15. A hydraulic jump (about 1 m) formed in the channel connecting Ponds D and E that was a complete barrier to the upstream movement of fish.

Initially, fish from both nets were counted and processed. However, when catches increased in the lower net, fish from the upper net were released. About 100 Arctic grayling from this fyke net were moved and released in Pond D above the hydraulic jump.

Fish were caught immediately after the fyke nets were set. Most of the fish caught were Arctic grayling and, except for angling on May 3 and 4, all fish were caught with the fyke nets. The Arctic grayling catch per unit of effort (CPUE) was low during the first days of sampling and may have been artificially low due to holes in the fyke net. Once the nets were repaired, reset and totally submerged, the CPUE increased. The CPUE reached a high of 6.76 Arctic grayling per hour on May 13, and then steadily declined until the nets were pulled on May 18 (Figure 16).

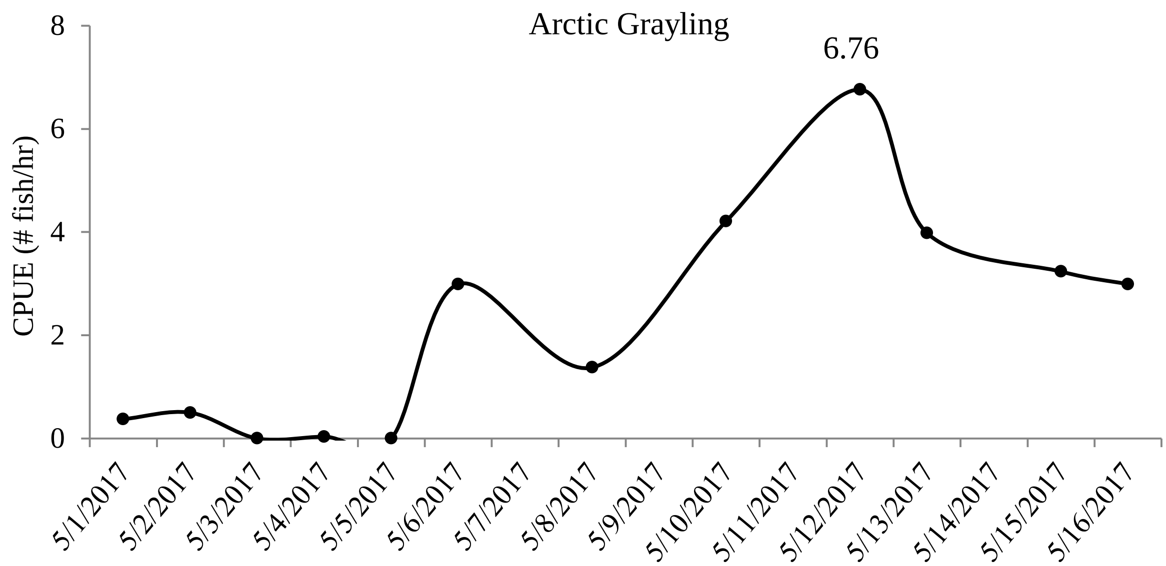


Figure 16. The catch per unit of effort of Arctic grayling (# of fish/hr) in the lower fyke net in the developed wetlands, 2017.

Peak daily water temperatures in Pond F outlet reached above 4°C on May 12, the same day that we successfully collected mature gametes from male and female Arctic grayling (Figure 17). Peak water temperatures continued to increase steadily through May 16. Based on the condition of fish in the fyke net, a high percentage of the females were spent, but on the last sample day (May 18), a number of new ripe females were captured (Figure 18), which was similar to previous years, when new ripe females continue to enter the wetland complex at the end of our sampling effort.

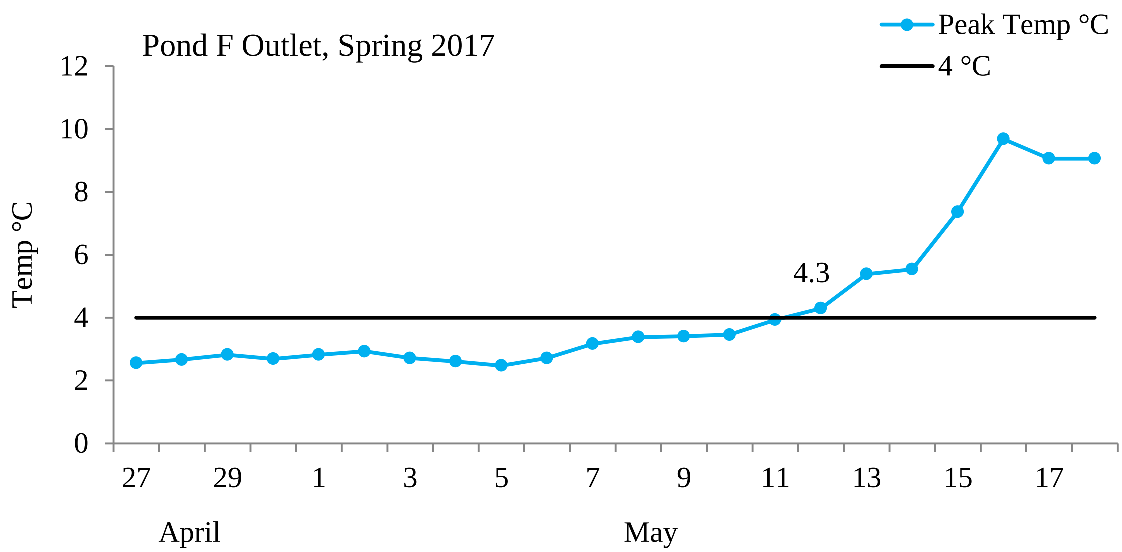


Figure 17. Peak daily water temperatures in Pond F outlet channel in spring 2017.

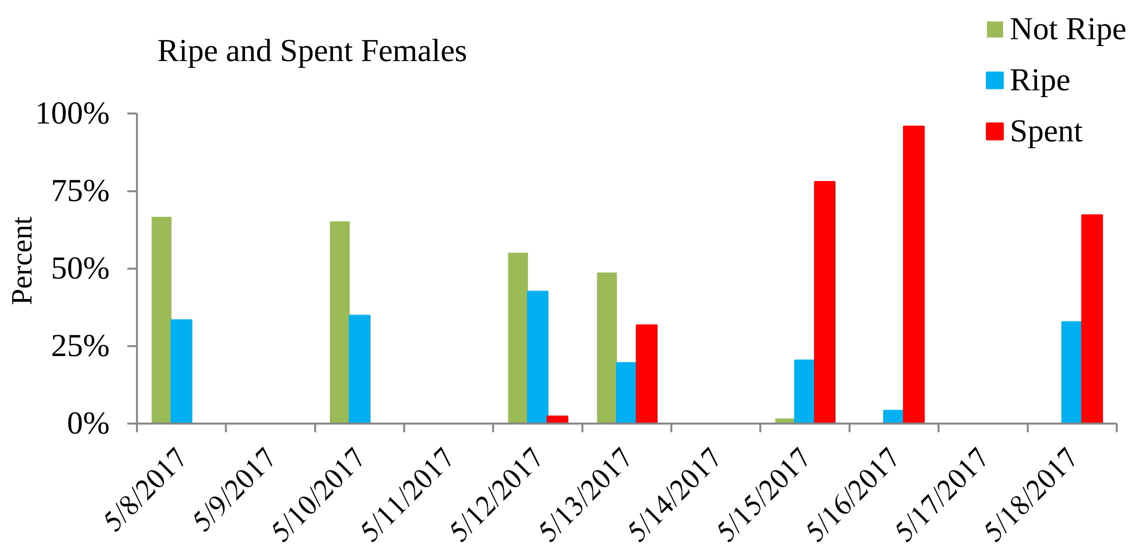


Figure 18. The percent of the Arctic grayling females handled that were categorized as: not ripe, ripe, or spent; 2017.

Spring water temperatures in Pond F outlet from 2010 to 2017 are presented in Figure 19. The warmest spring occurred in 2016, while 2013 was the coldest. The difference in spawning time between 2013 and 2016 was almost a full month.

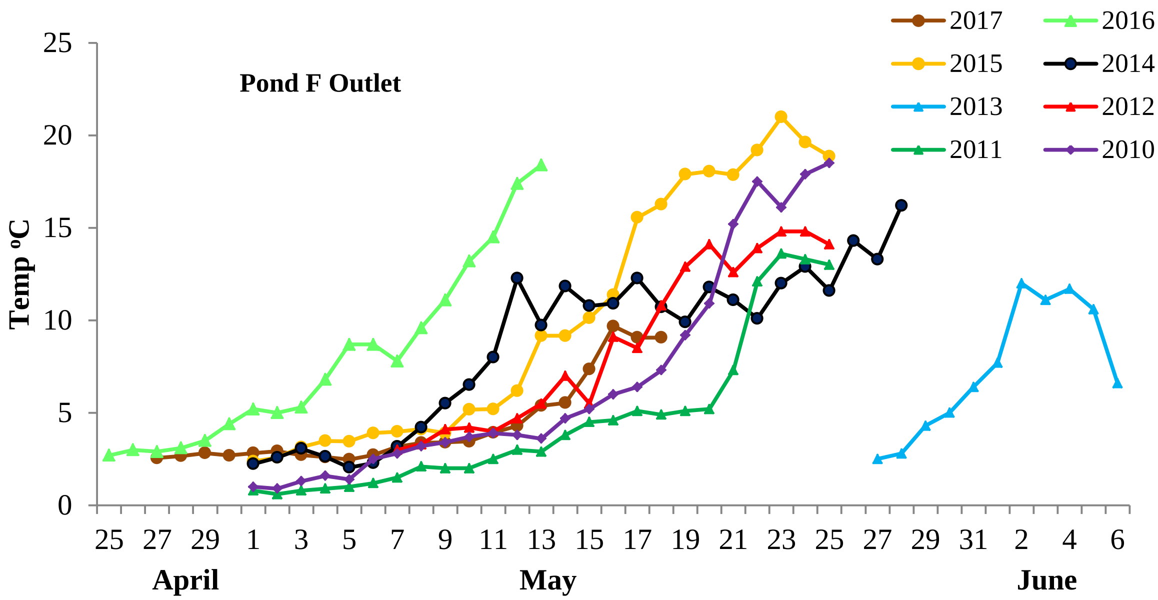


Figure 19. Peak daily water temperatures in Pond F outlet channel in spring 2010 to 2017.

On June 29, we caught three Arctic grayling fry (36, 38, and 40 mm), in the channel connecting Pond D and E with drift nets (Figure 20). These catches confirmed that the Arctic grayling that we moved from Pond F had successfully spawned in the wetland complex above the fish barrier (Figure 15).

Figure 20. Arctic grayling fry captured June 29, 2017 between Pond D and E.

Arctic Grayling Catches and Metrics

The abundance of Arctic grayling was estimated in the WSR using spring 2016 as the mark event and spring 2017 as the recapture event. In spring 2016, there were 1,138 marks when newly tagged and recaptured fish were combined. In spring 2017, 748 Arctic grayling ≥ 245 mm were captured, and of those, 193 were recaptures. For the 2016 estimated Arctic grayling population, length frequency distributions from 2016 and 2017 were compared to eliminate those fish handled in 2017 that would have been too small (< 200 mm) to mark in spring 2016. We had 406 fish caught that were < 245 mm long and these fish were not included in the population estimate.

The spring 2016 population estimate for Arctic grayling ≥ 200 mm long was 4,396 fish (95% CI 3,913 to 4,880 fish) (Figure 21 and Appendix 3). The population has been relatively stable since 2012 and then has slowly declined. The large number of new fish handled in spring 2017 likely indicates a shift to a higher population number.

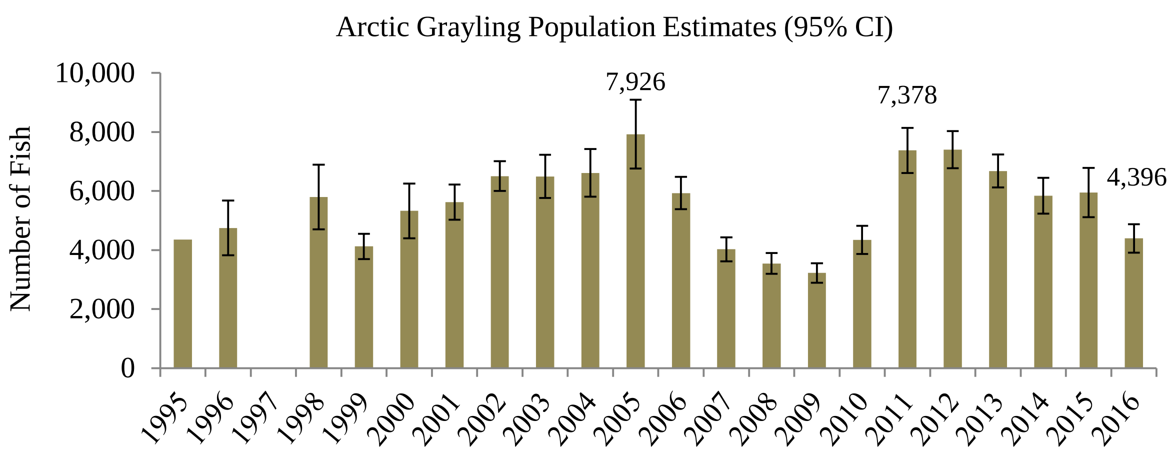


Figure 21. Estimates of the Arctic grayling population (fish ≥200 mm) in the WSR, with 95% Confidence Intervals, 1995-2016.

Substantial recruitment events were observed in the spring of 2004, 2010, 2014, and 2017 (Figure 22). A substantial recruitment event was defined as >300 fish encountered during a recapture sampling event that were not available for tagging based on size during the mark sampling event (typically fish between 200 and 240 mm).

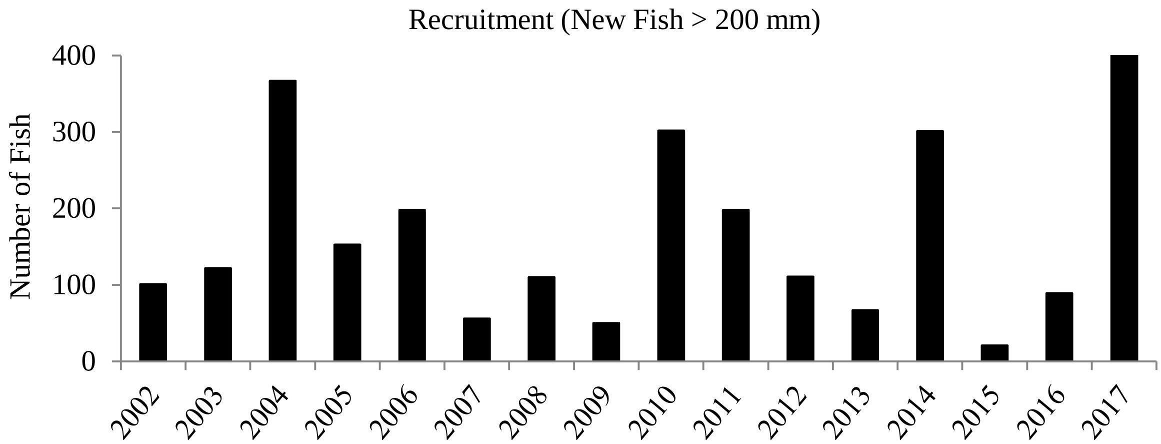


Figure 22. Number of new fish ≥ 200 mm that entered the population but would have been too small to mark in the previous year (based on growth of marked fish), 2002-2017.

The length frequency distribution of Arctic grayling captured in 2017 by angling and with a fyke net is presented in Figure 23. The fyke net is set in the spring at the mouth of the creek to target mature Arctic grayling moving upstream to spawning habitats. Thus the catch of small fish (i.e., non-spawners) in some years is low and may not be representative of how many small fish are present in the WSR. The length frequency distribution of Arctic grayling in 1995 also is presented in Figure 23 for comparison. The 1995 data set were obtained before construction of the freshwater dam and reflects the stunted condition of the population at that time. The current population is composed of much larger fish.

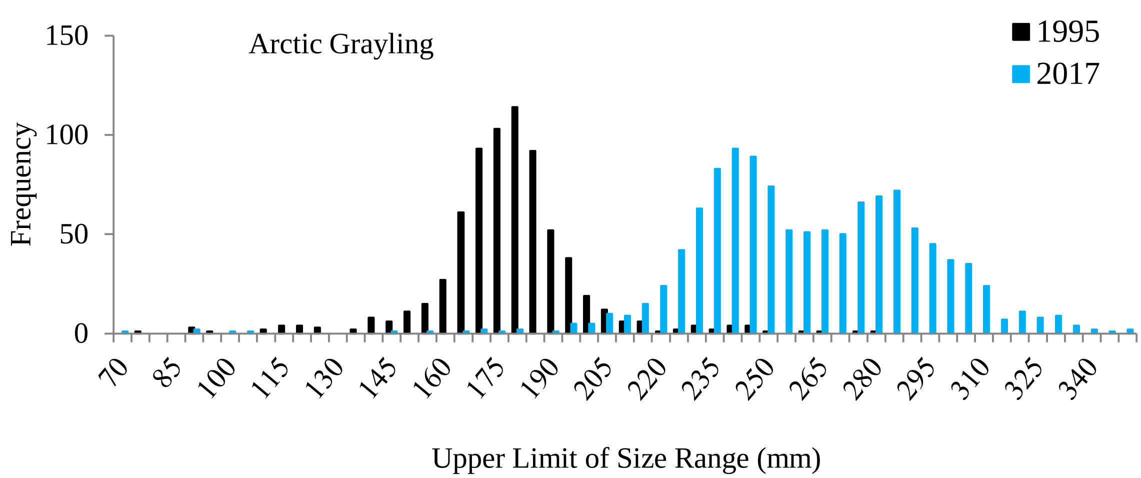


Figure 23. Length frequency distribution of Arctic grayling in 1995 and in 2017.

Average growth of Arctic grayling prior to development of the WSR ranged from 3 to 17 mm per year (Figure 24 and Appendix 4). After the WSR was flooded in 1995, annual growth for fish increased substantially. Average growth in summer 2014 was highest.

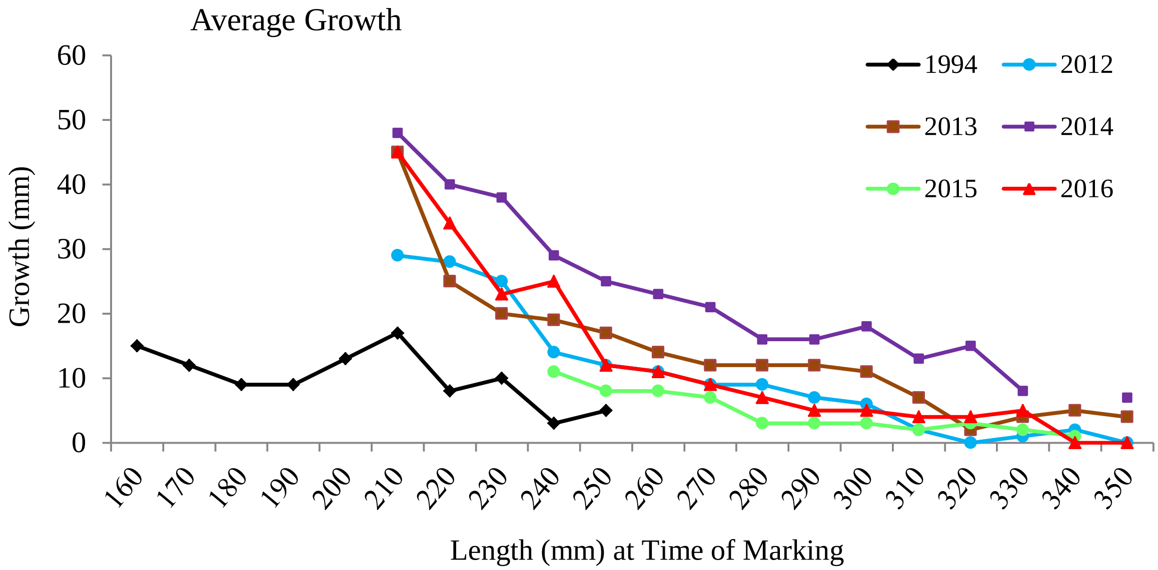


Figure 24. Average growth of marked Arctic grayling before the WSR (1995) and in summers 2012, 2013, 2014, 2015, and 2016.

Water Supply Reservoir, Burbot

In spring 2017, burbot were caught in fyke nets in the wetlands and in fall with hoop traps (n = 120) in the WSR. Ninety six of the burbot were caught in the hoop traps. Burbot ranged in size from 135 to 900 mm with an average length of 359 mm (Figure 25).

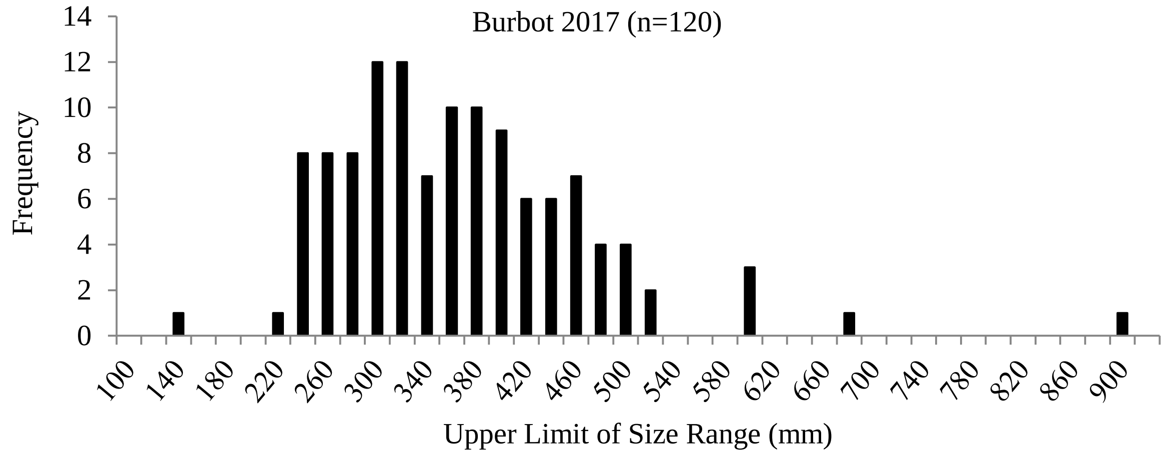


Figure 25. Length frequency of burbot in the WSR and developed wetlands, 2017.

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 26). Catches of smaller burbot were highest in 1998 (7.2 fish/day), but decreased quickly and have remained low.

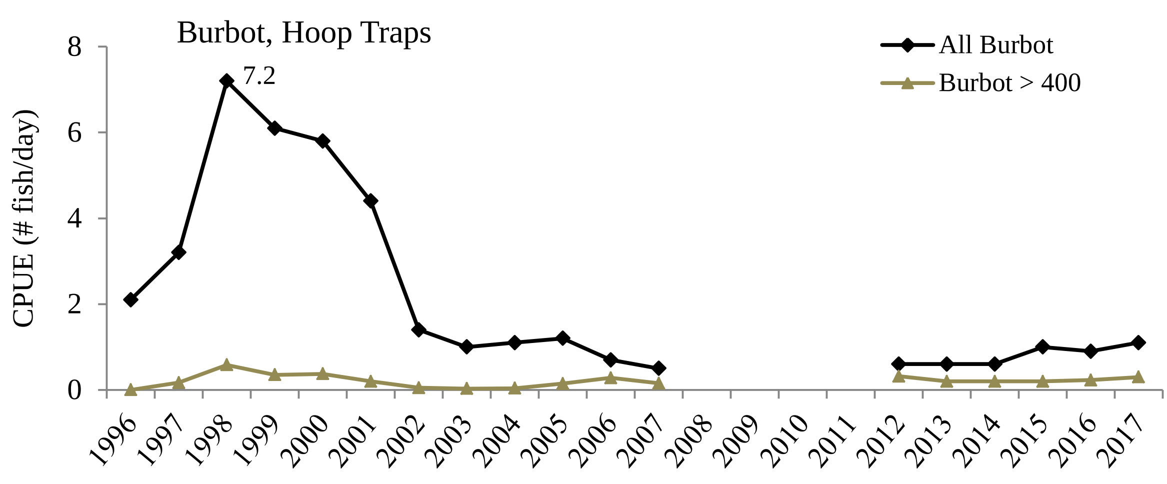


Figure 26. Catch per unit of effort (fish/trap day) of burbot in the WSR, 1996-2007 and 2012-2017.

Catches of large burbot (≥ 400 mm) followed a similar pattern with catches increasing after the WSR was flooded, decreasing the next several years, but have been stable the last six years (Figure 27).

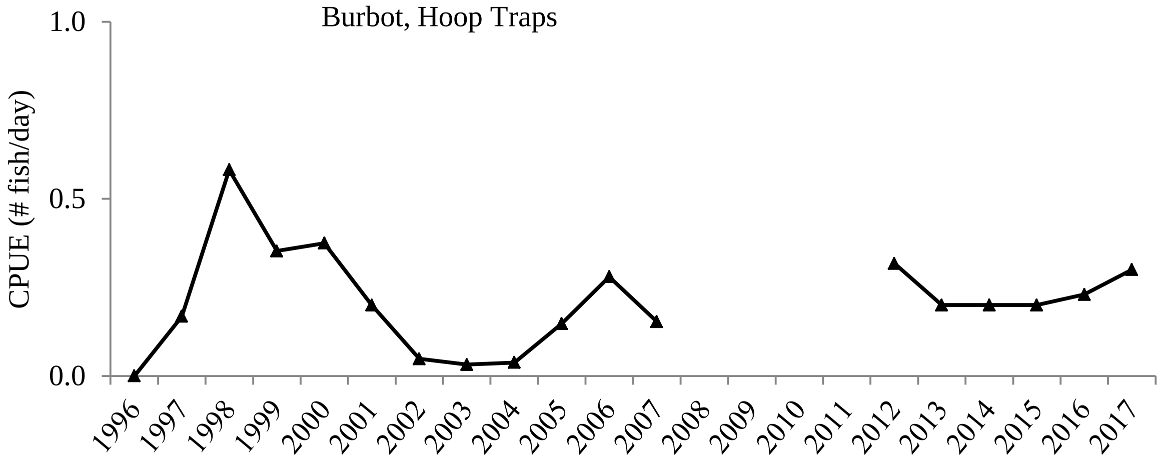


Figure 27. Catch per unit of effort (fish/trap day) of large burbot (≥400 mm) in the WSR, 1996-2007 and 2012-2017.

In spring and fall 2016, we marked or recaptured 29 burbot ≥ 400 mm. The number of burbot seen in spring and fall 2017 was 35, of which eight were recaptured fish seen in 2016. The estimated population of large burbot for summer 2016 was 119 fish (95% CI 65-173 fish) (Figure 28, Appendix 5).

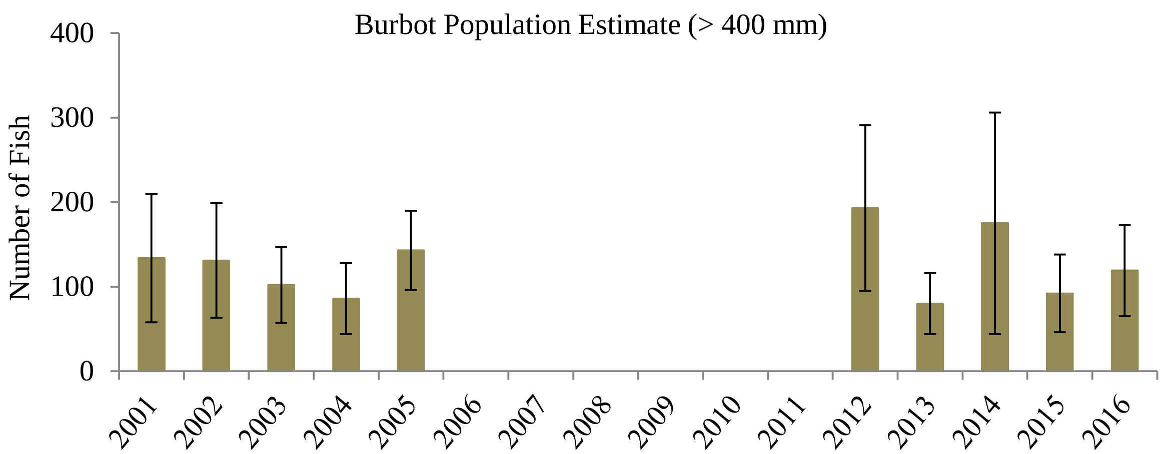


Figure 28. Burbot (≥400 mm) population estimates ± 95% CI in the WSR, 2001-2005 and 2012-2016.

Growth rates of burbot from 2000 to 2004 and from 2012 to 2016 are shown in Figure 29. Growth is from tagged fish (≥ 400 mm) marked or seen in the previous year and recaptured in the following year. Growth is highly variable and while the population appears stable, more large burbot were caught from 2000 to 2002 than from 2003 to 2016.

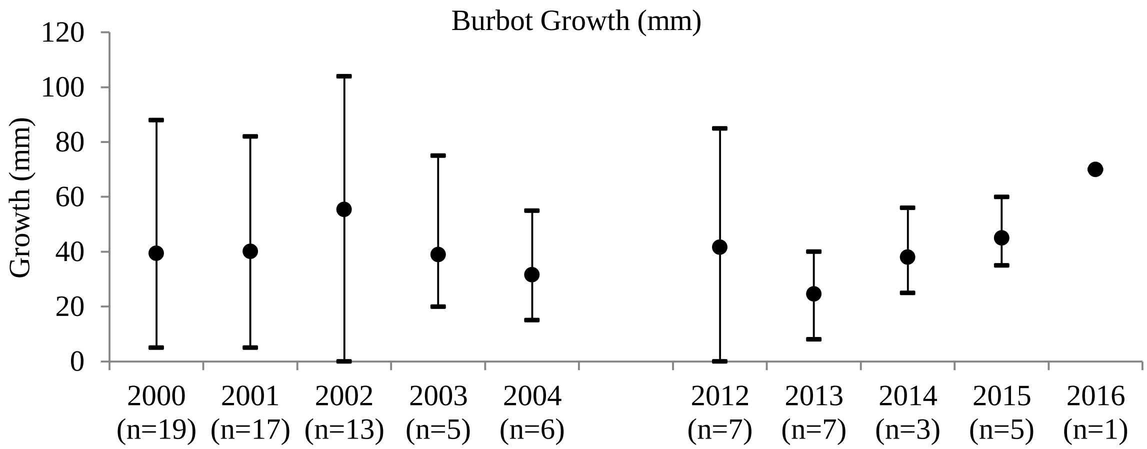


Figure 29. Growth (median, maximum, and minimum) of marked burbot (≥ 400 mm) in the WSR, 2000-2004 and 2012-2016.

Conclusion

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 . Our spring 2016 estimated population for Arctic grayling $\geq$ 200 mm was 4,396 fish which is a decrease from the estimated 2015 population. A goal for the burbot population was not set prior to construction, but a small population of fish larger than 400 mm is present in the WSR.

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 appears to remain a critical component to the productive capacity of the wetland complex for Arctic grayling.

Literature Cited

Chapman, D.G. 1951. Some practices of the hypergeometric distribution with applications to zoological censuses. University of California Publications in Statistics. 1:131-160.

Ott, A.G. and W.A. Morris. 2010. Arctic grayling and burbot studies at the Fort Knox mine, 2010. Alaska Department of Fish and Game Technical Report 10-05. Division of Habitat. Juneau.

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

Ott, A.G., H.L. Scannell, and P.T. Bradley. 2016. Aquatic biomonitoring at Red Dog Mine, 2015. Alaska Pollution Discharge Elimination System Permit No. AK00038652 (Modification #1). Alaska Department of Fish and Game Technical Report 16-01. Division of Habitat. Fairbanks.

References

Ott, A.G. and P.T. Bradley. 2016. Arctic grayling and burbot studies at the Fort Knox mine, 2016. Alaska Department of Fish and Game Technical Report 16-09. Division of Habitat. Fairbanks.

Ott, A.G., P.T. Bradley, and H.L. Scannell. 2015. Arctic grayling and burbot studies at the Fort Knox mine, 2015. Alaska Department of Fish and Game Technical Report 15-07. Division of Habitat. Juneau.

Ott, A.G., W.A. Morris, H.L. Scannell, and P.T. Bradley. 2014. Arctic grayling and burbot studies at the Fort Knox mine, 2014. Alaska Department of Fish and Game Technical Report 14-08. Division of Habitat. Juneau.

Ott, A.G., W.A. Morris, H.L. Scannell, and P.T. Bradley. 2013. Arctic grayling and burbot studies at the Fort Knox mine, 2013. Alaska Department of Fish and Game Technical Report 13-05. Division of Habitat. Juneau.

Ott, A.G., W.A. Morris, and H.L. Scannell. 2012. Arctic grayling and burbot studies at the Fort Knox mine, 2012. Alaska Department of Fish and Game Technical Report 12-09. Division of Habitat. Juneau.

Ott, A.G. and W.A. Morris. 2011. Arctic grayling and burbot studies at the Fort Knox mine, 2011. Alaska Department of Fish and Game Technical Report 10-06. Division of Habitat. Juneau.

Ott, A.G. and W.A. Morris. 2009a. Arctic grayling and burbot studies at the Fork Knox mine, 2009. Alaska Department of Fish and Game Technical Report 09-05. Division of Habitat. Juneau.

Ott, A.G. and W.A. Morris. 2009b. Arctic grayling and burbot studies at the Fork Knox mine, 2008. Alaska Department of Fish and Game Technical Report 09-01. Division of Habitat. Juneau.

Ott, A.G. and W.A. Morris. 2007. Arctic grayling and burbot studies at the Fork Knox mine, 2007. Alaska Department of Natural Resources Technical Report 07-01. Office of Habitat Management and Permitting. Juneau.

Ott, A.G. and W.A. Morris. 2006. Arctic grayling and burbot studies at the Fork Knox mine, 2006. Alaska Department of Natural Resources Technical Report 06-05. Office of Habitat Management and Permitting. Juneau.

Ott, A.G. and W.A. Morris. 2005b. Arctic grayling and burbot studies at the Fork Knox mine, 2005. Alaska Department of Natural Resources Technical Report 05-06. Office of Habitat Management and Permitting. Juneau.

Ott, A.G. and W.A. Morris. 2005a. Arctic grayling and burbot studies at the Fork Knox mine, 2004. Alaska Department of Natural Resources Technical Report 05-01. Office of Habitat Management and Permitting. Juneau.

Ott, A.G. and W.A. Morris. 2003. Arctic grayling and burbot studies at the Fork Knox mine, 2003. Alaska Department of Natural Resources Technical Report 03-09. Office of Habitat Management and Permitting. Juneau.

References (concluded)

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

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

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 Technical Report 01-2. Habitat and Restoration Division. Juneau.

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 Technical Report 00-1. Habitat and Restoration Division. Juneau.

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 Technical Report 99-2. Habitat and Restoration Division. Juneau.

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 Technical Report 98-1. Habitat and Restoration Division. Juneau.

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

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 Technical Report 96-5. Habitat and Restoration Division. Juneau.

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 Technical Report 95-4. Habitat and Restoration Division. Juneau.

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 Technical Report 94-5. Habitat and Restoration Division. Juneau.

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 Technical Report 93-4. Habitat and Restoration Division. Juneau.

Technical Reports summarizing field work can be found on the Alaska Department of Fish and Game, Division of Habitat Web Page:

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

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

2011

●February 9, 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).

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

●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.

●May 2, 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 – 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.

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

●July 19, 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.

●August 4, 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

●September 13, 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.

●September 28, 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.

●July 13, 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.

●September 27, 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

●February 20, FGMI received a Notice of Violation from the ACOE for the unauthorized discharge of fill material into 0.28 acres of wetlands.

●March 1, ADF&G informed FGMI that their 2012 Annual Report was extremely well done and FGMI's report was distributed to all habitat offices in the state.

●March 11, the ACOE issued an After-the-Fact authorization covering the 0.28 acres of wetland fill.

Appendix 1 (continued)

2013

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

●May 4, the ADNR transmitted comments on the December 2012 reclamation and closure plan.

●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.

●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.

●June 25, 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.

●October 14, ADF&G submitted comments on the Fort Knox 2013 reclamation plan – eight recommendations were made.

●November 27, ADF&G distributed the Fork Knox technical report for work done in 2013.

2014

●in early April emails were exchanged to determine when Fish Creek was removed from the list of impaired waterbodies – it was listed on the 1992 list but was removed from the 1994 listing because FGMI had bought out all the existing placer operations and was planning on building the freshwater dam.

●April, 2014, the decision was made to not collect winter water quality due to unsafe ice conditions and overflow.

●in spring 2014, we fished a fyke net in the developed wetlands just upstream of the WSR from April 29 until May 9 and then again from May 12 to 15. Arctic grayling spawned throughout the wetland complex in spring 2014 –the only beaver dam present was in the upper end of C Channel.

●Our estimated population of Arctic grayling (> 200 mm) for spring 2013 was 6,675 – a slight reduction from the 2011 and 2012 estimates.

●Our estimated population of large burbot ($\geq$ 400 mm) for spring 2013 was 80 – a substantial reduction from the spring 2012 estimate of 193.

●September 29, FGMI notified state agencies that the new Environmental Manager was Bartly Kleven.

Appendix 1 (continued)

2014

●September 4, we were notified that the road across Solo Creek had failed – FGMI will determine a proper fix – this is the second time the road has failed at the culvert crossing.
●September 26, the developed wetlands and lower Last Chance Creek were inspected, no beaver dams were observed in Ponds D and F and in lower Last Chance Creek (dams had been removed by FGMI during summer).
●October FGMI and ADFG discussed a draft design for the Solo Creek culvert replacement, conducted a field inspection, and are continuing discussions to decide what remedial work will be done.
●October 28, ADF&G distributed the Fork Knox technical report for work done in 2014.
●November 12, FGMI submitted a permit application to replace the Solo Creek culvert. ADF&G had several questions regarding the culvert design specifications and FGMI addressed these questions and a permit was issued on November 20, 2014 to install the new 10 foot diameter pipe.

2015

●March 2, we conducted a field visit to observe the discharge point for non-contact mine water to the old Fish Creek channel which except for breakup and periods of heavy rain is dry.
●FGMI initiated the discharge of non-contact water (about 250 gallons per minute) in mid-March and the discharge has been continuous except for a few shutdowns. The discharge was authorized by a permit issued by the ADEC.
●April 8 and 9, we collected water quality data in the WSR which was ice covered, high DO concentrations were found in Fish Creek Bay.
●April 17, we collected water quality data in the old Fish Creek channel downstream from where the non-contact mine water was being discharged and found very high DOs in the water – leading us to conclude that the discharge of non-contact mine water resulted in increased DOs in the WSR.
●early May, we field inspected the culvert replacement in Solo Creek and concluded that it had been installed in accordance with the Fish Habitat Permit.
●spring 2015, we fished a fyke net in the developed wetlands just upstream of the WSR from May 4 to 8 and then again from May 10 to 13. Arctic grayling spawned throughout the wetland complex in spring 2015.
●our estimated population of Arctic grayling ($\geq$ 200 mm) for spring 2014 was 5,841 – a slight reduction from the 2011 and 2012 estimates.
●our estimated population of large burbot ($\geq$ 400 mm) for spring 2014 was 175 – a substantial increase from the spring 2013, but with a large 95% CI.
●June 19 and July 23, we collected Arctic grayling fry in the wetland complex, average size on June 19 was 29.7 mm and on July 23 it was 57.3 mm.

Appendix 1 (continued)

2015

●June 19, we inspected the Last Chance culvert in the Gil Causeway, material at the east end of the pipe has slumped and the road was blocked with cones and flagging.
●October 28, ADF&G distributed the Fork Knox technical report for work done in 2015.

2016

●March 29 and 31, water quality data were collected at six sites in the WSR, five of which have been sampled nearly annually since 1998. Average winter water column dissolved oxygen at Site 2 (middle of the WSR) was the highest on record and likely the result of the near continuous discharge of non-contact water into the old Fish Creek channel just upstream of the wetland complex.
●in spring 2016, we fished two fyke nets in the developed wetlands just upstream of the WSR and in Pond F from April 25 to May 4. Based on the fyke net catches, most of Arctic grayling spawned in the wetland complex downstream of Pond F.
●our estimated population of Arctic grayling ($\geq$ 200 mm) for spring 2015 was 5,947 – a slight increase from the 2014 estimate.
●our estimated population of large burbot ($\geq$ 400 mm) for spring 2015 was 92 - a substantial decrease from spring 2014.
●in early October hoop traps fished in the WSR captured 26 burbot ranging in size from 200 to 630 mm long.
●October 12, we met with ADEC and FGMI to discuss plans to design and install a new water treatment plant just downstream of the tailings dam with an estimated discharge of 2,000 to 6,000 gallons per minute.
●October 28, we were notified by FGMI that beaver dams at Pond D outlet and downstream of Pond F had been removed.
●December 21, ADF&G sent a summary of our meeting on the new water treatment plant to FGMI.

2017

●April 12 and 19, water quality data were collected at six sites in the WSR, five of which have been sampled nearly annually since 1998. Average winter water column dissolved oxygen at Site 2 (middle of the WSR) was above the 15 year running average and the second highest on record, behind 2016.
●in spring 2017, we fished two fyke nets in the developed wetlands just upstream of the WSR and in Pond F from early May to May 18. Based on the fyke net catches and observations most of Arctic grayling spawned in the wetland complex downstream of Pond F.
●about 100 Arctic grayling adults were moved from the Pond F fyke net and released into Pond D upstream of a barrier. These fish successfully spawned in Pond D as fry were captured on June 29.
●our estimated population of Arctic grayling ($\geq$ 200 mm) for spring 2016 was 4,396, a decrease of about 1,500 fish from the 2015.

Appendix 1 (concluded)

2017

- ●May 26, ADEC issued Waste Management Permit 2014DB002 (Modification #1).
- ●May 26, ADNR issued a permit amendment for the construction of the Barnes Creek heap leach.
- ●July 19, ADNR issued a Certificate of Approval to construct a dam for the Barnes Creek heap leach (#AK00315).
- ●October 12, a site visit was conducted to check on the status of beaver dams in the wetland complex that had been removed recently by FGMI.
- ●October 24, historic information was provided to FGMI on the status of Fish Creek and why it was taken off the impaired waterbody list in 1994.
- ●December 12, FGMI, ADF&G, ADNR, and ADEC met to discuss alternatives for tailings disposal, closure configuration for the tailing dam at elevation 1557, and a new water treatment plant.
- ●December 13, FGMI acquired a new parcel of land that contains an estimated 2.1 million ounces of gold.

Appendix 2. Water Quality Data, from the Fort Knox Water Supply Reservoir (WSR), April 2017.

Site Number	Date	Depth (m)	Temperature (C)	% Saturation Dissolved Oxygen	Dissolved Oxygen (mg/L)	Conductivity (u S/cm)	pH	ORP
12 (Fish Creek Bay)	4/12/2017	1	0.19	67.5	9.59	132.7	6.99	402
		2	0.45	68.5	9.66	132.1	7.07	400
		3	0.52	52	7.33	140.4	6.98	402
		4	0.62	48.5	6.82	145.2	6.97	402
		5	0.72	46.4	6.5	146.5	6.96	401
		6	0.82	42.7	5.97	146.8	6.96	401
		7	0.91	41.8	5.82	146.6	6.95	401
12 (Fish Creek Inlet)	4/12/2017	1	0.56	68.6	9.65	133.6	7.05	265
2 (WSR near Dam)	4/12/2017	1	0.3	46.1	6.54	137.8	6.62	401
		2	0.35	46.2	6.54	137.3	6.71	401
		3	0.43	46.1	6.52	137.1	6.76	400
		4	0.66	45.8	6.44	135.6	6.84	400
		5	0.84	45.1	6.3	136.5	6.9	400
		6	0.98	44.1	6.14	136.5	6.92	400
		7	1.05	42.9	5.96	137	6.96	400
		8	1.15	40.7	5.64	137.2	6.97	400
		9	1.24	37.8	5.23	137.3	6.97	400
		10	1.3	36.3	5	138	6.99	400
		11	1.37	36.4	5.01	137.5	7	400
		12	1.43	35.2	4.84	139	7.01	399
		13	1.52	33.2	4.55	141.3	7.01	399
		14	1.6	29.4	4.03	144.6	7	399
		15	1.64	19.3	2.63	146.4	6.96	400
		16	1.72	20	2.74	149.4	6.97	400
		17	1.8	16.6	2.25	155.4	6.97	400
		18	1.83	15.4	2.09	158.2	6.97	399
		19	1.87	12.1	1.64	161.7	6.96	400
		20	1.94	5	0.67	168.5	6.93	314
		21	1.97	0.3	0.04	195.7	6.91	223
		22	1.99	0.1	0.01	197.5	6.92	209
		23	2.02	0.1	0.01	197.8	6.92	205

Appendix 2. concluded

Site Number	Date	Depth (m)	Temperature (C)	% Saturation Dissolved Oxygen	Dissolved Oxygen (mg/L)	Conductivity (u S/cm)	pH	ORP
1 (Middle WSR)	4/12/2017	1	0.22	51.6	7.35	148.1	6.92	372
		2	0.32	47.5	6.78	141.7	7.06	368
		3	0.57	44	6.19	138.5	7.06	368
		4	0.71	44	6.18	138.3	7.06	368
		5	0.91	43.9	6.1	137.3	7.07	368
		6	1.02	43.8	6.11	136.5	7.08	368
		7	1.12	43.6	6.01	136.2	7.07	368
		8	1.2	41.3	5.65	136.3	7.07	368
		9	1.27	38.3	5.29	136.7	7.05	369
		10	1.33	36.3	4.99	137	7.04	369
		11	1.37	32.2	4.44	138	7.02	369
		12	1.44	28.6	3.91	138.7	7.00	368
		13	1.47	26.8	3.66	139.8	6.99	367
3 (Solo Bay)	4/19/2017	1	0.11	53.8	7.58	145.5	7.05	335
		2	0.35	50.8	7.11	144.8	7.10	336
		3	0.63	47.2	6.57	142.3	7.13	336
		4	0.73	46.4	6.43	142.1	7.14	337
		5	0.82	45.6	6.31	141.9	7.13	337
		6	0.90	43.8	6.04	143.3	7.12	338
		7	0.97	43.4	5.97	142.0	7.12	331
11 (Polar Bay)	4/12/2017	1	0.17	54.6	7.77	142.6	6.4	410
		2	0.27	52.6	7.47	143.1	6.62	409
		3	0.36	49.4	6.99	146.1	6.69	409
		4	0.51	44.8	6.32	148.3	6.72	409
		5	0.64	41.1	5.78	149.9	6.74	408
		6	0.75	40.4	5.65	150.5	6.76	408
		7	0.88	41.1	5.74	149.9	6.78	407
		8	0.95	42.1	5.86	149.6	6.8	406
		9	1.07	43.5	6.04	147.8	6.83	406
		10	1.14	42.3	5.86	148	6.84	405
		11	1.23	33.1	4.57	152	6.81	406
		12	1.72	27.8	3.79	150.1	6.81	405
7 (Lower Last Chance Bay)	4/12/2017	1	0.22	47.8	6.8	132.1	6.71	413
		2	0.34	41.5	5.88	133.3	6.8	411
		3	0.51	37.5	5.29	135.1	6.87	410
		4	0.68	35.1	4.92	134.9	6.9	409
		5	0.8	33.3	4.65	135.5	6.91	409
		6	0.92	21.8	3.04	135.7	6.89	409
		7	1.07	19.3	2.68	135.2	6.89	408

Appendix 3. Population estimates of Arctic Grayling in the Fort Knox Water Supply Reservoir (WSR), 1995-2016.

Year	Population Estimate[1]	95% Confidence Interval
1995[2]	4,358	
1996[3]	4,748	3,824-5,672
1996[4]	3,475	2,552-4,398
1998[5]	5,800	4,705-6,895
1999	4,123	3,698-4,548
2000	5,326	4,400-6,253
2001	5,623	5,030-6,217
2002	6,503	6,001-7,005
2003	6,495	5,760-7,231
2004	6,614	5,808-7,420
2005	7,926	6,759-9,094
2006	5,930	5,382-6,478
2007	4,027	3,620-4,433
2008	3,545	3,191-3,900
2009	3,223	2,896-3,550
2010	4,346	3,870-4,823
2011	7,378	6,616-8,141
2012	7,404	6,775-8,033
2013	6,675	6,217-7,333
2014	5,841	5,235-6,446
2015	5,947	5,111-6,783
2016	4,396	3,913-4,880

[1]Population estimates from 1995-1996 include fish $\geq$ 150 mm, in all other years fish $\geq$ 200 mm.

[2]In 1995, we used estimates from the ponds and creeks for the Arctic grayling population; a confidence interval was not applicable to the data set.

[3]The 1996 estimate was made with a capture and recapture event in summer 1996 using fyke nets.

[4]In 1996, Arctic grayling were captured with a boat-mounted electroshocker for both the capture and recapture events in fall 1996 by Sport Fish Division.

[5]Starting in 1998 through 2016 the population estimates were made using a mark event in the spring of the year of the estimate, and the recapture event in spring of the following year.

Appendix 4. Arctic Grayling Growth in the WSR, 2016-2017.

Upper Limit (mm)	Average (mm)	Maximum (mm)	Minimum (mm)	Sample Size
210	45	45	45	1
220	34	34	34	2
230	23	30	10	5
240	25	39	16	6
250	12	20	3	5
260	11	21	3	20
270	9	20	1	45
280	7	17	0	43
290	5	15	0	23
300	5	15	0	8
310	4	10	0	8
320	4	5	3	2
330	5	7	3	2
340	0	0	0	1
350				0

Appendix 5. Population Estimate of Burbot (≥ 400mm) in the Fort Knox Water Supply Reservoir (WSR), 2001-2016.

Year	Population Estimate	95% Confidence Interval
2001	134	58-210
2002	131	63-199
2003	102	57-147
2004	86	44-128
2005	143	96-191
2006-2011 – no population estimates performed		
2012	193	95-290
2013	80	44-117
2014	175	44-305
2015	92	45-138
2016	119	65-173