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# Arctic Grayling and Burbot Studies at the Fort Knox Mine, 2012

**by Alvin G. Ott, William A. Morris, and Heather L. Scannell**

Pond F Outlet, Arctic Grayling Spawning, May 2012
Photograph by Alvin G. Ott

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Alaska Department of Fish and Game
Division of Habitat

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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, $\chi^2$, 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

●Water quality data were not collected in winter 2011/2012 (page 4)

### Arctic Grayling Stilling Basin

●Limited sampling occurred due to closure of the access road at Solo Creek (page 6)

### Arctic Grayling Water Supply Reservoir

●Arctic grayling spawning began on May 14 in the Pond F outlet channel and numerous spawning fish were observed through May 16. In the channel connecting Ponds D and E spawning was first observed on May 16. Spawning occurred throughout the wetland complex (page 11)

●The spring 2011 population estimate for Arctic grayling $\geq$ 200 mm long was 7,378 fish, a substantial increase from the 2010 estimate of 3,223 fish (page 12)

●A strong recruitment of small Arctic grayling was observed in spring 2012 – 111 new fish were captured and marked between 200 and 230 mm long (page 13)

●Larger, mature Arctic grayling dominated the early catch with smaller fish (< 200 mm long) showing up towards the end of the sampling event (Page 13)

●Average annual growth of Arctic grayling in the WSR decreased in 2010 and 2011 as compared with 2009 as the population increased (page 14)

●Data on population size and average growth of fish $\leq$ 250 and > 250 mm indicates an inverse relationship between population size and average growth (pages 14 and 15)

### Burbot Water Supply Reservoir

●We caught 140 burbot in the WSR and developed wetlands that ranged from 175 to 975 mm long – 61 of those fish were larger than 400 mm (page 16)

## 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, state and federal 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. Work continued throughout 2012 on the Walter Creek valley fill heap leach facility.


**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 and 2012, with emphasis on biological factors, is presented in Appendix 1. The chronology for previous years (1992 to 2010) can be found in Technical Report 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. 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. Some of their key recommendations are summarized below:

- Remove the culvert connecting the head of Pond C to the channel presently conveying high runoff (during breakup) on the north side of the road in the bottom of the Fish Creek valley to allow high runoff flows to remain in the north side drainage (this work was completed in summer 2012);
- Continue implementing wetland rehabilitation and restoration work in the Fish Creek valley between the tailing dam and WSR and continue to systematically document usage by wildlife and waterfowl until closure;
- Explore development of a "pilot" passive treatment constructed wetland for the purpose of removing arsenic, antimony, and any other "problem" elements from tailing seepage water that might reduce or eliminate long-term pump-back requirements;
- Start planning and designing future Fish Creek alignment from the tailing embankment to the small drainage on the north side of the Fish Creek valley bottom; and
- Develop a detailed plan and implementation schedule for the conversion of the existing causeway across the WSR into re-vegetated islands to increase habitat diversity and improve water exchange/circulation.

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, and Ott and Morris 2011) summarizing each year of 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. 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 data collected during 2012 and discusses these findings in relation to previous work.

# Methods

### Water Quality

In recent years, water quality sampling has been conducted once during late winter/early spring before breakup. Water quality sampling was not conducted during winter 2011/2012.

### Fish

Fish sampling methods included angling, visual observations, and fyke nets. Multiple fyke net sampling sites in the WSR and developed wetlands, including Last Chance Creek, have been used to capture Arctic grayling (Figure 2). Changes in fyke net locations are made each year to optimize catches and to accommodate fluctuating water levels in the WSR complex.

In spring 2012, two fyke nets were fished in the developed wetlands. On May 7, one fyke net was set in the outlet of Pond F and the second fyke net was set in the outlet channel immediately upstream of the WSR. The fyke net in Pond F outlet channel (Channel #5) was checked on May 8 and 9 and was allowed to fish until we reached our desired sample size on May 11. The fyke net near the WSR was checked on May 10 and 11, pulled, and reset on May 14 and checked and pulled on May 15. All Arctic grayling $\geq$ 200 mm were measured to fork length (nearest mm), inspected for tags and spawning condition, and released. Arctic grayling $\geq$ 200 mm were marked with a numbered Floy® T-bar internal anchor tag. Arctic grayling abundance was estimated using Chapman's modification of the Lincoln-Petersen two-sample mark-recapture model (Chapman 1951) and variance was estimated (Seber 1982).

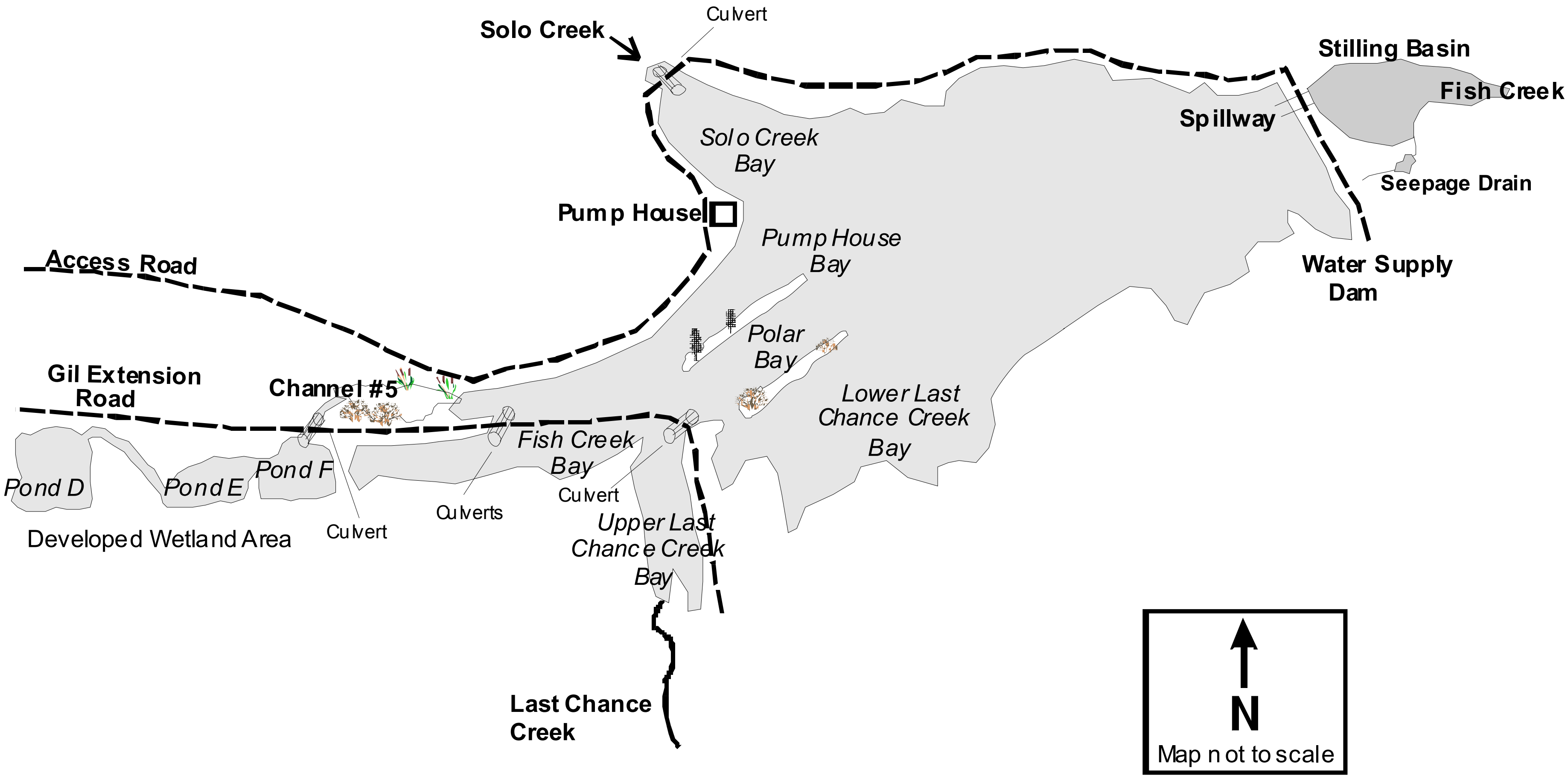


**Figure 2. Sample areas in the Fort Knox WSR, stilling basin, and developed wetlands.**

## 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 and again in the winters of 2007/2008 and 2009/2010. In 2009/2010, 1,167 acre-feet of water (380 million gallons) was pumped from the WSR (Table 1). Flow over the spillway ceased sometime in the fall of 2009 and flow did not reach the low flow channel in the spillway again until June of 2011. There was negligible water use during winter 2011/2012. Water was flowing over the spillway throughout summer 2012.

**Table 1. Winter water use from the WSR, 1997 to 2012.**

| 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 |

Seepage flow through the WSR was monitored continuously by FGMI and has remained relatively constant over the last 14 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 |

[1]Average flow rate

## 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 (Figure 3). 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 September, 1998.

**Figure 3. Spillway, looking downstream, at the Fort Knox freshwater dam in spring 2009.**

*Arctic Grayling and Burbot*

Limited Arctic grayling sampling using angling was conducted in spring 2012. We fished for 30 min on April 26, 2012, catching six juvenile Arctic grayling (135 to 195 mm). We also fished hoop traps in the stilling basin catching seven juvenile burbot (160 to 291 mm) in late May. Road access to the stilling basin was blocked for most of the summer at the Solo Creek crossing where fill material had subsided. Plans were discussed for the removal of the culvert and installation of a bridge. Fill has been placed at the crossing site and access had been reestablished by September 2012.

**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 2). Channel #5 was constructed to bypass a perched pipe and provided 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 the majority of years. However, substantial aufeis and resultant cold water temperatures in the wetland complex, in addition to newly created 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 2012, we fished two fyke nets in the developed wetlands. Aufeis was minimal, compared with previous years. Beavers had not reconstructed dams in the wetland complex and fish had access to spawning areas throughout the complex. Active spawning was observed in the outlet of Pond F, at the outlet of Pond D, and in the upper end of Channel C. Observations of Arctic grayling spawning activity, ice conditions, and distribution of fish in the developed wetland complex are presented in Table 3.

**Table 3. Spawning activity, ice conditions, and distribution of Arctic grayling in spring 2012.**

| Date | Pond F Outlet Channel | Ponds E and F | Pond D Outlet Channel | Pond D | Channel C |
|---|---|---|---|---|---|
| 4/26/2011 | open flow from culvert to the water supply reservoir, one adult Arctic grayling observed in outlet | 100% ice cover, outlet of Pond F open | continuous flow, some ice across the channel but channel is open | 100% ice cover | minimal aufeis in channel, the least amount of aufeis observed in seven years |
| 5/7/2012 | male Arctic grayling defending territories in outlet, 3.5°C water temperature | 90% ice cover, some moating, ice rotten, Arctic grayling observed | open channel, no ice, 2.5°C water temperature, no fish observed | 90% ice cover, some moating, ice rotten | aufeis still present, surface flow visible from road |
| 5/11/2012 | male Arctic grayling defending territories | numerous Arctic grayling, still substantial ice cover | a few Arctic grayling observed | Arctic grayling present, still substantial ice cover | aufeis still present |
| 5/14/2012 | active spawning observed in Pond F outlet just below the culvert | estimated to be about 50% ice over | several Arctic grayling observed | still no active spawning at outlet, ice cover estimated to be about 50% | most of the aufeis is gone, seems to be surface flow throughout the channel |
| 5/16/2012 | active spawning observed in Pond F outlet just below the culvert | ice free | ice free, fish in channel | ice free, some spawning activity at outlet | fish observed, 25 plus in one area, near the head of C Channel just below the ponds |
| 5/18/2012 | active spawning observed in Pond F outlet just below the culvert, but fewer fish than previous days | ice free | ice free, fish in channel | ice free, some spawning activity at outlet | |
| 5/21/2012 | spawning basically done | | | spawning basically done | fish observed all the way to head of channel, in horseshoe shaped ponds |

We first captured Arctic grayling on May 8 in the WSR at the Pond F outlet. Catches gradually decreased until sampling ended on May 17 (Figure 4). Large numbers of Arctic grayling already had entered the wetland complex when our sampling began. There was a substantial movement of mature fish into the wetland complex from the WSR before the ponds were ice free.

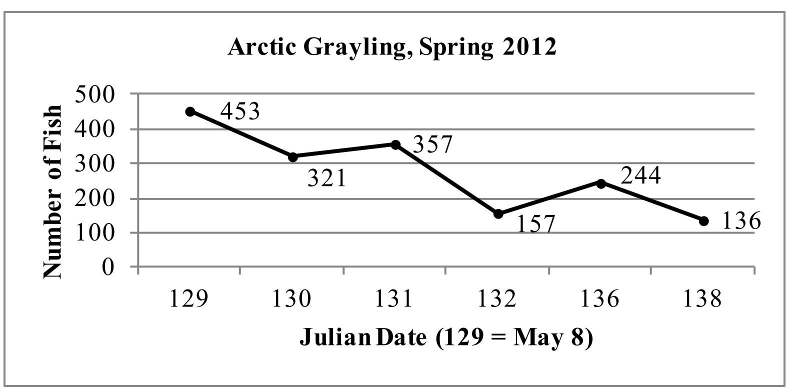


**Figure 4. Catch per unit of effort (grayling/day/fyke net) for Arctic grayling in spring 2012 in the wetland complex.**

Active spawning in the outlet of Pond F peaked from May 14 to 16 with some fish still spawning on May 18, 2012. Peak temperatures ranged from 5.5°C on May 15 to 10.8°C on May 18 (Figure 5). Spawning in the outlet of Pond D began on May 18 and had concluded by May 21. Adult Arctic grayling were observed throughout the wetland complex on May 21.

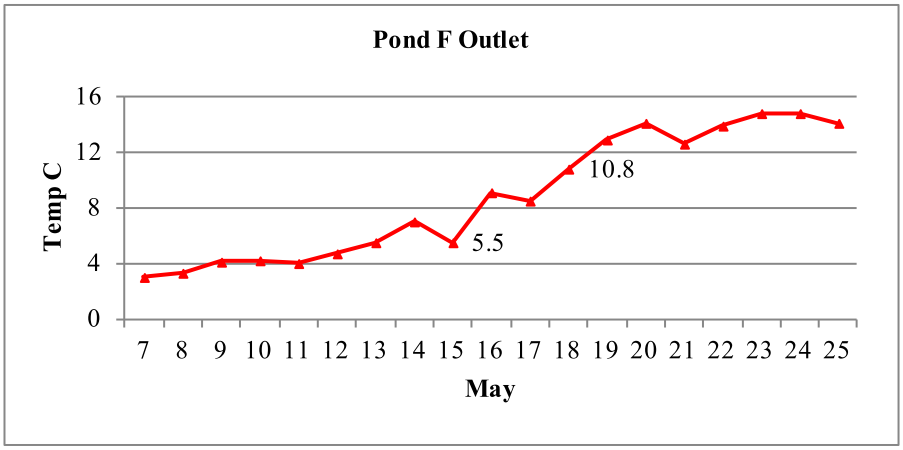


**Figure 5. Peak daily water temperatures in Pond F outlet channel, May 2012.**

Arctic grayling fry were seen during our September 2012 field trip, but no other observations were made in summer 2012.

*Arctic Grayling Catches and Metrics*

The abundance of Arctic grayling was estimated in the WSR using spring 2011 as the mark event and spring 2012 as the recapture event. In spring 2011, there were 1,190 marks when newly tagged and recaptured fish were combined. In spring 2012, 1,486 Arctic grayling ≥ 230 mm were captured, and of those, 239 were recaptures. For the 2011 estimated Arctic grayling population, length frequency distributions were compared for fish marked in spring 2011 with those recaptured in spring 2012 to eliminate those fish handled in 2012 that would have been too small (< 200 mm) to mark in spring 2011. We reduced the total number of marked fish handled in spring 2012 by 107 fish that were ≤ 230 mm long, yielding a total of 1,486 fish handled in 2012 for use in estimating the 2011 population.

The spring 2011 population estimate for Arctic grayling ≥ 200 mm long was 7,378 fish (95% CI 6,616 to 8,141) (Figure 6 and Appendix 2). As predicted based on the spring catch in 2011 (Ott and Morris 2011), the Arctic grayling population increased substantially since the 2010 estimate. The 2011 population estimate is slightly less than the previous highest estimate of 7,926 fish in 2005.

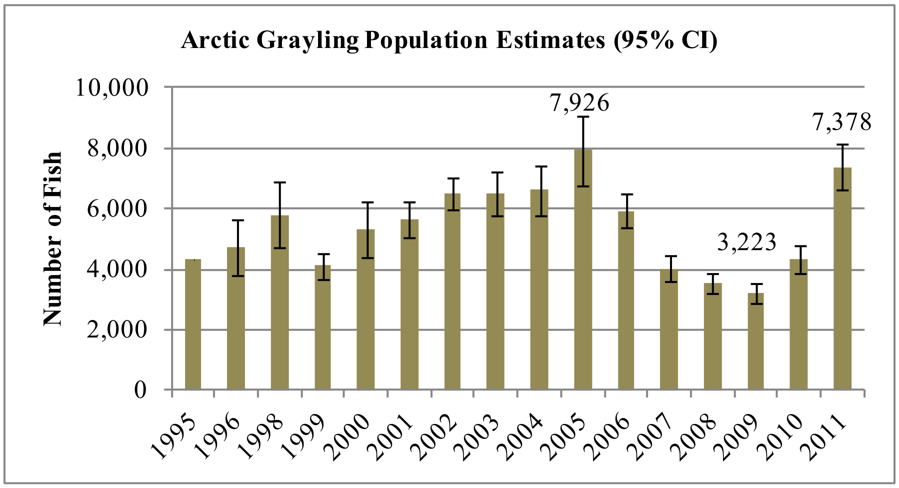


**Figure 6. Estimates of the Arctic grayling population in the WSR.**

The decrease in the total population of fish ≥ 200 mm from 2005 to 2009 is attributed to a lack of recruitment because of reduced availability and quality of spawning habitat in the developed wetland complex. However, spawning in 2008 extended throughout the wetland complex, from 2009 through 2011 spawning was observed from Pond D downstream, and in 2012 spawning again was distributed throughout the wetlands. Increased access to spawning habitat from 2008 to 2012 was provided by the removal of beaver dams in spring 2008 followed by beaver management. Use of the upper portion of the wetland complex (upstream of Pond D) in 2008 and 2012 was limited due to aufeis. In summer 2012, beavers reconstructed dams in multiple locations including Pond F and Pond D outlets and in the headwaters of the wetland complex. Removal of these dams along with beaver management is planned for 2013 prior to spring breakup.

Substantial recruitment of fish ≥ 200 mm was observed in springs 2010, 2011, and again in 2012 (Figure 7). We captured 111 fish between 200 and 230 mm long that we marked in spring 2012. Large Arctic grayling (> 250 mm long) were caught early, and small Arctic grayling (< 200 mm long) were captured later in the sampling event (Figure 8). This pattern is common with the smaller fish showing up later in the spring sampling event.

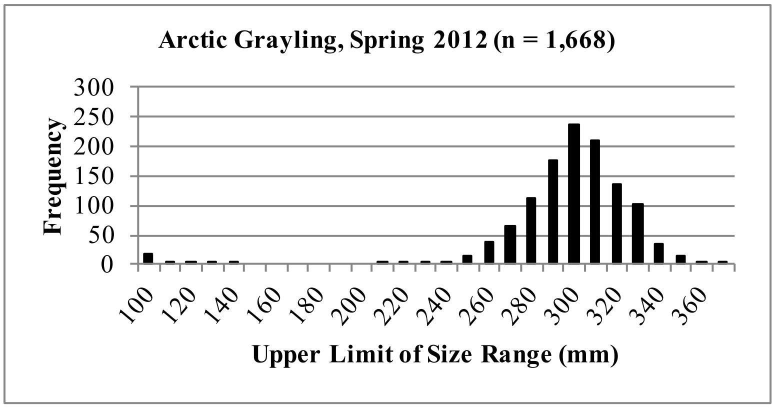


**Figure 7. Length frequency of Arctic grayling in the WSR and developed wetlands in spring 2012.**

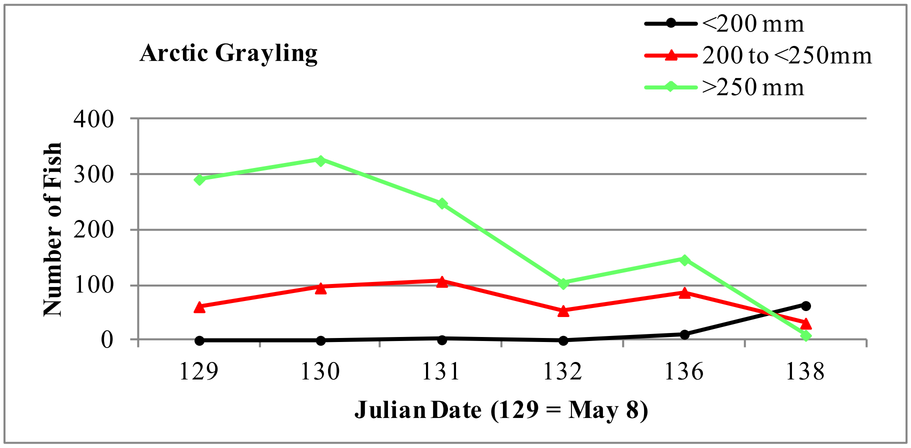


**Figure 8. Arctic grayling catch by size group from May 8 through May 17, 2012.**

Average growth of Arctic grayling prior to development of the WSR ranged from 3 to 17 mm per year (Appendix 3). After the WSR was flooded in 1995, annual growth for marked fish increased substantially. Growth rates decreased in 2010 and 2011 compared with 2009 (Figure 9).

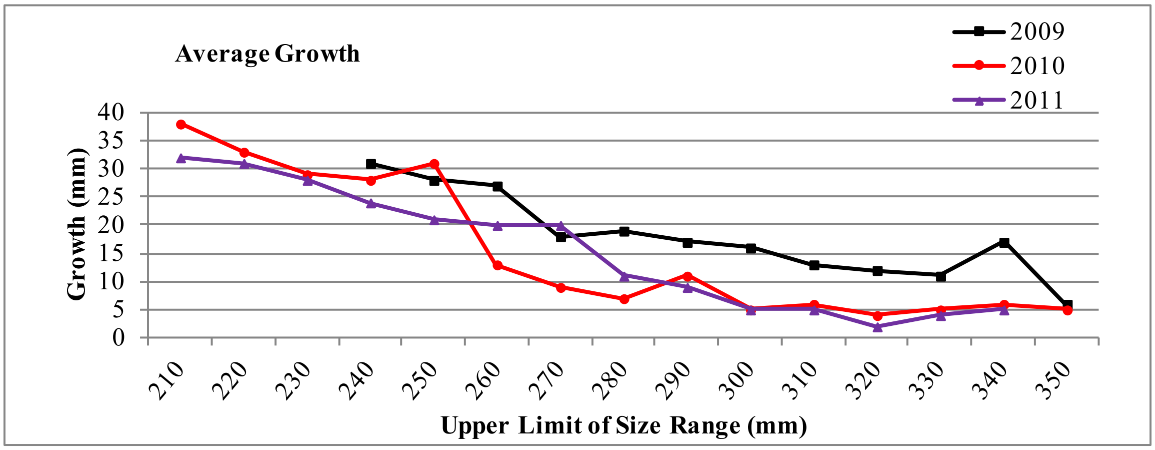


**Figure 9. Growth of marked Arctic grayling in the WSR in 2009, 2010, and 2011.**

We observe an inverse relationship between growth rates and the Arctic grayling population size. 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 and 2011 continued to be lower than in summer 2009.

Average growth of Arctic grayling for fish ≤ 250 mm and for fish >250 mm for all sample years where population estimates were made is presented in Figure 10. 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 an 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.

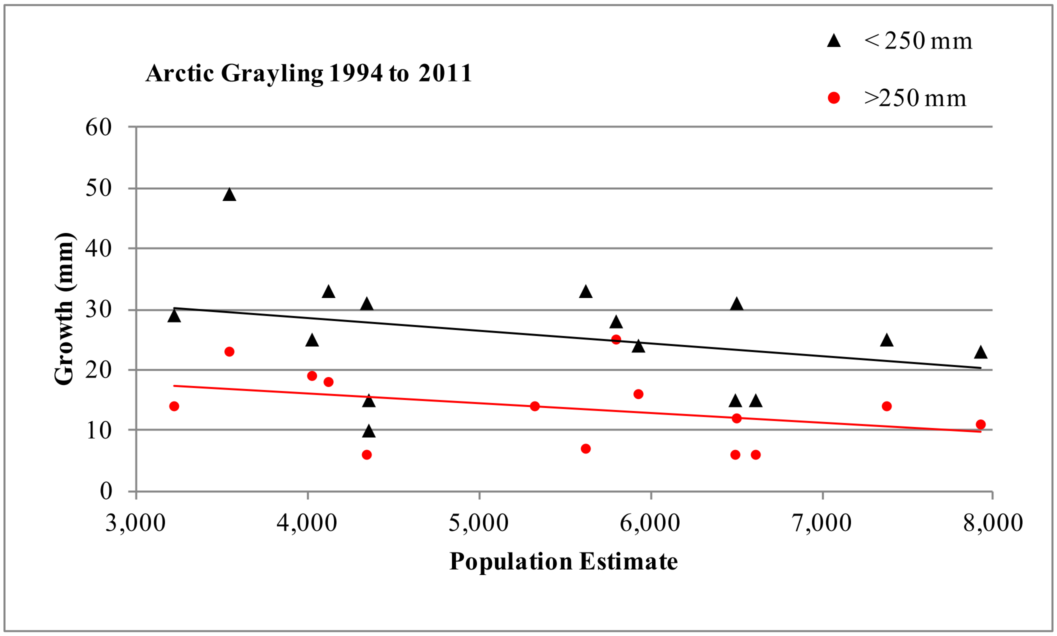


**Figure 10. Growth of marked Arctic grayling in the WSR versus the estimated population of fish. Linear trendlines are shown for each group of fish.**

**Water Supply Reservoir, Burbot**

Burbot were captured in spring 2012 in fyke nets fished in the developed wetlands and in hoop traps fished in the WSR. Burbot ranged in size from 175 to 975 mm, and 61 of the burbot were ≥ 400 mm (Figure 11). Most burbot (109) were caught in hoop traps fished in the WSR from May 14 to 30, 2012.

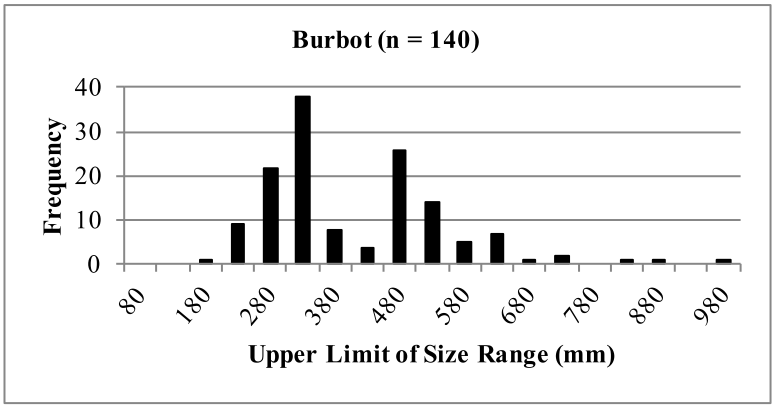


**Figure 11. Length frequency of burbot in the developed wetlands and WSR in spring 2012.**

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 12). Catches of smaller burbot were highest in 1998 (7.2 fish/day), but decreased quickly and have remained low for a number of years.

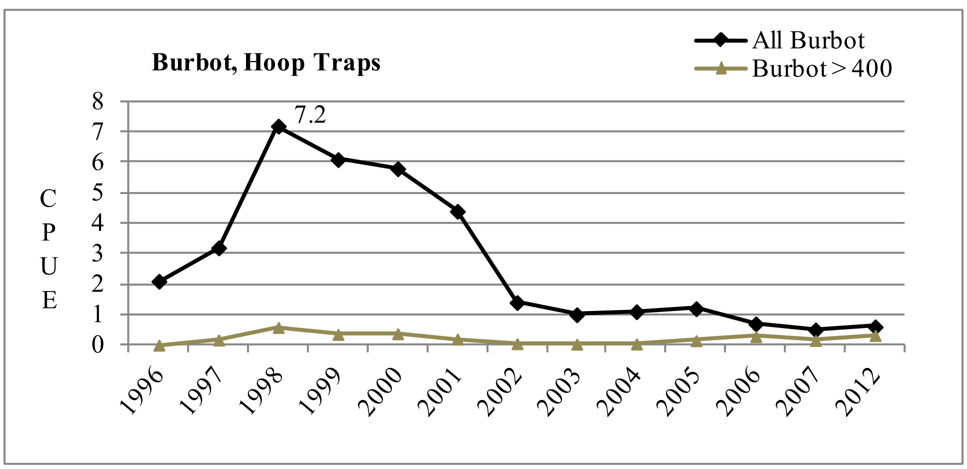


**Figure 12. Catch per unit of effort (fish/trap day) of burbot in the WSR from 1996 to 2012.**

## 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 2011 estimated population for Arctic grayling $\geq$ 200 mm was 7,378 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. During summer 2012, FGMI did conduct some rehabilitation work on the road down the valley to separate the developed wetlands from the proposed construction of a second wetland system along the north side of the Fish Creek valley.

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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 (concluded).**

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 a 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.

## Appendix 2. 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 |

[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 2011 population estimates were made using a mark event in spring of the year of the estimate, but the recapture event was in spring of the following year.

## Appendix 3. Arctic Grayling Growth in the WSR.

| 2011 to 2012 growth grayling (n=239) | | | |
|---|---|---|---|
| Upper Limit (mm) and Sample Size | Average (mm) | Maximum (mm) | Minimum (mm) |
| 210 (n=5) | 32 | 40 | 20 |
| 220 (n=15) | 31 | 46 | 20 |
| 230 (n=24) | 28 | 43 | 14 |
| 240 (n=36) | 24 | 39 | 4 |
| 250 (n=44) | 21 | 36 | 6 |
| 260 (n=40) | 20 | 36 | 1 |
| 270 (n=31) | 20 | 51 | 8 |
| 280 (n=8) | 11 | 17 | 1 |
| 290 (n=4) | 9 | 17 | 0 |
| 300 (n=3) | 5 | 9 | 1 |
| 310 (n=10) | 5 | 11 | 0 |
| 320 (n=9) | 2 | 7 | 0 |
| 330 (n=4) | 4 | 5 | 3 |
| 340 (n=5) | 5 | 11 | 1 |
| 350 (n=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) |