PEACE/WILLISTON
FISH & WILDLIFE
COMPENSATION
PROGRAM

BC hydro

BRITISH
COLUMBIA

Arctic Grayling Workshop 2000

R. J. Zemlak
February 2000

PWFWCP Report No. 210

The Peace/Williston Fish & Wildlife Compensation Program is a cooperative venture of BC Hydro and the provincial fish and wildlife management agencies, supported by funding from BC Hydro. The Program was established to enhance and protect fish and wildlife resources affected by the construction of the W.A.C. Bennett and Peace Canyon dams on the Peace River, and the subsequent creation of the Williston and Dinosaur Reservoirs.

Peace/Williston Fish and Wildlife Compensation Program, 1011 Fourth Ave.
3rd Floor, Prince George B.C. V2L 3H9

Website: *www.bchydro.bc.ca/environment/initiatives/pwcp/*

This report has been approved by the Peace/Williston Fish and Wildlife Compensation Program Fish Technical Committee.

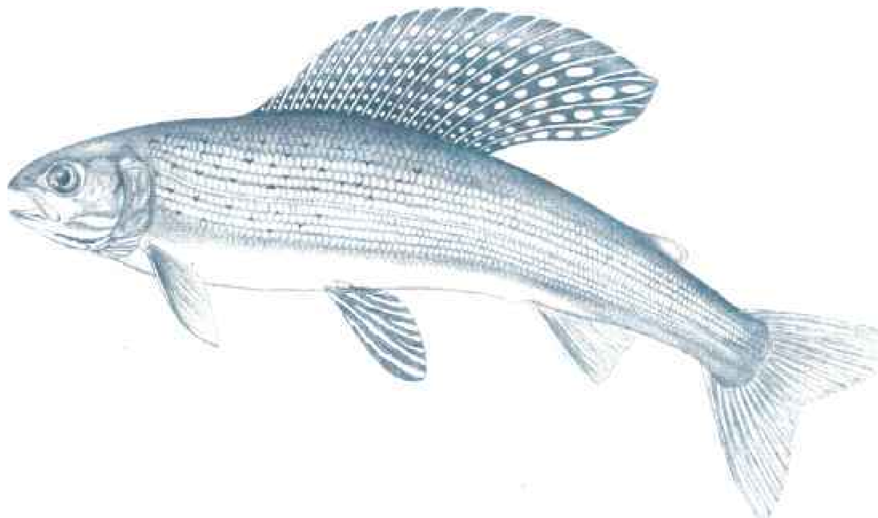
Citation: R. J. Zemlak. February 2000. Arctic Grayling Workshop 2000. Peace/Williston Fish and Wildlife Compensation Program, Report No. 210. 20pp plus appendices.

Author(s): Randy J. Zemlak[1]
Address(es): [1] Peace/Williston Fish and Wildlife Compensation Program, 1011 Fourth Ave., 3rd Floor
Prince George, B.C. V2L 3H9

PREFACE

This report presents the "Program" that was developed for the Arctic Grayling Workshop sponsored by the Peace/Williston Fish and Wildlife Compensation Program. The Workshop occurred on January 18 to 20, 2000, in Prince George, BC. The intent of this workshop was to gather data on Arctic grayling from British Columbia, Alberta, Northwest Territories, and Montana, USA. In addition, there was an exchange of ideas from many biologists discussing habitat preferences of Arctic grayling, harvest regulations, and basic biology (population dynamics, genetics, and community interactions). With all of this information, the future management of this species will be further defined and ultimately ensure the longevity of this species of special concern.

Arctic Grayling Workshop



SPONSORED BY:

Peace/Williston

FISH & WILDLIFE COMPENSATION PROGRAM

JANUARY 18 - 2O, 2OOO
RAMADA HOTEL
PRINCE GEORGE, BRITISH COLUMBIA

WELCOME TO THE ARCTIC GRAYLING WORKSHOP

Hosted by:

Peace/Williston Fish and Wildlife Compensation Program

Who *are we?*

The Peace/Williston Fish and Wildlife Compensation Program (PWFWCP) was established in 1988 as a joint initiative of BC Hydro and the Provincial Fish and Wildlife agencies (Ministry of Environment, Lands and Parks and the Ministry of Fisheries). This Program was designed to compensate for the environmental and ecological effects of the construction of two hydroelectric facilities on the Peace River: W.A.C. Bennett Dam (Williston Reservoir) and Peace Canyon Dam (Dinosaur Reservoir). These facilities are located in northeastern BC at Hudson's Hope.

Prior to creation of Williston Reservoir in 1968, the Finlay and Parsnip rivers met to form the Peace River. The W.A.C. Bennett Dam now impounds a drainage area of approximately 70,000 km^2, forming Williston Reservoir with a storage volume of up to 74,256.7 million m^3. Water from Williston Reservoir is then discharged to the much smaller Dinosaur Reservoir. This narrow reservoir is a run-of-the-river reservoir, capable of storing only 215.86 million m^3 of water. Water from Dinosaur Reservoir is then discharged into the Peace River flowing east through Alberta to the Slave River before eventually draining to the Arctic Ocean.

In 1988, BC Hydro established an $11 million fund to support fish and wildlife research and enhancement projects in the Williston and Dinosaur Reservoir watersheds. A portion of the interest generated by the fund is used to finance the PWFWCP; while the fund principle remains untouched, allowing the Program to continue in perpetuity. The principle is currently $27 million while the operating budget for the Fish Program in 1999/2000 is $584,000.

Williston Reservoir

Since the establishment of Williston Reservoir in 1968, species composition and relative abundance of fish in the reservoir has changed to favour species suited to the lacustrine habitat. Currently, 22 different fish species are known to inhabit the Williston watershed. The loss of littoral productivity associated with water level fluctuations has also meant that fish dependent on benthic invertebrates as a food source have declined relative to plankton feeders and their predators. For this reason, species that feed primarily on insects and other benthos, such as Arctic grayling and mountain whitefish, have declined while species such as lake whitefish have increased. Other factors such as loss of habitat, degradation of existing habitat, and Overharvesting have also contributed to this decline. Some of the more popular game fish species in Williston Reservoir include bull trout, lake trout, rainbow trout, and kokanee.

Dinosaur Reservoir

Dinosaur Reservoir contains the same native fish species as those found in Williston Reservoir and also contains two additional sculpin species. The predominant game fish is rainbow trout, which is also stocked in the reservoir. Other popular game fish include bull trout, lake whitefish, and lake trout. Limited availability of spawning habitat restricts natural fish production in the Dinosaur watershed.

Historical Background of Arctic Grayling in the Williston Watershed

Limited fisheries information is available on Arctic grayling *(Thymallus arcticus)* prior to the formation of the reservoir. In the mid 1970's this species was suspected to be very numerous and widespread in the watershed. This species remained abundant in both the reservoir and streams until the early 1980's when populations started to decline. Arctic grayling had almost completely disappeared from the reservoir by 1988 and most populations in smaller streams flowing directly into the reservoir have disappeared as well. Viable populations still exist in some of the larger less accessible rivers.

Initially the decline was blamed on the reservoir flooding out key spawning and rearing areas, but this does not explain how this species could apparently flourish for over a decade and then disappear abruptly. In the early years of the reservoir, many fish species flourished. The newly flooded areas released nutrients and the floating mats of timber provided cover for fish as well as habitat for invertebrate communities. By the early 1980's, the nutrient levels in the reservoir were suspected to be declining, and much of the floating timber had been cleared from the reservoir. This process would have resulted in a decline in the amount of food available in the reservoir and a loss of cover. In addition, increased road development greatly improved access for anglers to the stream mouth areas where large numbers of Arctic grayling congregated.

The environment in the Williston Watershed has been dramatically changed, and overfishing may have seriously depleted many populations. The formation of the reservoir and industrial activities may have changed the environment to such an extent that species that formerly could not compete with Arctic grayling now have a competitive advantage. The reservoir provides habitat that is generally warmer and has a longer growing season than was previously available. This change in habitat is advantageous to species such as rainbow trout whose populations were potentially restricted by cold temperatures and short growing seasons.

Arctic grayling have been classified as "red listed" within this watershed according to the BC Conservation Data Centre. Red-listed species are those considered to be extirpated, endangered, or threatened in BC. As a result, the Provincial Fish and Wildlife Agencies have now imposed a catch and release regulation for this species. Preliminary surveys have been conducted in some key areas to document distribution and relative abundance and there are ongoing studies evaluating the genetic makeup of the remaining populations, habitat utilization, and migratory patterns. It is suspected that a combination of overfishing, stream habitat degradations and the decline of productivity/suitability in the reservoir have contributed to the severe declines in Arctic grayling stocks.

WORKSHOP SPONSORS

The organizing committee for the Peace/Williston Fish and Wildlife Compensation Program Arctic Grayling Workshop would like to thank the following sponsors for their contributions and assistance in making this workshop a success:

BC Hydro

Environmental Dynamics Inc.

Ministry of Environment, Lands and Parks

Ministry of Fisheries

Pacific Western Brewing Company

Qualstar Solutions Inc.

WORKSHOP PROGRAM

All presentations take place in the Cranbrook Ballroom of the Ramada Hotel

TUESDAY, ***JANUARY 18, 2000***

7:00 p.m. - 10:00 p.m. Early Registration Begins in the Cranbrook Ballroom
Wine and Cheese Reception
Sponsored by Pacific Western Brewing Company

WEDNESDAY, JANUARY 19, 2000

7:00 a.m. - 8:00 a.m. Late Registration, located in the Cranbrook Ballroom

Morning Session Chair: **Don Cadden, Regional Fisheries Biologist (Omineca Region)**

8:00 a.m. - 8:10 a.m. Welcome
By Ted Down, Ministry of Fisheries

8:10 a.m. - 8:15 a.m. Introduction
By Don Cadden

8:15 a.m. - 9:15 a.m. **Keynote Speaker, Dr. Don McPhail**:
"Biogeography of the upper Peace system: a unique environment for Arctic grayling"

Arctic Grayling within the Williston and Dinosaur Watersheds

9:15 a.m. - 9:35 a.m. **Brian Blackman:**
"Arctic Grayling studies in the Williston Reservoir watershed"

9:35 a.m. - 9:55 a.m. **Pat Slaney:**
"Responses of fish populations, including Arctic grayling, to fertilization of the Mesilinka River at Williston Reservoir in northern British Columbia"

9:55 a.m. - 10:15 a.m. Coffee Break
Sponsored by Environmental Dynamics Inc.

10:15 a.m. - 10:35 a.m.	**Jim Trask:** "Fish and fish habitat inventories in Arctic grayling watersheds"

Arctic Grayling within other watersheds in Northern BC

10:35 a.m. - 10:55 a.m.	**Nick Baccante:** "Arctic Grayling in the Burnt River, BC: An Overview"
10:55 a.m. - 11:15 a.m.	**Jeff Burrows:** "Arctic grayling movement patterns in the Halfway River and Sukunka River watersheds"
11:15 a.m. - 11:35 a.m.	**Mike Stamford:** "Zoogeography and conservation genetics of Arctic Grayling"
11:35 a.m. - 11:55 a.m.	**Curtiss McLeod:** "Arctic grayling of Surprise Lake, BC"
11:55 a.m. - 1:00 p.m.	Lunch (provided)

Panel Discussions

1:00 p.m. - 2:15 p.m.	Discussion Topic #1 **"Habitat - includes all aspects of habitat requirements, degradation, enhancement, mitigation, protection, and rehabilitation"**
2:15 p.m. - 2:30 p.m.	Coffee Break **Sponsored by PWFWCP**
2:30 p.m. - 3:45 p.m.	Discussion Topic #2 **"Harvest Regulations - traditional and innovative approaches, need for experimental management. evaluating effectiveness of regulations, etc."**
3:45 p.m. - 4:30 p.m.	Summary of Discussion Topics
Evening	Dinner at delegate's leisure (We suggest the Buffalo Brewing Company)

Arctic grayling Modeling (Wednesday Night)

7:30 p.m. - 8:30 p.m. **Michael Sullivan:**
"Computer Simulation Modeling of Fisheries in Alberta"

THURSDAY, *JANUARY 20, 2000*

Morning Session Chair: **Nick Baccante, Regional Fisheries Biologist (Peace Region)**

8:00 a.m. - 8:15 a.m. Introduction and announcements
By Nick Baccante

8:15 a.m. - 9:15 a.m. **Keynote Speaker, Dr. Tom Northcote:**
"Arctic grayling biology relevant to their management: Gleanings" from the literature and comparisons with other graylings"

Alberta's Arctic Grayling

9:15 a.m. - 9:35 a.m. **Jim O'Neil:**
"Distribution and Status of Arctic grayling in Alberta"

9:35 a.m. - 10:00 a.m. **David Berry:**
"Managing Arctic Grayling in Alberta"

10:00 a.m. - 10:20 a.m. Coffee Break
Sponsored by Qualstar Solutions Inc.

Montana's Arctic Grayling

10:20 a.m. - 10:40 a.m. **James Magee:**
"Life history, status, and restoration of Montana fluvial Arctic grayling"

Arctic Grayling Stock Assessments

10:40 a.m. - 11:00 a.m. **Travis Ripley:**
"A stock assessment of the Kakwa River Arctic grayling *(Thymallus arcticus)* population, fall 1997"

11:00 a.m. - 11:20 a.m. **Jim Stelfox:**
"Stocked Arctic grayling fisheries in Kananaskis Country"

Arctic Grayling Habitat Alterations

11:20 a.m. - 11:40 a.m. **Ian Birtwell:**
"The responses of Arctic Grayling *(Thymallus arcticus)* to sediment from Yukon Placer Mining Operations"

11:40 a.m. - 12:00 p.m. **Craig Thomas:**
"Arctic Grayling *(Thymallus arcticus)* habitat creation and enhancement - Stream habitat compensation at BHP Diamonds Inc. Ekati™ Mine, Northwest Territories"

12:00 p.m. - 1:00 p.m. Lunch (provided)

Panel Discussions

1:00 p.m. - 2:15 p.m. Discussion Topic #3
"Biology population dynamics, genetics, community interactions, etc."

2:15 p.m. - 2:30 p.m. Coffee Break
Sponsored by PWFWCP

2:30 p.m. - 3:30 p.m. Discussion Topic #4
"General issues"

3:30 p.m. - 4:00 p.m. Summary of Discussion Topics

4:00 p.m. - 4:20 p.m. Closing remarks
By Dr. Tom Northcote

PRESENTATION ABSTRACTS

(Listed in order of presentation)

Biogeography of the upper Peace system: A unique environment for Arctic grayling

Dr. Don McPhail
University of British Columbia, Department of Zoology, Vancouver BC

For fish, the Rocky Mountains are one of the great faunal barriers of North America. Waters draining the eastern flanks of the Rockies flow to the Gulf of Mexico, Hudson Bay, and the Arctic Ocean while waters draining the western flanks flow to the North Pacific. This barrier is at least 20 million years old and, not surprisingly, very different fish faunas evolved on the eastern and western sides of the mountains. At scattered sites, however, a few cold-adapted headwater species have crossed the mountains. Thus, the mountains are not a total barrier; however, there is only one site where a major faunal exchange has occurred — the Peace River. Sometime late in the last Ice Age the divide between the Fraser and Peace drainage systems was broached and a major faunal exchange occurred. Western North American species gained access to the upper Peace system and eastern or Great Plains, species gained access to the Fraser system. Like most dispersal corridors, the connection between the Fraser and Peace systems acted as a filter and only a subset of the eastern and western fish faunas were able to use the connection. The species that used this corridor had to be present at the appropriate time and had to be physiologically and ecologically adapted to the environmental conditions prevailing early in deglaciation. Curiously, although grayling now occur in the upper Peace system, they did not cross the drainage divide into the Fraser. This implies that either grayling entered the upper Peace system from some source other than the northern Great Plains (e.g., the upper Liard system) or that they arrived in the lower Peace after the connection between the Fraser and the Peace was severed. If they arrived later, they are the only component of the northern Great Plains fish fauna to make it above the velocity barrier that divides the Peace into upper and lower sections. Regardless of how they entered the system, the upper Peace grayling now are unique in North America in terms of the fish fauna with which they coexist. So far, interaction between upper Peace grayling and the western faunal elements occupying the same waters are unstudied. Indeed, these fish may have no impact on grayling ecology. Interestingly, however, although the Fraser-Peace faunal exchange probably occurred about 10,000 years ago, none of the species that used this corridor have dramatically expanded their ranges in the new area. Given, that once species crossed the drainage divide dispersal would be downstream, dispersal on both sides of the mountains has been remarkably slow. This suggests that interactions between the original fauna and the new immigrants may be important.

Arctic Grayling within the Williston and Dinosaur Watersheds

Arctic Grayling Studies in the Williston Reservoir Watershed

Brian Blackman
Peace/Williston Fish and Wildlife Compensation Program, Prince George BC

Information on Arctic grayling in the upper Peace River Watershed is limited, prior to the formation of Williston Reservoir in 1968. During the period from 1974-77 this species was very numerous and widespread in the watershed. Then in about 1982 there was a severe decline for no obvious reason. Arctic grayling populations in all small (<400 km^2) and medium sized (400-1500 km^2) streams flowing directly into the reservoir disappeared. Only those stocks utilizing the largest river systems (>2000 km^2) remained. Initially the decline was blamed on the reservoir, flooding key spawning and rearing areas, but this does not explain how this species could apparently flourish for over a decade and then disappear abruptly. Grayling stocks in this watershed are fairly short lived, with very few fish living past age six, so at least two complete cycles would have occurred between the time the reservoir was flooded and when the populations declined. In the early years of the reservoir may fish species flourished. The newly flooded areas released nutrients and the floating mats of timber provided cover for fish as well as a habitat for an invertebrate community. By the early 1980's the nutrient levels in the reservoir were probably declining, and much of the floating timber had been cleared from the reservoir. This would have resulted in a decline in the amount of food available in the reservoir, a loss of cover, and greatly improved access for anglers to the stream mouth areas, where large numbers of grayling congregated. It is speculated that the declines were a result of a combination of factors. Overfishing at the stream mouth areas probably depleted many populations. It is also possible that for one or more life history stages were unable to compete with species better able to take advantage of the reservoir environment, once productivity began to decline. The reservoir may have also interfered with migration patterns, not to block migrations but to cause fish to stray or be unable to locate spawning streams. This may have affected Arctic grayling more than adaptable species such as bull and rainbow trout. Work has been underway to protect the remaining stocks and determine if this species can be reintroduced back into historic habitats. Information has been gathered on life history, migration patterns, and habitat utilisation in a number of systems, and work is underway to develop cost effective index methodologies in order to determine which factors may be limiting the populations. Data has been gathered on distribution, growth rates and age class composition in a number of systems. Radio telemetry studies were used to evaluate migratory patterns and timing as well as to locate spawning areas and assess site fidelity. Emergence timing, distribution, and relative abundance surveys of newly hatched fry were examined as a possible technique to locate spawning areas and as an index method to evaluate spawning success. Extensive electrofishing and beach seine projects have examined young of the year and juvenile distribution, relative abundance, growth, and habitat preference. Underwater (snorkel) surveys and mark recapture methodologies have been employed to determine adult relative abundance, distribution and habitat preference in two systems. Results of these studies and potential problems with the methodologies are discussed.

Responses of fish populations, including Arctic grayling, to fertilization of the Mesilinka River at Williston Reservoir in northern British Columbia

Slaney, P.A.[1], K.I. Ashley[2], and G. Wilson[2]

'Ministry of Environment, Lands and Parks, Watershed Restoration Program, VancouverBC

[2]BC Ministry of Fisheries, Fisheries Research and Development Section, VancouverBC

With the development of Williston Reservoir in northeastern B.C., considerable riverine habitat of native fish stocks, especially Arctic Grayling, was lost in the flooded major drainages as well as the lower reaches of tributary rivers. The addition of inorganic nutrients to increase the productivity of riverine habitat was investigated as a potential option to offset some of the negative impacts of impoundment by augmenting productivity of remaining lotic habitats. At the oligotrophic Mesilinka River, an upstream control reach and two downstream treatment reaches (Tl and T2) were studied before fertilization in 1992 and 1993 and during fertilization from 1994 to 1999. Inorganic fertilizer was added upstream of each of the two treatment reaches at target loadings of up to 15 and 5 $\mu g \cdot L^{-1}$ nitrate nitrogen and phosphorus, respectively, although actual levels were about a third less than that targeted. Peak periphyton accrual increased several fold during the first two years of fertilization, but moderated thereafter as the benthic insect community responded, similar to that reported elsewhere. Mean biomass of benthic invertebrates collected in sampling baskets was 2-3 times greater by 1997 in the treated reaches than the control reach. Numerical and growth responses of fish populations including mountain whitefish, rainbow trout, Arctic grayling and bull trout were evident, but varied. Increases in numbers of whitefish (up to five-fold) and rainbow (2-3 fold) were most pronouced, whereas grayling increased by about 1.5 to 2-fold. A shift in bull trout abundance lagged until a marked increase of 2-3-fold by 1999. A greater percentage of larger fish within size compositions was also detected, except in bull trout, and was most pronounced among rainbow trout in the lower treated reach of the river. The importance of nutrients in driving the productivity of cool north temperate rivers was demonstrated by this large-scale ecological experiment, which may require additional time for the fish community to reach an equilibrium.

Fish and Fish Habitat Inventories in Arctic Grayling Watersheds

Trask, Jim

Triton Environmental Consultants Ltd., Prince George BC

Significant gaps exist in our present knowledge of Arctic grayling distribution within the Williston watershed, which require new baseline inventories in order to assess population status and develop long term management plans. The Peace/Williston Fish & Wildlife Compensation program continues to direct funds to grayling research, however these are typically more focused studies and not baseline inventories. Forest Renewal B.C. (FRBC) funds reconnaissance level fish and fish habitat inventory projects throughout the Province. These inventories typically involve sampling a subset (15-30%) of all identified stream reaches. FRBC objectives are based on identifying fish species presence, distribution and relative abundance within a watershed. The timing, sampling techniques and distribution of sampling effort within a watershed are typically inconsistent with identifying

grayling presence, distribution and key habitats. Therefore, special considerations are needed in the development of a sampling plan and selection of sampling techniques to determine grayling presence, distribution and abundance, and habitat utilization. An FRBC funded project was conducted to identify and describe Arctic grayling and bull trout habitat utilization, abundance and distribution in the upper Mesilinka watershed. Fieldwork was conducted in 1996 and 1997. A total of 111 stream reaches were surveyed and 145 fish sampling events were conducted in 1996 and 1997. In both years electrofishing was the primary sampling method, but angling, minnow trapping and snorkel surveys were also utilized where appropriate. A total of 1,266 fish of 10 species were captured or observed, including 33 Arctic grayling. Grayling were captured by electrofishing (7) and angling (13), and observed (12) during snorkel surveys. Adult Arctic grayling were found in moderate densities in the mainstem Mesilinka River, and were captured at only two other sites that were not in the mainstem river. Large juvenile Arctic grayling were observed at very low densities in the mainstem and were captured in the lower portions of direct tributaries below the Blackpine Bridge. Only 4 young-of-year grayling were captured, 1 in a side channel and three in a small tributary within 500m of the Mesilinka River. A total of 10 Mesilinka River side channels were surveyed in 1996 and 1997. Although young-of-year Arctic grayling are known to utilize Mesilinka River side channels downstream of the Blackpine Bridge, none were captured upstream. An FRBC funded 1:20,000 Reconnaissance Fish and Fish Habitat Inventory was conducted in the Missinka River watershed in 1998. A total of 222 stream reaches were surveyed (22.4% sampling intensity). A total of 2676 fish of 11 different species were captured or observed (snorkel), including 71 Arctic grayling, which were exclusively captured/observed within the mainstem river. Grayling were captured by electrofishing (11) and angling (8), and observed (52) during snorkel surveys. A total of 11 young-of-year grayling were captured, most in side channel habitats. No grayling were captured in tributaries. The limit of grayling distribution was coincident with a 2.2 m high bedrock falls on the mainstem, ~32 km upstream from the Parsnip River. Grayling had a clumped distribution, with most fish occurring in large (30-50m dia) deep (5-10m) pools. A group of 26 adult grayling were observed below the falls in a deep (>5m) canyon pool. The largest, deepest pools sustain the greatest numbers of fish, typically ~200 mountain whitefish, 5 or 6 adult grayling, several rainbow trout and 3 or 4 bull trout.

Arctic Grayling within other watersheds in Northern BC

Arctic grayling in the Burnt River, BC: An Overview

Euchner, T.[1], Baccante, D.A.[2], Burrows, J.[3], and T. Down[4]

[1]Diversified Environmental Services Ltd., Fort St. John BC

[2]Ministry of Environment, Lands and Parks, Fisheries Section, Fort St. John BC

[3]Ministry of Environment, Lands and Parks, Fish Inventory Section, Fort St. John BC

[4]BC Ministry of Fisheries, Conservation Section, Victoria BC

The Burnt River flows out of the Hart Ranges on the east slopes of the Rocky Mountains. It is a tributary to the Sukunka River, approximately 20 km south of Chetwynd, B.C., and is part of the Peace River watershed. The Burnt is known for its excellent Arctic grayling fishery, and it supports healthy populations of mountain whitefish, rainbow and bull trout. This area of the province contains a significant concentration of industrial activities, such as forestry, mining, oil and gas exploration. These activities are responsible for increased road access in the area, which increases the potential for exploitation of fish populations. Permanent road access to the lower Burnt River was established in 1990, and in 1991 the first catch-and-release regulations in the Peace Region were instituted on this river, to try and preserve angling quality. A combination of angling, electrofishing and visual counts of tagged and untagged grayling from snorkel swims were carried out in 1992, 1993, 1998 and 1999. The 1992 data is essentially representative of pre-catch-and-release regulations put in place in 1991. Estimates indicate that overall average density of Arctic grayling in the Burnt has consistently remained high, ranging from 121 in 1992 to 297 fish/km in 1999. Relative abundance by size categories indicates that physical barriers, such as waterfalls, play an important role in habitat segregation. Grayling less than 10 cm appear only below the first set of fall on the Burnt. In the furthest upstream section no grayling smaller than 20 cm were observed, almost all fish were 30 cm and greater. Comparison of angling and snorkeling data indicates that angling is much more selective, as expected. Most grayling caught by angling range between 20 to 40 cm. Snorkeling surveys allow enumeration of fish smaller and larger than the size range vulnerable to angling. Snorkeling data suggests that accuracy of the estimates are likely improved by utilizing the same, experienced personnel to conduct the surveys. Repeated catch and release angling of reaches indicate that catch rates decrease with heavy angling pressure. This was not due to incidental mortality or fish vacating the area, as corroborated by snorkel surveys, rather due to a behavioral response of grayling resulting in lure avoidance. Incidence of "sore mouth" caused by illegal use of large, artificial tackle with barbed hooks is also a likely factor lure avoidance. Growth rates of grayling in the Burnt are above average compared to waters in similar latitudes. Size at age ranges from about 23 cm at age 2 to about 40 cm at age 9. All age classes are well represented indicating good recruitment in the population, as expected with low exploitation rates. The management objectives for the Burnt are: 1. Maintain a high quality fishery for Arctic grayling; 2. Prevent habitat degradation in the watershed; 3. Establish an artificial-fly only regulation, and promote the river as a destination for high quality Arctic grayling angling.

Arctic grayling movement patterns in the Halfway River and Sukunka River watersheds

Burrows, J.[1], Euchner, T.[2], and Baccante, D.A.[3]

[1]Ministry of Environment, Lands and Parks, Fish Inventory Section, Fort St. John BC

[2]Diversified Environmental Services Ltd., Fort St. John BC

[3]Ministry of Environment, Lands and Parks, Fisheries Section, Fort St. John BC

In 1997 BC Fisheries (Fort St John) initiated a project designed to identify spawning locations, movement patterns, and seasonal habitat use of Arctic grayling in two northeastern B.C. watersheds. In 1997 and 1998, we surgically implanted 49 radio transmitters (149.54-149.70 MHz) in Halfway River and Sukunka River grayling ranging from 330 mm to 405 mm. Subsequent to surgery we used mobile (usually from aircraft) radio receivers to track grayling movements, completing these observations in March, 1999. A mid-project change from manual position recording to automated position recording quantitatively improved our mobile tracking efficiency, accuracy, and precision. Tracking has revealed new information about Arctic grayling movement patterns in these watersheds, including 1. an annual range of movement of up to approximately 100 km, 2. spring upstream movements to previously unknown spawning sites in small Halfway River tributaries, and 3. fall downstream movements to larger main stem overwintering areas. This new information has potential management implications for protected areas and instream-work timing windows.

Zoogeography and conservation genetics of Arctic grayling (Thymallus arcticus)

M. Stamford and E.B. Taylor
University of British Columbia, Department of Zoology, Vancouver BC

The distributions of most Holarctic freshwater fish species were severely altered and restricted during the many glaciation events that have occurred throughout the Pleistocene. Isolation of groups of fish into distinct glacial refugia provided the opportunity for genetic divergence during these periods of allopatry through genetic drift and novel selection pressures. We are examining the genetic signature of such isolation and subsequent postglacial colonization in the Arctic grayling *(Thymallus arcticus)* by assaying mitochondrial and microsatellite (nuclear) DNA variation among samples that have been collected from throughout the species' range in North America. Genetic diversity is expected to be highest in geographic regions where Arctic grayling survived the last ice age because bottlenecks and founder events reduce diversity as species colonize vacant regions that were once covered in ice. We found a dramatic decline in genetic diversity from Alaska to British Columbia, which points to expansion from Beringia into the south. There are genetic similarities between the Upper Yukon River, the Liard River and North Coast drainages suggesting that headwater transfers have occurred between the Yukon River and Pacific and Arctic watersheds in British Columbia. Low haplotype diversity and low heterozygosity in the Peace River and North Coast drainages suggest that severe bottlenecks occurred during colonization. We have found at least 2 variable microsatellite loci that show signs of genetic differentiation within the Peace River. Two different genotypes, one unique to the Lower Liard River the other unique in Montana and Saskatchewan, suggest Arctic grayling survived in at least 2 glacial refugia in North America other than Beringia.

Arctic Grayling of Surprise Lake, BC

Curtiss McLeod
R.L.&L. Environmental Services Ltd., Edmonton AB

The fish fauna of Surprise Lake, in northwestern B.C., is restricted to two species - Arctic grayling and slimy sculpin. The extent of Arctic grayling critical habitat in the lake and associated tributaries was evaluated as part of an impact assessment for a proposed hydroelectric development. Spawning Arctic grayling were collected from 9 of 14 streams examined in May and early June, 1991. Pine Cup Creek, entering the north end of Surprise Lake, was the primary spawning stream and contained 72% of the total spawning habitat available in all tributary streams. Siltation from placer mining operations on streams on the south end of Surprise Lake has eliminated spawning substrate in many of the tributaries and also in the main outlet stream, Pine Creek. Of potential importance to the Arctic grayling in the outlet of the lake was the selection of one small, unnamed stream. This creek originated from exposed shallow ponds in an upland area, and dropped 35m in elevation through a narrow channel to Pine Creek. Spawning occurred from its confluence, to the outflow pond over 1 km distance upstream. A significant number of fish, previously tagged at an outlet trap on Surprise Lake, selected this tributary for spawning. Water temperature in the stream on 23 May was 11.1C, compared to 5.0C at the lake outlet and 3.9C in a second, nearby, creek. During rearing surveys, Arctic grayling fry were observed in 9 of 16 tributaries examined. Habitat use and rearing success appeared to be influenced by water temperatures. Low water temperatures in many tributaries and the lake resulted in extended incubation and early rearing periods, with fry in some areas reaching only 20 mm length by the end of July. However, in tributaries which had higher early season temperatures, fry exhibited accelerated growth, with fish in the small, unnamed, tributary averaging 44 mm length by late July. Adult fish appeared to leave the tributaries shortly after spawning and return to the lake. Fry in some of the spawning streams migrated into the lake shortly after emergence; the remainder reared in the streams until mid to late September. The lake has a restricted littoral area and overall productivity is low. This is reflected by the slow growth rates, with Arctic grayling from Surprise Lake being smaller than corresponding age-classes from populations in many other northern locations.

Arctic Grayling Modeling

Computer Simulation Modeling of Fisheries in Alberta

Michael Sullivan
Natural Resources Service, Alberta Environment, Edmonton AB

Fisheries biologists in Alberta are faced with the dilemma of managing low productivity, boreal fisheries under the pressure of a large and increasing human population. Large-scale petrochemical development and industrial forestry are increasingly improving access to Alberta's limited fisheries. Overfishing and habitat degradation appears to be the inevitable consequences resulting from the scale and speed of this development. Site-specific and problem-specific fisheries management is presently strained and will likely be unable to cope will increasing demands. A proactive solution is needed, on an unprecedented scale of space and time. We have had good success with computer simulation modeling in Alberta in designing large-scale walleye and pike fishing regulations. These models are not predictive (few models are), but do allow us to compare the potential difference in effects of regulations over meaningful time, based on our present data. The regulations that have been implemented are then modified through field studies and the iterative process of adaptive management. We currently use four types of fishery simulation models in Alberta. These are: static production-harvest estimators (e.g. lake trout management at Cold Lake), static-biological and dynamic-effort regulation models (e.g. pike fishery regulations), single species age-class structured dynamic models (e.g. walleye fishery regulations), and complex dynamic, multiple-species habitat models (e.g. grayling and bull trout habitat management). These models are written using STELLA modeling software. This software is relatively simple to learn and has proved to be invaluable in exploring and explaining complex fisheries processes. The most recent and complex series of models include habitat (as modified by development) and species interactions. These models will help us to quantify and rank the most critical issues that will likely arise under increasing industrial development. Wide-scale, pro-active strategies could be implemented prior to the problems being seen in the field. For example, initial modeling suggests that two consequences of road building: habitat fragmentation caused by culverts, and overfishing caused by increased angler access far overshadow other detrimental factors such as siltation and temperature changes. Field studies are being planned to measure rates of culvert failures and policies are being discussed to coordinate road development and access between industrial sectors.

Arctic grayling biology relevant to their management: Gleanings from the literature and comparisons with other graylings

T.G. Northcote
Professor Emeritus, Department of Zoology, UBC, Vancouver BC

Four (possibly five) species of the genus *Thymallus* (graylings) occur in the Northern Hemisphere with the Arctic grayling *(T. arcticus)* being the most widespread and variable species. It now ranges across North America from western shores of Hudson Bay (formerly around parts of the three largest Great Lakes and with native or stocked populations in Montana and adjoining areas) to virtually all of Alaska and in much of Siberia westward to middle-north Eurasia. The European grayling *(T.thymallus)* ranges from the Pyrenees eastward through much of Europe to the Ural Mountains and overlaps with Arctic grayling in the Kara River system. Two other species occur in Mongolia and possibly one in the upper Amur basin. Recreational or quasi-recreational fisheries have taken place on all species, probably for the longest time on the European grayling, though apparently most intensively on the Arctic grayling. Special features of Arctic grayling biology relevant to its management, restoration and enhancement are reviewed focussing on its reproductive and migratory behaviour, its early life history, its feeding and growth, and its stocks and population controls. Comparisons are made with mainly the European grayling which in some ways seems more resilient than the Arctic grayling, but also for what little seems known about the other species.

Alberta's Arctic Grayling

Distribution and Status of Arctic Grayling in Alberta

Jim O'Neil
RL&L Environmental Services Ltd., Edmonton AB

Arctic grayling *(Thymallus arcticus)* exhibit a holarctic distribution, occurring in northern freshwater drainages in Canada (west of Hudson Bay), Alaska and Eurasia. In Alberta, Arctic grayling are native to streams and rivers in the Athabasca, Peace, and Hay river drainages. These systems, which drain more than half the area of the Province, flow into the Mackenzie River and eventually the Arctic Ocean. Arctic grayling are also occasionally recorded in the Belly River, which is located in the southwest corner of the Province. The range of Arctic grayling in Alberta generally corresponds to the boreal forest and foothills natural regions. Although, at first glance, the number and length of streams that Arctic grayling could potentially inhabit in these regions appear extensive, the recorded distribution is restricted due to the discontinuous availability of preferred stream habitats. A number of basic land form and climatic features interact to limit the distribution and abundance of Arctic grayling. These include: 1) the presence of topographic relief to produce preferred gradient characteristics, 2) appropriate surficial geology to provide suitable streambed materials for spawning and rearing, and 3) mid-summer water temperature regime (location of stream relative to July air temperature isotherms). Based on the limited scientific documentation and anecdotal evidence, the Province supported many stable and abundant Arctic grayling populations in the early decades of the 1900's. This status remained relatively unchanged until the 1950's and 60's when intensive oil and

gas development was initiated in the foothills and boreal forest regions. Overfishing and habitat alteration severely depleted many populations during this period of rapid development. In recent years, continuing energy development, intensive timber harvesting and other land use activities have resulted in further deterioration of grayling habitat. Fishing pressure has also increased both in terms of total effort applied and ease of access to the resource. As a result, Arctic grayling populations in the majority of watersheds are severely fragmented. Some populations have been extirpated and others are extremely susceptible to extinction. To prevent further decline and possibly restore populations, the Alberta government recently developed a management and recovery plan, which included the implementation of new angling regulations in 1998. Whether or not the management and recovery plan will be effective is uncertain. However, it seems likely that many of the stream populations are beyond recovery. As such, it is imperative that the remaining high quality Arctic grayling fisheries be identified and protected, preferably at a watershed level. This initiative should be supported by government, industry, and the angling community.

Managing Arctic Grayling in Alberta

David Berry

Fisheries and Wildlife Management Division, Alberta Environment, Edmonton AB

Alberta's Arctic Grayling Management and Recovery Plan is based on the goals, objectives and guiding principles presented in the document *A Fish Conservation Strategy for Alberta* (Fisheries Management Division 1997). Habitat maintenance, fish conservation and fish-use allocation are three major components of the plan. Arctic grayling *(Thymallus arcticus)* are found in many streams and a few lakes across northern Alberta. Increased human population, habitat alteration and improved access have contributed to population declines. Sportfishing is the largest use of the grayling resource and past sportfishing regulations were not sustaining populations. Therefore, new sportfishing regulations were implemented in 1998. Although four different life-history patterns may exist in Alberta, the grayling populations in three geographical regions have similar patterns of growth, age-class distributions, age of maturity and size at maturity. Therefore, a single approach to the regulation of sportfishing for Arctic grayling was applied throughout the species range in Alberta. A minimum-size limit of 35cm total length was selected to protect grayling to the age of full maturity plus 1 year (at least three mature age-classes-ages 3, 4 and 5). A catch limit of 2 was selected to distribute the available harvest more fairly among anglers. The general season during which anglers are allowed to catch and keep grayling was restricted to the summer, followed by catch-and-release fishing in some areas during a portion of the fall and total closure for the winter and spring. Catch-and-release fisheries were established at a few streams, to recover collapsed populations, to sustain unique recreational opportunities at quality fisheries, and to ensure the quality of the wilderness experience at "heritage" river systems. The long-term success of the plan depends on the availability of good and timely information; therefore, inventory, monitoring and research needs were identified.

Montana's Arctic Grayling

Life history, status, and restoration of Montana fluvial Arctic grayling

James Magee
Montana Fish, Wildlife & Parks, Montana USA

In the continental United States, fluvial Arctic grayling *(Thymallus arcticus)* historically occupied streams in Michigan and Montana. Michigan grayling declined and disappeared by 1936. Once widely distributed in the Missouri River and its tributaries, fluvial Arctic grayling currently exist only in the Big Hole River, reduced to only 4% of its historic range in Montana. Declines have been attributed to; overharvest, climatic change, habitat degradation, and competition with non-native species. When the Big Hole River population dramatically declined in the mid 1980's, biologists were concerned the population was at risk of extinction. In 1987, fisheries biologists and managers formed the Arctic grayling Workgroup and implemented a Recovery Program. In 1991, the United States Fish and Wildlife Service (USFWS) received two petitions to list the fluvial Arctic grayling for protection under the Endangered Species Act. The 1994 findings by the USFWS was that fluvial grayling were warranted protection under the Endangered Species Act but listing was precluded by the on-going recovery efforts and higher priority species. The Recovery Plan long-term goal is to by the year 2020 establish five self-sustaining fluvial Arctic grayling populations in three separate drainages within the historic range. Short term goals are to: 1) Identify and address limiting factors in the Big Hole River to secure and stabilize the last remaining population, 2) Develop a genetically competent brood stock in which to expand the distribution of fluvial grayling, and 3) Identify and reintroduce fluvial grayling into suitable sites within its historic range. Past and on-going research and management, have addressed stream dewatering, competition, overharvest, and habitat degradation on the Big Hole River. A fluvial brood stock and egg take program has been developed and yearling grayling are raised for restoration efforts. These efforts will encompass four river systems in 2000 with the hope of establishing self-sustaining populations.

Arctic Grayling Stock Assessments

A stock assessment of the Kakwa River Arctic grayling (Thymallus arcticus) population, fall 1997

Travis D. Ripley[1], Trevor M. Thera[2], and Paul J. Hvenegaard[2]
[1]Alberta Environment, Natural Resources Service, Grande Prairie AB
[2]Alberta Conservation Association, Peace River AB

Arctic grayling *(Thymallus arcticus)* were captured using a 5.0 GPP float electrofishing unit within a 32 km study section of the Kakwa River, Alberta, in 1997. In combination with electrofishing, angling as a capture method was also used to collect grayling within deeper pools, often where

electrofishing was less effective. The stock assessment was accomplished using population estimates, length distribution and age composition. The long section of river was chosen to determine the validity of all assumptions associated with population estimates and to accurately predict Arctic grayling abundance. Movement probabilities were tested and the population structure was stratified when necessary. A Peterson mark-recapture technique was used to calculate population estimates. The population abundance within the study area was 482 (SE = 34) for the combined (angling and electrofishing) estimate, 603 (SE = 96) for electrofishing only and 185 (SE = 19) for angling. The length frequency distribution ranged from 149 mm to 410 mm fork length which spanned 3 to 11 years of age with age five comprising the majority of the sample. No significant differences in size distribution between each capture method was observed. The comparison of these capture methods leads to unique conclusions about the effectiveness of each method for conducting stock assessments on Arctic grayling.

Stocked Arctic grayling fisheries in Kananaskis Country

Jim D. Stelfox
Alberta Environment, Calgary AB

Stocking of Arctic grayling sac fry in several lakes in Kananaskis Country, west of Calgary, has resulted in the creation of very popular fisheries. Bear Pond (3.5 ha) and Big Iron Lake (1.6 ha) were first stocked in May 1985 at a rate of 1500 fish/ha. Growth was excellent, with grayling reaching 25 cm by age-1 and 35 cm by age-2. Despite the implementation of a 30-cm minimum-size limit in 1987 and a two-fish bag limit and bait ban in 1989, all of the grayling from the 1985 plant were harvested by 1990. However, both lakes continued to provide fisheries, as they had been stocked with grayling sac fry in 1987, at the same rate as in 1985. Survival of stocked sac fry was excellent, given that about 13 % of the grayling stocked in Bear Pond in 1987 survived to age-6. Growth rates were slower for the second stocking, but by 1991 some fish were large enough to be harvested. To maintain quality fisheries, catch-and-release regulations were implemented at both lakes in 1992. During the 1990 to 1995 period, average annual catch rates ranged from 1.2 to 2.6 fish/h at Bear Pond, and from 2.1 to 2.8 fish/h at Big Iron Lake. Although Bear Pond and Big Iron Lake both lack inlets and outlets suitable for spawning, natural reproduction was confirmed to occur in both lakes, and appeared to be sufficient in Big Iron Lake to maintain the fishery. Bear Pond and Big Iron Lake completely winterkilled in 1995 and 1996, respectively, and were restocked with grayling sac fry in 1997. Three additional lakes in Kananaskis Country were also stocked with grayling sac fry in 1997, but one winterkilled. It is hoped that eggs for future stocking of grayling can be collected from one of these four lakes, rather than from wild stocks.

Arctic Grayling Habitat Alterations

The responses of Arctic Grayling (Thymallus arcticus) to sediment from Yukon Placer Mining Operations

Ian. K. Birtwell[1], Don. J. McLeay[2], Gordon. F. Hartman[3], and J. Steve. Macdonald[4]

[1] Department of Fisheries and Oceans, Science Branch, Marine Environment and Habitat Sciences Division, West Vancouver BC
[2]McLeay Environmental Ltd., Victoria BC
[3]1217 Rose Anne, Nanaimo BC
[4] Department of Fisheries and Oceans, Science Branch, Marine Environment and Habitat Sciences Division, Cooperative Resource Management, Burnaby BC

The responses of Arctic grayling to sediment from Yukon placer mining operations were determined under controlled laboratory conditions and in the field. Sublethal responses were evoked during 4 day exposures to $\leq$ 250,000 mg•L^{-1} inorganic, and $\leq$ 50,000 mg•L^{-1} organic sediment in the laboratory; there was no evidence of gill damage. Mortalities only occurred at 5 °C with inorganic sediment concentrations $\geq$ 20,000 mg•L^{-1}. Exposure to sediment concentrations $\geq$ 1,000 mg•L^{-1} for 6 weeks resulted in impaired feeding, reduced growth rates, , and downstream displacement. Stress responses were recorded after 1-4 day exposures to organic sediment concentrations as low as 50 mg•L^{-1}. Inorganic sediment concentrations $\geq$ 10,000 mg•L^{-1} caused the fish to surface. In the Minto Creek drainage, Yukon Territory, underyearling grayling survived 4 and 5 day exposures in cages within the placer mined tributary Highet Creek ($\leq$ 1,210 mg•L^{-1} sediment), and in Minto Creek upstream of their confluence ($\leq$ 34 mg•L^{-1} sediment). Hematocrit values for fish at these locations were similar but plasma glucose levels (indicative of acute stress responses) were elevated in those fish held in the placer mined creek. Underyearling grayling were most abundant in the clear waters of the drainage and before the input of turbid waters from Highet Creek. Low numbers of underyearlings were captured in Highet Creek. Numbers increased in Minto Creek with downstream progression from the confluence with Highet Creek, and were also numerous in clear tributary streams. Highet Creek exhibited the lowest number of invertebrate taxa in drift samples, but the highest density (dominated by chironomid larvae). The greatest number of taxa in invertebrate drift samples occurred at sites unaffected by placer mining. The diet of underyearling grayling reflected the reliance upon drift organisms, especially chironomids. Despite the relatively high densities of prey (chironomids) for underyearling grayling in the waters of the placer mined creek, individuals were scarce, only using this tributary as suspended sediment levels decreased in response to a reduction of mining activities. While the majority of the gills of the underyearling grayling taken from the Minto Creek drainage area were normal, marked gill histopathologies were noted for older individuals. In the absence of parasitic infection the cause of the histopathologies was probably associated with exposure to sediment. We concluded that a major part of the Minto Creek drainage was used by grayling but that turbid waters induced by placer mining activities seemingly confined underyearlings to the less sediment-laden waters.

Arctic grayling (Thymallus arcticus) habitat creation and enhancement - stream habitat compensation at BHP Diamonds Inc. Ekati™ Mine, Northwest Territories

Craig J. Thomas [1], Mark Brobbel[1], and Derek Chubb[2]
[1]Dillon Consulting Limited, Yellowknife NT
[2]BHP Diamonds Inc., Ekati™ Mine, Yellowknife NT

BHP Diamonds Inc.'s (BHP) Ekati™ Mine is Canada's first diamond mine. Located approximately 300 km Northeast of Yellowknife, the Ekati™ Mine currently accesses kimberlite pipes through open pit mining techniques. Kimberlite, the parent geological material of the diamond-bearing pipes is typically covered by small glacial lakes which form within depressions left from the volcanic creation of these pipes. Over time, northern fish communities have inhabited many of these lakes. To access and mine the underlying kimberlite material lake de-watering and removal of the resident fish communities and associated habitats are required. Additionally, the diversion of connecting streams and lake tributaries has been necessary as a requirement of mine site development and operation. The end result of such activities is the harmful alteration and/or loss of fish habitat and the need for a Fish Habitat Compensation Plan to support a fisheries authorization approval as administered by the federal Department of Fisheries and Oceans (DFO). Initiated in 1994, BHP designed and constructed the 3.4-km Panda Diversion Channel to divert water flow from upper Panda Lake to Kodiak Lake and to target the maintenance of historic fish movement between these lakes. The constructed channel was designed, in part, to form the basis of subsequent habitat enhancement for stream habitat compensation of lost lake tributaries, a result of initial mine development. Channel construction was completed in the winter of 1997 with initial flows occurring during the spring freshet of the same year. A detailed Stream Habitat Compensation Plan was developed by BHP and approved by DFO prior to the open water season in May 1998. The primary focus of the plan was the creation and enhancement of fish habitat within the Panda Diversion Channel targeting migration, spawning and rearing habitat for Arctic Grayling *(Thymallus arcticus)*. As a component of the Fisheries Authorization and Compensation Plan, BHP's commitment to conduct post-construction/enhancement monitoring included the assessment of stability, function, and effectiveness of the constructed/enhanced habitat. This paper describes the monitoring results from 1998 and 1999 that relate to habitat design and constructed/enhanced stream habitat within the Panda Diversion Channel that targets the various life stages of Arctic Grayling. These results indicate that suitable habitat for all life stages of grayling are being established and maintained within the diversion channel.