1999 Summary Report

A Multi-Year Study to Evaluate the Effects of Land-Use on Fish:
Year 2: Fish Populations and Habitats in Selected Watersheds in the Foothills Model Forest

For
The Fisheries Management Enhancement Program of The Alberta Conservation Association

by
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Abstract

This study represents the second year of data collection to describe fish populations and habitats prior to evaluating the effects of land-use on these resources. Four new watersheds were sampled in 1999. These watersheds included Lynx, Fish, and Anderson creeks and the upper Erith River watershed. Fish community compositions, abundance, sizes, habitats and watersheds were described for each watershed. Brook trout and bull trout distributions and abundance differed between the monitoring watersheds in 1999. Rainbow trout population density estimates were also collected from Wampus and Deerlick creeks at locations that have been sampled for the previous 30 years. The densities for the 3 most accessible of the 4 sites on these creeks were lower than seen in previous years. Although natural variability of fish populations or changes to habitats from industrial land-use were potential explanations for this decrease, we suspect that illegal angling has been occurring and was likely contributing to this change.
Acknowledgements

The Alberta Conservation Association funded this project through the Fisheries Management Enhancement Program. Additional funding and support was received from the Foothills Model Forest and the Forest Resource Improvement Association of Alberta. These funds were provided through support of Weldwood of Canada (Hinton Division).

Several employees of Alberta Natural Resources Service, Fisheries Management Division, including George Sterling, Rudy Hawryluk, and Paula Siwik also assisted with this project. George reviewed study design. Both George and Rudy assisted with fieldwork and contributed field equipment. Cal McLeod, Sheldon Kowalchuk, George Sterling, and Rick Bonar provided critical reviews of this report.

The field crew from the Fish and Aquatics Program at the Foothills Model Forest for the summer of 1999 included Stephen Spencer, Cameron Davis, Jason Cooper, Mike Blackburn, and Chantel Bambrick.
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1. Introduction

1.1 Project Scope and Objectives

Fish distributions and habitats have been described in many streams within the Foothills Model Forest (Johnson and Spencer 1998). However, understanding how land-use activities have affected fish and fish habitats in this area has been limited. To increase the understanding of fish and land-use interactions, a multiple-year study was initiated in 1998.

1999 was the second year of the study to describe fish populations, habitat, and landuse in a variety of watersheds. This initial description will serve as a baseline with which future data can be compared. The overall objective of this study was to describe the cumulative effects of human use in the forest on fish populations. In this context, human use includes industrial and recreational uses.

Ideally, this study would include all streams within the study area. However, this goal is simply unattainable given the large size of the Foothills Model Forest (approximately 2,750,000 hectares) and limited resources. Therefore, for this investigation, the scale of the project has been reduced from a landscape scale to a watershed scale and only nine basins have been studied in detail; five in 1998 (McCleary and Johnson 2000) and four in 1999.

The main objective during the first year of the project in 1998 was to gather baseline information on fish populations and their habitats within selected watersheds. In 1999 four new watersheds were added to the study. After the initial descriptions have been made regarding the present status of fish species distribution and status in these watersheds, the focus of the study will shift to evaluating the effects of land-use activities on fish populations. At this time, landuse data will be described and presented for each of these watersheds.

1.2 Study Area

All or part of each study watershed is located within the Forest Management Agreement area (FMA) operated by Weldwood of Canada (Hinton Division) and the Foothills Model Forest (Figure 1).
Figure 1. The Foothills Model Forest and its location within the province of Alberta.
2. Methods

2.1 Selection of Study Watersheds

Five small watersheds were studied in 1998 (McCleary and Johnson 2000). These watersheds included Wampus, Deerlick, MacKenzie, Moon, and Solomon creeks. Four additional watersheds were included for study in 1999. Two of the watersheds sampled in 1998 were re-sampled in 1999.

Four of the six watersheds were selected because forest harvesting by Weldwood had occurred or was proposed, and were of interest to both Weldwood and Alberta Environment, Natural Resources Service (NRS). These watersheds included Lynx, Anderson, and Fish creeks and the upper Erith River (Figure 2). The data collected from these basins may serve as baseline information for future monitoring efforts as development proceeds.

The two watersheds re-sampled in 1999 include Wampus and Deerlick creeks from the Tri-Creeks Experimental Watershed Area. Researchers have studied the relationships between fish population dynamics and land-use within the Tri-Creeks Experimental Watershed Area for more than three decades (Sterling 1990). Fish population densities collected since 1970 provides a unique opportunity to monitor the changes in fish populations over a long period of time. Continuity of the data set through annual monitoring is a desired objective of both NRS (Edson) and Weldwood. The information collected from Tri-Creeks will allow the analysis of long-term trend data.
Figure 2. Map of the 1998 and 1999 monitoring watersheds within the study area.
2.2 Watershed Description

A classification of natural sub-regions based on topography, elevation, climate and vegetation was completed throughout Alberta (Alberta Environmental Protection 1994). The area of these natural sub-regions within each study watershed was determined using ArcView (ESRI 1997).

Physical attributes of the different watersheds were calculated from spatial data projected in NAD27 using a procedure called Hydrology Attributes Generated from a Geographic Information System (HAGGIS), formerly known as the Watershed Assessment Model (WAM) (Traynor 1997). HAGGIS is a procedure in ARC/INFO (ERSI 1998), that generates various physiographic and land-use density attributes related to a particular point on a stream. The streams used in this analysis were generated from a 25m digital elevation model using HAGGIS. Streams originated where the upslope area exceeded 6.5 ha (100 cells that were 25m x 25m). Selected watershed descriptors from the model that were used during the present study were:

1) drainage area (km\(^2\))
2) stream order at mouth
3) gradient of channel at site (% slope)

2.3 Inventory of Fish and Fish Habitat

Field methods were consistent with those used by the Foothills Model Forest in previous years (Johnson and Spencer 1998; Johnson and Spencer 1999). These methods are described below.

2.3.1 Site Location

There were two methods for site selection. For the streams within the Tri-Creeks Experimental Watershed Area (Deerlick and Wampus creeks), sample locations were identical to those selected by previous researchers (Sterling 1990). For all other watersheds, sites were selected first from the range of stream orders available and secondly by their accessibility by all-terrain-vehicle or truck. The selected sites were intended to provide a representative sample of habitats and therefore fish populations within the mainstem and tributary streams (Figure 3 - Figure 7).
Figure 3. Map of sample locations within Lynx Creek watershed.
Figure 4. Map of sample sites within Fish Creek watershed.
Figure 5. Map of sample locations within Anderson Creek watershed.
Figure 6. Map of sample locations within Wampus and Deerlick Creeks.
Figure 7. Map of sample locations within the upper Erith River watershed.
The number of sites selected for each watershed varied with access and basin size (Table 1). Most sites were sampled during both spring and summer to describe potential differences in seasonal use by the different fish species that inhabit the study area.

Table 1. Number of locations and sample visits within each monitoring watershed, 1996-99.

<table>
<thead>
<tr>
<th>Watershed Name</th>
<th>1996*</th>
<th>1997*</th>
<th>1998*</th>
<th>1999</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sites</td>
<td>Visits</td>
<td>Sites</td>
<td>Visits</td>
<td>Sites</td>
</tr>
<tr>
<td>Lynx Creek</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
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<tr>
<td>Fish Creek</td>
<td>3</td>
<td>3</td>
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<td>5</td>
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</tr>
<tr>
<td>Anderson Creek</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>upper Erith River</td>
<td>6</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Wampus Creek</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Deerlick Creek</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>17</td>
<td>18</td>
<td>11</td>
<td>16</td>
<td>14</td>
</tr>
</tbody>
</table>

* Sites sampled prior to establishing the monitoring program in these watersheds

Between 1996 and 1999, a total of 95 sites were sampled in the 6 watersheds (Table 1). In 1999, between 17 and 26 different locations were sampled in the four new study watersheds. Both Wampus and Deerlick creeks had a total of 3 sites sampled in each. Two of the sites in each of these watersheds have been sampled annually since 1996. With the exception of population density data for Wampus and Deerlick creeks, only those data collected in 1999 will be presented in this report.

2.3.2 Site Layout

In the field, the downstream location of each site was determined using a handheld global positioning system (GPS) unit. Although most sample sites were 300 meters in length for backpack electrofishing, some were shorter because of physical restrictions within the stream (e.g. excessive depths, the stream flows underground, beaverdams, etc.). The length of each site was recorded for future calculations of site area. Sites were divided with transects located in 50 m intervals upstream of the starting point and were oriented perpendicular to the thalweg. Fish and habitat data were collected at each transect.
2.3.3 Fish Inventory

The method used to capture fish most often was backpack electrofishing. Although different Smith-Root backpack electrofishers with pulsed DC current were used (Type 12-A, XI-A, and VII), similar power settings were used whenever possible. On most occasions, 1 crew of 2 people would inventory a site. All electrofishing was done in accordance with the Alberta NRS electrofishing policy and safety guidelines (Kraft, et al. 1982). At each inventory site, sampling duration (seconds electrofished) was recorded. Alternate sampling techniques were employed where backpack electrofishing was not possible. These techniques included angling, gillnetting, and minnow trapping.

While backpack electrofishing small streams, fish were sampled at each 50 meter transect and released. Biological data collected from fish included: species, fork length (to nearest mm), sex, and state of maturity (when possible). We also collected total body weight (to the nearest 0.1g), from most fish using an Ohaus electronic balance. Fish species were recorded using the species codes outlined in Mackay et al. (1990). Complete necropsies of any incidental mortalities were performed with the following additional data collected: sex, state of maturity, and ageing structures.

2.3.4 Habitat Inventory

Habitat data measured at each site included stream widths, depths, and water temperature. Wetted and rooted (bankfull) widths were measured to the nearest 0.1 meter at each transect. Wetted stream width was the width of the wetted portion of the stream channel. The rooted stream width was the width of the stream channel between woody vegetation (trees or shrubs), on either bank, measured at the base of the stem. To measure water depths, the stream was divided into thirds (left, center and right) across each transect. At the estimated mid-point in each third, depth was measured to the nearest 0.01 meter. Air and water temperatures were measured (usually at the first transect) to the nearest 1°C using an alcohol thermometer (-35°C to +50°C).

Estimated habitat parameters included substrate composition, available cover composition, bank stability and potential obstructions to fish passage. To ensure consistency, these estimates were discussed between both workers present. Substrate composition was estimated as the percentage of each substrate type [fines (clay, sand, silt <2mm), small gravel (2-16mm), large gravel (17-64mm), small cobble (65-128mm), large cobble (129-256mm), boulder (>256mm), and bedrock] present at each transect. Substrates were estimated at 3 points across the channel (right, center,
and left). Available cover composition was estimated as a percentage of the cover types available between each 50 meter transect. The cover types estimated included surface turbulence, instream debris, terrestrial canopy, and undercuts. The stability of each bank was ranked on a scale from stable (1), to unstable (4) for the 50m section between transects. Potential obstructions to fish passage (beaver dams, waterfalls, chutes, etc.) were noted and described as well.

Habitat potential was a subjective rating of either low, medium or high for the entire inventory site. The categories for habitat potential were rearing, over-wintering, and spawning habitats for salmonids. Rearing habitats were defined as those areas with refugia for small fish such as debris, rocks, aquatic vegetation, etc. If young-of-the-year were captured in the section, a rating of good was assigned for rearing potential. Over-wintering habitat potential was based on the size and abundance of pools. Good spawning habitats were assumed to have clean substrates of an appropriate size. The results from these subjective ratings were discussed between the two members of the field crew. Throughout the summer, field staff switched between crews in order to improve the overall consensus in the application of this rating.

In 1999, field crews also classified fish habitats using a visual guide by Johnson et al. (1998). This improved both the consistency and precision of habitat information collected by a variety of field workers.

Representative photographs of each site were taken using 35mm cameras. Any unusual phenomenon encountered was photographed as well.

Water temperatures were measured every 45 minutes near the mouth of each monitoring watershed (Figure 8) during the summer. These temperatures were measured and recorded using a remote data-logger called a Hobo Temp (Onset Computer Corporation). All temperature data were downloaded from the Hobo Temps using Boxcar V.2.06 (Onset 1996) and imported to a Microsoft Excel spreadsheet for analyses.
Figure 8. The location of monitoring stations near mouths of each watershed where water temperatures were recorded.
2.4 Data Management and Analyses

Data were entered into a relational database developed by the Foothills Model Forest that is resident in Microsoft Access 97. Each site was given a 5-digit number (e.g. 99001) that became a unique identifier. The first two digits of the number referred to the year (e.g. 1999) while the last three digits were a sequential identifier. Maps identifying sample sites were produced. Quality control checks were performed using several methods. First, field notes were compared with database output reports and mapped site locations. Second, data were plotted graphically to identify outliers that may have occurred during field measurement or data entry.

Standard inventory reports and associated map products (FMF 1996, FMF 1997, FMF 1998, FMF 1999) were generated from the database for each inventory site and distributed to the local land managers and partners of the Foothills Model Forest including Weldwood, NRS (Edson), and the ACA. Summary statistics were generated for fish data (minimum, maximum and mean fork lengths) for each species and mean values for habitat parameters. In addition to these summary statistics, fork length frequency distributions (by electrofishing catch rate) were generated when 15 or more individuals of the same species were captured at a site.

Depletion-removal or Zippin-type population estimates (Zippin 1958) were recommended by Rimmer (1984) and by local fisheries managers (C. Hunt, Natural Resources Service, pers. comm. 1995). Data for these estimates were collected over a reach that was usually 300 m in length. Block nets were installed at the upstream and downstream ends of the study reach in order to restrict immigration and emigration of fish. Population estimate data were analyzed using MicroFish 3.0 (Van Deventer and Platts 1989). Confidence intervals (95%) were also calculated using MicroFish 3.0. Population estimates were converted to density estimates (number of fish/0.1 ha) by calculating the wetted surface area of the study section (length*mean wetted width) and applying the population estimate to this value. This conversion to a density estimate was done to allow for comparisons of fish populations in streams of different size. In 1999, population estimates were completed in Wampus and Deerlick creeks at locations where population density data existed from previous research (Sterling 1990). The sites chosen for population estimates were located within study reaches established by Sterling (1990) at upper (WE) and lower (WA) Wampus Creek and upper (DB) and lower (DA) Deerlick Creek. Rainbow trout population density data for these sites prior to 1992 (Sterling 1990) are presented in the "Results" section for comparative purposes. Population density data collected in 1993 at lower Wampus and Deerlick creeks (NRS unpublished data) were also included. From 1996-1998,
population density estimates were collected as part of the Foothills Model Forest inventory and monitoring program (FMF 1996, FMF 1997, FMF 1998) at these locations.
3. Results

3.1 Physical Characteristics of Monitoring Watersheds

3.1.2 Study Watersheds and Natural Sub-Regions

At least half of each watershed sampled in 1999 were located within the upper foothills natural sub-region (Table 2). The lower foothills region was represented in Lynx and Fish creeks and a portion of the Anderson Creek watershed was located in the sub-alpine. The entire upper Erith River watershed was within the upper foothills natural sub-region. Neither the alpine or montane natural sub-regions were present in any of the new watersheds sampled in 1999.

Table 2. Distributions within the four study watersheds of natural sub-region types available in the Foothills Model Forest; 1999.

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Alpine (% area)</th>
<th>Sub-Alpine (% area)</th>
<th>Upper Foothills (% area)</th>
<th>Lower Foothills (% area)</th>
<th>Montane (% area)</th>
<th>Total Area (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lynx Creek</td>
<td>0</td>
<td>0</td>
<td>61.0</td>
<td>39.0</td>
<td>0</td>
<td>84.0</td>
</tr>
<tr>
<td>Fish Creek</td>
<td>0</td>
<td>0</td>
<td>50.2</td>
<td>49.8</td>
<td>0</td>
<td>49.9</td>
</tr>
<tr>
<td>Anderson Creek</td>
<td>0</td>
<td>24.2</td>
<td>75.8</td>
<td>0</td>
<td>0</td>
<td>75.0</td>
</tr>
<tr>
<td>upper Erith River</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>126.0</td>
</tr>
</tbody>
</table>
3.1.3 Water Temperature
Water temperatures were collected using remote recorders from July to October. During July, daily maximum water temperatures were highest in Lynx, Fish and the upper Erith watersheds (Figure 9). In August, daily maximum water temperatures averaged 12°C or higher in all watersheds except Anderson Creek, which averaged 11°C. The maximum daily water temperatures in September were highest in Lynx, Fish and Erith watersheds. During October, Anderson Creek had the highest daily maximum temperatures.

Figure 9. Daily maximum water temperature averaged by month for six watersheds.
During the month of July, daily water temperature range (daily maximum – daily minimum) was highest in Deerlick Creek watershed (Figure 10). In August, average daily temperature range was highest in Fish Creek watershed. In September and October, daily water temperature range was the highest in Erith River watershed. Daily water temperature range was lowest in Wampus Creek during all months.

Figure 10. Daily temperature range (daily maximum – daily minimum) averaged by month for six watersheds.
In the Lynx, Fish and Erith watersheds, daily water temperature exceeded 10°C on more than 50 of the 62 days during the months of July and August (Figure 11). In the Lynx and Erith watersheds, daily water temperature exceeded 15°C on more than 15 days during July and August. In the Fish Creek watershed, daily water temperatures exceeded 15°C on two days, while in Anderson, Wampus and Deerlick watersheds, water temperatures never exceeded 15°C during the summer of 1999.

![Bar Chart]

Figure 11. Number of days that maximum water temperature exceeded 10° C and 15°C during July and August 1999 in six watersheds.
3.2 Description of Fish Habitat and Fish Distribution

The organization for the following section is as follows. Each watershed was described in succession, from the most northern watershed to the most southern watershed. The description was presented in text, tables, watershed maps and also through representative photographs. The tables contain data that were generated by HAGGIS (order, elevation, gradient), as well as information from the field surveys (all other variables). Representative photographs are presented in Appendix 1 (Plates 1-76).

3.2.1 Lynx Creek Watershed

Eighteen different locations were surveyed within the Lynx Creek watershed (Table 3 and Plates 1-16). These sites were distributed throughout the watershed in an attempt to describe fish species distributions and habitats at a variety of stream orders, gradients, and sizes in the watershed. The gradients of sites sampled in the Lynx Creek watershed varied from 0.1% slope at Location 12 to 4.9% slope at Location 7. Small and large cobbles were the dominant substrates at most locations in the watershed and fine substrates were found to be the dominant substrate most often. Instream cover was dominated by undercut banks. Surface turbulence and large woody debris were other cover types seen frequently. Fish were captured at 61% of the locations sampled. At those locations found to support fish, rooted stream width varied from a minimum of 3.3 m at Location 16 (Plate 16), to a maximum of 13.3 m at Location 2 (Plate 2). Similar results were found for stream order. Fish were captured at sites that varied in order from 1-5, the range of orders available in the Lynx Creek watershed.
Table 3. Summary of fish habitat and species distribution from sites sampled in the Lynx Creek watershed in 1999.

<table>
<thead>
<tr>
<th>Stream</th>
<th>Location</th>
<th>Order</th>
<th>Elevation (m)</th>
<th>Gradient (% slope)</th>
<th>Site ID</th>
<th>Date</th>
<th>Rooted Stream Width (m)</th>
<th>Dominant Substrate(^1)</th>
<th>Total Cover (%)(^2)</th>
<th>Dominant Cover Type(^3)</th>
<th>Catch Rate by Sport Species (#fish/100m(^2))^4</th>
<th>Total Catch Rate (#fish/100m(^2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lynx Creek</td>
<td>1</td>
<td>5</td>
<td>1000</td>
<td>0.3</td>
<td>99068</td>
<td>13-Jun-99</td>
<td>12.6</td>
<td>boulder</td>
<td>34</td>
<td>surf. turb.</td>
<td>2.1</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>99176</td>
<td>22-Sep-99</td>
<td>9.6</td>
<td>sm. cobble</td>
<td>33</td>
<td>surf. turb.</td>
<td>2.9</td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5</td>
<td>1015</td>
<td>0.5</td>
<td>99032</td>
<td>31-May-99</td>
<td>9.9</td>
<td>lg. cobble</td>
<td>48</td>
<td>undercut</td>
<td>2.0</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>99175</td>
<td>22-Sep-99</td>
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</tr>
<tr>
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<td>5</td>
<td>1021</td>
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<td>13-Jun-99</td>
<td>9.9</td>
<td>boulder</td>
<td>37</td>
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<td>2-Jun-99</td>
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<td>fines</td>
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</tr>
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<tr>
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<td>78</td>
<td>terr. can.</td>
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<tr>
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<td>5</td>
<td>1015</td>
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<td>99033</td>
<td>31-May-99</td>
<td>4.7</td>
<td>lg. cobble</td>
<td>55</td>
<td>LWD</td>
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<td>1045</td>
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<td>13-Jun-99</td>
<td>n/a</td>
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<td>73</td>
<td>LWD</td>
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<td>99039</td>
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<td>3.8</td>
<td>boulder</td>
<td>125</td>
<td>undercut</td>
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<td>1.3</td>
<td>fines</td>
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<td>4.4</td>
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<td>99048</td>
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<td>fines</td>
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<td>sm. cobble</td>
<td>59</td>
<td>undercut</td>
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<td>99182</td>
<td>28-Sep-99</td>
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<td>sm. cobble</td>
<td>74</td>
<td>undercut</td>
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<td>2.8</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>3</td>
<td>1056</td>
<td>0.9</td>
<td>99063</td>
<td>12-Jun-99</td>
<td>3.3</td>
<td>fines</td>
<td>81</td>
<td>terr. can.</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Trib. to #5</td>
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<td>3</td>
<td>1057</td>
<td>1.4</td>
<td>99060</td>
<td>12-Jun-99</td>
<td>3.6</td>
<td>fines</td>
<td>91</td>
<td>LWD</td>
<td>0.0</td>
<td>0.0</td>
</tr>
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<td>1069</td>
<td>1.1</td>
<td>99043</td>
<td>2-Jun-99</td>
<td>3.8</td>
<td>sm. cobble</td>
<td>73</td>
<td>LWD</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

1. Dominant substrate from the following categories: fines, small gravel, large gravel, small cobble, large cobble, boulder and bedrock.
2. Total cover equals the sum of estimated percent cover from the four cover types evaluated during this survey.
3. The four cover types include: surface turbulence, undercut banks, large woody debris and terrestrial canopy.
4. Fish species: BKTR = brook trout, BLTR = bull trout, MNWH = mountain whitefish, RNTR = rainbow trout.
Four of the five species captured in the Lynx Creek watershed in 1999 were sport-species (Table 4). These included brook trout \((Salvelinus fontinalis)\), rainbow trout \((Oncorhynchus mykiss)\), mountain whitefish \((Prosopium williamsoni)\), and burbot \((Lota lota)\). Longnose sucker \((Catostomus catostomus)\) was the only non sport-species captured. More rainbow trout were captured (92.5 % of total catch) than any other species. With the exception of burbot, fewer than 10 individuals from each species were represented in the sample.

Table 4. Summary of total catch by fish species for four watersheds sampled during 1999.

<table>
<thead>
<tr>
<th>Species</th>
<th>Lynx Creek</th>
<th>Fish Creek</th>
<th>Anderson Creek</th>
<th>upper Erith River</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td># captured</td>
<td>% composition</td>
<td># captured</td>
<td>% composition</td>
</tr>
<tr>
<td>ARGR</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>BKTR</td>
<td>1</td>
<td>0.2%</td>
<td>133</td>
<td>35.1%</td>
</tr>
<tr>
<td>BLTR</td>
<td>0</td>
<td>0.0%</td>
<td>4</td>
<td>1.1%</td>
</tr>
<tr>
<td>BURB</td>
<td>23</td>
<td>5.4%</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>LNDC</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>LNSC</td>
<td>3</td>
<td>0.7%</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>MNWH</td>
<td>5</td>
<td>1.2%</td>
<td>9</td>
<td>2.4%</td>
</tr>
<tr>
<td>PRDC</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>RNTR</td>
<td>393</td>
<td>92.5%</td>
<td>232</td>
<td>61.4%</td>
</tr>
<tr>
<td>SPSC</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>TRPR</td>
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<td>0.0%</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>WHSC</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>TOTALS</td>
<td>425</td>
<td></td>
<td>378</td>
<td></td>
</tr>
</tbody>
</table>


Rainbow trout had the widest distribution of any species captured in the Lynx Creek watershed (Figure 12). The other species captured were restricted to the lower portion of the watershed. Locations where no fish were captured were usually the mid to upper reaches of tributary streams.
Figure 12. Summary of fish distribution within Lynx Creek watershed.
3.2.2 Fish Creek Watershed

Seventeen different sites were surveyed within the Fish Creek watershed (Table 5 and Plates 17-32). The sites sampled ranged in gradient from 1.2% slope at Location 2 to 6.9% slope at Location 11. Boulders were the dominant substrate type at most of the sites sampled followed by fines, cobbles, and gravel. Instream cover was dominated by undercut banks at most locations. Surface turbulence, terrestrial canopy, and large woody debris were also represented as dominant cover-types at some of the locations. Where fish were captured, rooted stream width varied from 1.1 m at Location 17 (Plate 32), to 9.0 m at Location 2. Similar results were found for stream order. Fish were captured at sites that varied in order from 1-5, the range of orders available in the Fish Creek watershed.
Table 5. Summary of fish habitat and species distribution from sites sampled in the Fish Creek watershed in 1999.

<table>
<thead>
<tr>
<th>Stream</th>
<th>Location</th>
<th>Order</th>
<th>Elevation (m)</th>
<th>Gradient (% slope)</th>
<th>Site ID</th>
<th>Date</th>
<th>Rooted Stream Width (m)</th>
<th>Dominant Substrate¹</th>
<th>Total Cover (%)²</th>
<th>Dominant Cover Type³</th>
<th>Catch Rate by Sport Species (#fish/100m²)⁴</th>
<th>Total Catch Rate (#fish/100m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish Creek</td>
<td>1</td>
<td>5</td>
<td>961</td>
<td>2.0</td>
<td>99002</td>
<td>11-May-99</td>
<td>7.4 lg. cobble</td>
<td>terr. can.</td>
<td>0.3</td>
<td>0.1</td>
<td>0.1 0.1 0.1 0.5</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>99159</td>
<td>5-Sep-99</td>
<td>7.1 sm. cobble</td>
<td>terr. can.</td>
<td>0.7</td>
<td>0.5</td>
<td>0.5 0.5 0.5 1.6</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5</td>
<td>969</td>
<td>1.6</td>
<td>99003</td>
<td>11-May-99</td>
<td>9.0 sm. cobble</td>
<td>terr. can.</td>
<td>1.0</td>
<td>0.1</td>
<td>0.1 0.1 0.1 1.4</td>
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</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>99160</td>
<td>5-Sep-99</td>
<td>8.1 boulder</td>
<td>undercut</td>
<td>1.2</td>
<td>0.7</td>
<td>0.2 0.2 0.2 2.0</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>5</td>
<td>1084</td>
<td>2.6</td>
<td>99097</td>
<td>12-Jul-99</td>
<td>7.8 sm. cobble</td>
<td>surf. turb.</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5 0.5 0.5 1.0</td>
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<td>99173</td>
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<td>surf. turb.</td>
<td>2.8</td>
<td>3.3</td>
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<td>1108</td>
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<td>7.3 lg. cobble</td>
<td>surf. turb.</td>
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<td>0.6 0.6 0.6 2.3</td>
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<td>7.7 boulder</td>
<td>terr. can.</td>
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<tr>
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<td>5</td>
<td>1230</td>
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<td>6.4 boulder</td>
<td>surf. turb.</td>
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<td>2.8 boulder</td>
<td>undercut</td>
<td>1.1</td>
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<tr>
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<td>1312</td>
<td>3.6</td>
<td>99093</td>
<td>11-Jul-99</td>
<td>3.4 fines</td>
<td>undercut</td>
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<td>1322</td>
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<td>99094</td>
<td>11-Jul-99</td>
<td>1.9 fines</td>
<td>undercut</td>
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<tr>
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<td>12-Jul-99</td>
<td>1.7 boulder</td>
<td>65 surf. turb.</td>
<td>1.4</td>
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<td>1307</td>
<td>6.9</td>
<td>99091</td>
<td>11-Jul-99</td>
<td>1.1 fines</td>
<td>100 terr. can.</td>
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<td>2.6 lg. gravel</td>
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<td>1330</td>
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<td>99105</td>
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<td>2.1 lg. gravel</td>
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<td>1312</td>
<td>3.6</td>
<td>99101</td>
<td>13-Jul-99</td>
<td>2.4 lg. cobble</td>
<td>75 surf. turb.</td>
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<td>99102</td>
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<td>1323</td>
<td>3.6</td>
<td>99103</td>
<td>13-Jul-99</td>
<td>1.1 boulder</td>
<td>92 undercut</td>
<td>2.0</td>
<td></td>
<td>2.0 2.0 2.0 2.0</td>
<td>2.0</td>
</tr>
</tbody>
</table>

1. Dominant substrate from the following categories: fines, small gravel, large gravel, small cobble, large cobble, boulder and bedrock.
2. Total cover equals the sum of estimated percent cover from the four cover types evaluated during this survey.
3. The four cover types include: surface turbulence, undercut banks, large woody debris and terrestrial canopy.
4. Fish species: BKTR = brook trout, BLTR = bull trout, MNWH = mountain whitefish, RNTR = rainbow trout.
Rainbow trout, brook trout, bull trout (*S. confluentus*), and mountain whitefish were captured in the Fish Creek watershed (Table 4). Rainbow trout represented 61.4% of the total catch in the watershed, followed by brook trout at 31.5%. Four bull trout and nine mountain whitefish were captured in the Fish Creek watershed.

As with the Lynx Creek watershed, rainbow trout were distributed throughout the Fish Creek watershed (Figure 13). Brook trout, bull trout, and mountain whitefish were captured in the lower portion of the watershed. Fish were not captured at three locations. These sites were located at the upper reaches of the mainstem or tributary streams.
Figure 13. Summary of fish distribution within Fish Creek watershed.
3.2.3 Anderson Creek Watershed

Sampling occurred at 21 locations throughout the Anderson Creek watershed (Table 6 and Plates 33-50). The gradient or slope of these sites ranged from 1.9% at Location 14 to 5.5% at Location 21. Substrate types varied between sites, with fines, gravels, and cobbles represented. The dominant substrate seen most frequently was small cobble. Undercut banks were the dominant cover-type available for fish, followed by surface turbulence, terrestrial canopy, and large woody debris. Stream size varied from a rooted width of 1.1-12.7 m. The smallest stream that fish were captured in was 1.6 m wide. Stream orders ranging from 1-5 were sampled throughout the watershed. Fish were captured through the entire range of orders in the watershed.
Table 6. Summary of fish habitat and species distribution from sites sampled in the Anderson Creek watershed in 1999.

<table>
<thead>
<tr>
<th>Stream</th>
<th>Location</th>
<th>Order</th>
<th>Elevation (m)</th>
<th>Gradient (% slope)</th>
<th>Site ID</th>
<th>Date</th>
<th>Rooted Stream Width (m)</th>
<th>Dominant Substrate¹</th>
<th>Total Cover (%)²</th>
<th>Dominant Cover Type³</th>
<th>Catch Rate by Sport Species (#fish/100m²)⁴</th>
<th>Total Catch Rate (#fish/100m²)</th>
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<td>LWD</td>
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</tbody>
</table>

1. Dominant substrate from the following categories: fines, small gravel, large gravel, small cobble, large cobble, boulder and bedrock.
2. Total cover equals the sum of estimated percent cover from the four cover types evaluated during this survey.
3. The four cover types include: surface turbulence, undercut banks, large woody debris and terrestrial canopy.
4. Fish species: BKTR = brook trout, BLTR = bull trout, MNWH = mountain whitefish, RNTR = rainbow trout.
Similar to the Lynx Creek watershed, five species of fish were captured in the Anderson Creek watershed (Table 4). These species included four sport species and one non-sport species. Rainbow trout represented 71.7% of the catch in the watershed. Bull trout was the second most numerous species at 23.3% of the total catch. Each of the other species (burbot, mountain whitefish, and longnose dace (*Rhinichthys cataractae*) represented less than 4% of the overall catch.

Bull trout and rainbow trout were distributed through most of the Anderson Creek watershed where fish were captured (Figure 14). Rainbow trout distribution was slightly more extensive, with individuals captured in some of the upper reaches of the mainstem and tributaries.
Figure 14. Summary of fish distribution within Anderson Creek watershed.

rntr = Rainbow Trout
bltr = Bull Trout
mnwh = Mountain Whitefish
burb = Burbot
n.f.c. = No Fish Captured

Streams
Sample Sites
Watershed Boundary

2 0 2 4 K i l o m e t e r s
3.2.4 Upper Erith River Watershed

The upper Erith River watershed was sampled in 26 different locations located throughout the basin (Table 7 and Plates 51-76). The gradients of these locations varied from 0.5% at Location 2 to 7.8% at Location 4. Fines were the dominant substrate seen at most of these sites. Large gravel was the only other dominant substrate type reported. Undercut banks, large woody debris, terrestrial canopy, and surface turbulence were the dominant cover types reported. Of these, undercut banks were reported most frequently at these locations. The rooted widths of the locations sampled varied from 0.9-9.2 m. Fish were captured at all of the stream orders available in the upper Erith River watershed, ranging from 1-5.
Table 7. Summary of fish habitat and species distribution from sites sampled in the upper Erith River watershed in 1999.

<table>
<thead>
<tr>
<th>Stream</th>
<th>Location</th>
<th>Order</th>
<th>Elevation (m)</th>
<th>Gradient (% slope)</th>
<th>Site ID</th>
<th>Date</th>
<th>Rooted Stream Width (m)</th>
<th>Dominant Substrate¹</th>
<th>Total Cover (%)²</th>
<th>Dominant Cover Type³</th>
<th>Catch Rate by Sport Species (#/fish/100m²)</th>
<th>Total Catch Rate (#/fish/100m²)</th>
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<td>undercut</td>
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<td>fines</td>
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<td>20</td>
<td>terr. can.</td>
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<td>0.0</td>
</tr>
</tbody>
</table>

1. Dominant substrate from the following categories: fines, small gravel, large gravel, small cobble, large cobbles, boulder and bedrock.
2. Total cover equals the sum of estimated percent cover from the four cover types evaluated during this survey.
3. The four cover types include: surface turbulence, undercut banks, large woody debris and terrestrial canopy.
4. Fish species: BKTR = brook trout, BLTR = bull trout, MNWH = mountain whitefish, RNTR = rainbow trout.
The upper Erith River watershed had the highest species richness of all watersheds sampled in 1999 with 10 species (Table 4). Half of the species captured were sport species. Of the sport species, rainbow trout were the most numerous, accounting for 83.3% of the total catch. Mountain whitefish were the second most numerous species at 8.0% of the total. The remaining sport species represented 1% or less of the total catch. The upper Erith River was the only location that Arctic grayling (*Thymallus arcticus*) were captured in 1999. The other species captured were longnose and white sucker (*C. commersoni*), pearl dace (*Margariscus margarita*), spoonhead sculpin (*Cottus ricei*), and trout-perch (*Percopsis omiscomaycus*).

As with the other watersheds sampled in 1999, rainbow trout had the widest distribution of all species captured in the upper Erith River watershed (Figure 15). Bull trout were captured along with rainbow trout at three of the locations sampled in the upper portion of the watershed. Mountain whitefish and Arctic grayling, the other sport-species captured, were found at three of the locations on the mid-reaches of the mainstem. Fish were not captured at five locations in the watershed. These locations were found in the upper reaches and small tributaries to the Erith River.
Figure 15. Summary of fish distribution within upper Erith River watershed.
3.3 Description of Fish Abundance and Size

3.3.1 Bull Trout

3.3.1.1 Catch Rates

Bull trout were captured in three of the four watersheds. Anderson Creek had the highest catch rate, followed by the upper Erith River then Fish Creek (Figure 16). No bull trout were captured in the Lynx Creek watershed.

Figure 16. Catch rates for 1999 bull trout sites within the four study watersheds (catch rate = total # of bull trout captured from single pass or first pass electrofishing from all bull trout sites / total area sampled from bull trout sites).
3.3.1.3 Size Distribution

The size distribution of bull trout in Anderson Creek ranged from 60-270mm fork length (Figure 17). Most of the bull trout captured were between 110-140mm. The mean for the sample was 119mm. The distribution for fish greater than 170mm were patchy, with few individuals represented in these size-classes. There were not a sufficient number of bull trout captured in the Fish Creek and upper Erith River watersheds to describe the fork length frequency distributions.

![Length-frequency distribution for bull trout captured in Anderson Creek watershed in 1999.](image)

Figure 17. Length-frequency distribution for bull trout captured in Anderson Creek watershed in 1999.
3.3.2 Rainbow Trout

3.3.2.1 Catch Rates

Rainbow trout were captured in all four watersheds. The upper Erith River and Lynx Creek had the highest catch rates for rainbow trout (Figure 18). Anderson and Fish creeks had the lowest catch rates for rainbow trout ranging from 0.8 to 1.25 fish / 100m$^2$ respectively.

![Catch rates for 1999 rainbow trout sites within the four study watersheds](image)

Figure 18. Catch rates for 1999 rainbow trout sites within the four study watersheds (catch rate = total # of rainbow trout captured from single pass or first pass electrofishing from all rainbow trout sites / total area sampled from rainbow trout sites).

3.3.2.3 Size Distribution

The minimum sizes of rainbow trout captured in the four watersheds were similar and ranged from 40-50 mm fork length (Figures 19-22). The majority of the distributions were also similar with most of the fish being in the 90-180 mm size-classes, and maximum sizes of 240-250 mm. Lynx Creek and Fish Creek were the only watersheds sampled where rainbow trout larger than 300 mm fork length were captured. In both of these streams, these large rainbow trout were captured from locations near the creek mouths during May and June. The mean length for rainbow trout in the Lynx Creek watershed was the lowest of the four watersheds sampled. This was a result of the large number of small individuals captured. Lynx Creek and the upper Erith
River watersheds had the greatest sample sizes and the highest total catch rates for rainbow trout. Lynx Creek and the upper Erith River watersheds had the smallest mean fork lengths. The relative abundance of fish smaller than 180 mm was lowest in the Fish Creek and Anderson Creek watersheds. These watersheds also had the largest mean fork length of the four watersheds sampled.
Figure 19. Length-frequency distribution for rainbow trout captured in Lynx Creek watershed in 1999.

Figure 20. Length-frequency distribution for rainbow trout captured in Fish Creek watershed in 1999.
Figure 21. Length-frequency distribution of rainbow trout captured in Anderson Creek in 1999.

Figure 22. Length-frequency distribution for rainbow trout captured in the upper Erith River watershed in 1999.
3.3.3 Mountain Whitefish

3.3.3.1 Catch Rates

Mountain whitefish were captured in all four study watersheds. The upper Erith River had the highest catch rate, followed by Anderson, Fish and Lynx creeks (Figure 23).

![Mountain whitefish catch rate graph](image)

Figure 23. Catch rates for 1999 mountain whitefish sites within the four study watersheds (catch rate = total # of mountain whitefish captured from single pass or first pass electrofishing from all mountain whitefish sites / total area sampled from mountain whitefish sites).
3.3.3.3 Size Distribution

The size distribution of mountain whitefish in the upper Erith River ranged from 70-270 mm fork length (Figure 24). The distribution was patchy, with most of the individuals caught being 70-90 mm in length. There was not a sufficient number of mountain whitefish captured in the Lynx Creek, Anderson Creek, and Fish Creek watersheds to describe the fork length frequency distributions.

Figure 24. Length-frequency distribution for mountain whitefish captured in the upper Erith River watershed in 1999.
3.3.4 Brook Trout

3.3.4.1 Catch Rates

Fish and Lynx creeks were the only watersheds in this study where brook trout were captured (Figure 25). Brook trout were not captured in Anderson Creek or the upper Erith River.

Figure 25. Catch rates for 1999 brook trout sites within the four study watersheds (catch rate = total # of brook trout captured from single pass or first pass electrofishing from all brook trout sites / total area sampled from brook trout sites).
3.3.4.4 Size Distribution

The size distribution of brook trout in Fish Creek ranged from 50-230 mm fork length (Figure 26). Two modes were present at 60 mm and 110 mm. Although most of the fish were represented in the median size-classes, there was a good representation of both smaller and larger brook trout. The mean fork length of brook trout captured in the Fish Creek watershed was 112 mm. There was not a sufficient number of brook trout captured in the Lynx Creek watershed to describe the fork length frequency distribution.

Figure 26. Length-frequency distribution for brook trout captured in Fish Creek watershed in 1999.
3.4 Rainbow Trout Population Densities – Tri-Creeks Experimental Watershed Area

Prior to data collection at Tri-Creeks by the Foothills Model Forest (1996), rainbow trout population densities in the lower Wampus Creek site fluctuated from 56 to 417 fish / 0.1 ha (Figure 27). The mean population density during this period was 208 rainbow trout / 0.1 ha. From 1996-1999, the population densities ranged from 44 to 88 rainbow trout / 0.1 ha. The density estimates from both 1997 and 1998 (49 and 44 fish / 0.1 ha respectively) were lower than any density estimate reported to date. The mean population density for 1996-1999 was 60 rainbow trout / 0.1 ha. This mean density was also lower than the mean density reported prior to 1987.

Figure 27. Rainbow trout population densities in lower Wampus Creek between 1970 and 1999.
Population densities in upper Wampus Creek ranged from a low of 20 fish / 0.1 ha in 1983 to a high of 642 fish / 0.1 ha in 1975 (Figure 28). The mean population density for the period prior to 1996 was 373 rainbow trout / 0.1 ha. Population density data collected from 1996-1999 continued to show these fluctuations, but unlike the densities seen for the same period in lower Wampus Creek, these densities were not the lowest densities reported. The mean density since 1996 was 272 rainbow trout / 0.1 ha. Although this mean was lower than the mean density reported prior to 1996, these data were still within the range of variability reported prior to 1996.

Figure 28. Rainbow trout population densities in upper Wampus Creek between 1970 and 1999.
Rainbow trout population densities for lower Deerlick Creek were similar to densities reported for upper Wampus Creek. Prior to 1996, the site on lower Deerlick Creek had densities that ranged from 47-254 rainbow trout / 0.1 ha, with a mean density of 130 rainbow trout / 0.1 ha (Figure 29). The density estimates for 1996-1999 fell within this range with a minimum of 84 and maximum of 127 rainbow trout / 0.1 ha in 1997 and 1998 respectively.

Figure 29. Rainbow trout population densities in lower Deerlick Creek between 1970 and 1999.
Unlike the previous sites, the mean population density estimate for upper Deerlick Creek from 1996-1999 (177 rainbow trout / 0.1 ha) was higher than the mean density from 1970-1995 (69 rainbow trout / 0.1 ha) (Figure 30). Broad fluctuations occurred in upper Deerlick Creek from 1970-1995, ranging from 14 rainbow trout / 0.1 ha in 1981 to 204 fish / 0.1 ha in 1971. The highest densities reported for upper Deerlick Creek were 234 and 214 rainbow trout / 0.1 ha reported in 1998 and 1999 respectively. Both of these densities were higher than any previously reported population densities at this site. Although the population was still fluctuating, it was doing so at a level higher than reported previously.

Figure 30. Rainbow trout population densities in upper Deerlick Creek between 1970 and 1999.
4. Discussion

4.1 Ecological Land Classification and Fish Distribution

Previous evaluations of the effects of land use on watersheds have been most successful when geomorphological and ecological approaches were used to understand processes (Reid 1993). Although geomorphological information were not located for this study area, ecological information in the form of Alberta’s natural sub-region classification was available. The four study watersheds were found to be distributed within the sub-alpine, upper foothills and lower foothills natural sub-regions, with the majority of each watershed occupying the upper foothills region. Although some relationship between fish species distribution and ecological land classification was expected, this natural sub-region classification was not a very useful predictor of fish community composition among the study watersheds. This may be because the natural sub-region classification was largely based on elevational zones within west central Alberta (Beckingham et. al. 1996) and the topographic characteristics of the individual basins were not considered. The ecological land classification system for west central Alberta was hierarchical in nature and at a finer scale the system includes a site level classification based on air photo interpretation and field surveys (Beckingham et. al. 1996). Weldwood has undertaken this eco-site classification for much of their FMA and the findings from that effort may help to understand important ecological regions and boundaries which may also influence fish distributions within the project study area.

Geomorphological information on both hillslopes and stream channels will be helpful when attempting to understand important processes which are influenced by land-use. Obtaining this information is an important component of this multi-year study and information on hillslope slope class and a morphological stream classification (Rosgen 1996) will be available for all study watersheds. With an understanding of the ecology and geomorphology, it will be possible to make reasonable comparisons and inquiries into changes to fish populations resulting from human-use.

4.2 Fish Life Histories within Monitoring Watersheds

Although some fish were known to inhabit the small streams within the study watersheds throughout the year, some information collected during this study suggests that seasonal use by rainbow trout and mountain whitefish was also occurring. In Lynx Creek and Fish Creek,
rainbow trout exceeding 30 cm were captured at locations nearest the mouth during the spring sampling. This information suggests that these individuals had migrated from the Athabasca River to spawn in these tributary streams.

Similar conclusions can be made for mountain whitefish. Most of the mountain whitefish captured were small, and were found in the lower reaches of these streams. This suggests that adult mountain whitefish may be migrating from the larger rivers to spawn in these tributaries.

4.3 The Effects of Previous Introductions and Water Temperatures on Brook Trout Invasion

One of the factors influencing bull trout abundance and survival in western North America was competition and replacement by brook trout (Berry 1994). Understanding the processes that may be contributing to this replacement could be an important step in bull trout conservation. Two factors that may be influencing the spread of brook trout within the study area watersheds were water temperature (McMahon et.al. 1999) and previous introductions (McCart 1997).

Brook trout and bull trout distributions and abundance differed between the monitoring watersheds in 1999. In Anderson Creek, bull trout abundance was high and brook trout were absent. Conversely, in Fish Creek, brook trout abundance was high and catches of bull trout were incidental. Brook trout were known to inhabit the McLeod River near the mouth of Anderson Creek and brook trout likely have had the opportunity to immigrate into Anderson Creek. Therefore, a closer examination of the physical factors in these watersheds seems warranted.

Recent studies have suggested that brook trout have competitive advantage over bull trout especially at temperatures >12°C (McMahon et. al. 1999). During the summer months, average daily maximum temperature was less than 12°C in Anderson Creek and equal to or greater than 12°C in Fish Creek. Anderson Creek also had smaller daily temperature fluctuations than Fish Creek. Further studies would be required to confirm if these differences are a result of more abundant ground water sources within Anderson Creek, a higher degree of shading from streamside forests in Anderson Creek, or other potential factors.

Prior to formulating conclusions with respect to relationships between water temperature and brook trout – bull trout interactions, the location of historical brook trout introductions should be
understood. This would provide evidence whether brook trout have the opportunity to invade the monitoring watersheds or not. For example, if brook trout have not been introduced to the Berland River watershed, there would be no opportunity for invasion and the use of data collected from Moon Creek (tributary to the Berland River) would not be valid for studying brook trout – bull trout interactions.

4.4 Tri-Creeks Watershed and Effects of Access on Fish Populations

Many factors, both natural and human, affect fish populations. These include drought, floods, sedimentation, angling and creation of barriers to fish migration. In “working forests” several of these processes may act simultaneously and as a result it can be very difficult to identify the specific cause for a detected change in a fish population. However, angling has been banned in both Wampus and Deerlick creeks since 1965. This provides researchers with an opportunity to examine fish populations that do not have increased mortality rates resulting from angling. Data collected by the Foothills Model Forest, in combination with data collected as part of the Tri-Creeks Experimental Watershed study (Sterling 1990) provides us with an excellent opportunity to describe changes to these populations with this variable eliminated.

However, there was some doubt whether angling has been eliminated or merely reduced in these watersheds. During our surveys, we have found discarded hook-packages, hooks in streams, and footprints (personal observations) at these sites. This suggests that some illegal angling may be occurring. Population density data collected during our surveys seem to support this. The mean rainbow trout population densities from 1996-1999 were lower at three of the sites sampled in these watersheds compared to previous years. Upper Deerlick Creek was the only site where the mean density was as high or higher that the mean density seen in the past. We also need to note that access differs between these sites. Access to upper Deerlick Creek was difficult and required the use of an all-terrain-vehicle. Each of the other three sites can be accessed easily with four-wheel drive trucks. This makes it relatively simple for most anglers to reach upper and lower Wampus Creek and lower Deerlick Creek if they desire. There was the potential that the lower density at these sites was a result of the natural variability of these populations or that the habitats have been affected from land-use activities. However, it is reasonable to assume that individuals in these populations were experiencing increased mortality because of angling. Increased mortality from angling will result in decreased population densities. This is unfortunate because it will be more difficult to use Wampus and Deerlick creeks as references for describing the
effects of land-use activities on rainbow trout populations. Likewise it will be more difficult to describe the characteristics of a population unaffected by angling.

4.5 Recommendations For Future Work

- Complete the first round of sampling in the remaining watersheds during 2000 field season.

- Incorporate stream classification (modified Rosgen) information being developed at the Foothills Model Forest. This information may provide a better description for these watersheds that will better help explain fish species distributions, community composition, site productivity, etc.

- Incorporate industrial land-use data available for the study watersheds. This information will be required for future comparisons and to complete the detailed descriptions of these watersheds. Information required includes forest harvesting, linear development, and road crossing descriptions. Must investigate options to describe forest harvesting activities that more accurately reflects the present state of the forest rather than area harvested alone. This will be required as forests regenerate (change) through time. An example may be to use the equivalent clear-cut area procedure. We also need to investigate options to better describe potential change to fish habitats with respect to roads and the generation of sediment. An existing protocol to do this may be the universal soil-loss equation.

- Investigate options to expand land-use information to include human-use, and specifically recreational use. Anglers cause direct mortality to fish and must be included in these analyses to be successful in describing change and cumulative effects of human-use on fish populations.

- We must determine a sampling schedule for these watersheds and sites that will be sufficient to describe change. To successfully describe change, one must be able capture the variation that exists for a particular parameter. The effort required to describe change must then be balanced with the cost to achieve these objectives. Specifics include the number of sample sites that will be sufficient in each watershed and the sampling effort required.

- We must ensure that monitoring programs incorporate links to the existing criteria and indicator programs that have been established by the Foothills Model Forest and our partners.
To eliminate duplication of effort and to increase efficiencies, we need to consider indicators identified by these existing programs for this monitoring project. Any recommendations with respect to these indicators regarding their effectiveness will need to be communicated to the partners.
5. References


FMF (Foothills Model Forest). 1996. 1995-96 Fish and stream inventory-site summaries. Prepared for the ACA, Weldwood of Canada (Hinton Division), and the NRS. FMF, Hinton, Alberta.


FMF (Foothills Model Forest). 1999. 1999 Fish and stream inventory-site summaries. Prepared for the ACA, Weldwood of Canada (Hinton Division), and the NRS. FMF, Hinton, Alberta.


Appendix 1. Representative Photographs from Sampling Locations Within the Four Monitoring Watersheds

Abbreviations used in this section include:

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<tr>
<th>Abbreviation</th>
<th>Species</th>
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<td>Rainbow Trout</td>
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<td>Mountain Whitefish</td>
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<td>Trout-Perch</td>
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<td>Large Woody Debris</td>
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Appendix 1. Section 1. Lynx Creek Watershed Representative Photographs

Plate 1. Lynx Creek. Location 1. Site 99176. Low cover. RNTR and MNWH.

Plate 2. Lynx Creek. Location 2. Site 99175-1. Undercut banks dominant cover. RNTR.

Plate 3. Lynx Creek. Location 3. Site 99069. Undercut banks dominant cover RNTR.

Plate 4. Lynx Creek. Location 4. Site 99044-5. Flooding created by beaverdam.

Plate 6. Lynx Creek. Location 5. Site 99066. Large cobble dominant substrate. RNTR.

Plate 7. Lynx Creek. Location 6. Site 99067. Terrestrial canopy dominant cover. RNTR.

Plate 8. Lynx Creek. Location 7. Site 99049. LWD dominant cover. RNTR.
Appendix 1. Section 1. Lynx Creek Watershed Representative Photographs

Plate 9. Lynx Creek. Location 8. Site 99065. Undercut banks dominant cover. NFC.

Plate 10. Tributary #1. Location 9. Site 99033. LWD dominant cover. NFC.

Plate 11. Tributary #1. Location 10. Site 99055. Moderate over-wintering potential. NFC.

Plate 12. Tributary #3. Location 12. Site 99061. Fines dominant substrate. RNTR and BURB.
Appendix 1. Section 1. Lynx Creek Watershed Representative Photographs


Plate 14. Tributary #5. Location 14. Site 99048. LWD dominant cover. NFC.

Plate 15. Tributary #5. Location 15. Site 99182. Undercut banks dominant cover. RNTR.

Appendix 1. Section 2. Fish Creek Watershed Representative Photographs

Plate 17. Fish Creek. Location 3. Site 99097. Small cobbles and boulders dominant substrates. RNTR and BKTR.

Plate 18. Fish Creek. Location 3. Site 99173. Spawning brook trout up to 223mm captured on September 20, 1999.

Plate 19. Fish Creek. Location 4. Site 99083. Large cobble and boulders dominant substrates. RNTR, BKTR, and BLTR.

Plate 20. Fish Creek. Location 5. Site 99096. Boulders dominant substrate. RNTR captured.
Appendix 1. Section 2. Fish Creek Watershed Representative Photographs

Plate 21. Fish Creek. Location 6. Site 99092. Undercut banks dominant cover. RNTR.

Plate 22. Fish Creek. Location 7. Site 99206. Undercut banks dominant cover. RNTR.

Plate 23. Fish Creek. Location 8. Site 99094. Undercut banks dominant cover. NFC.

Plate 24. Fish Creek. Location 9. Site 99104. Undercut banks dominant cover. NFC.
Plate 25. Tributary #1. Location 10. Site 99095. Boulders dominant substrate. RNTR.

Plate 26. Tributary #2. Location 11. Site 99091. Abundant cover. NFC.

Plate 27. Tributary #3. Location 12. Site 99103. Undercut banks dominant cover. RNTR.

Appendix 1. Section 2. Fish Creek Watershed Representative Photographs

Plate 29. Tributary to #3. Location 14. Site 99105. Abundant cover. RTNR.

Plate 30. Tributary #4. Location 15. Site 99101. Large cobble dominant substrate. RNTR.


Plate 32. Tributary #4. Location 17. Site 99100. LWD dominant cover. RNTR.
Appendix 1. Section 3. Anderson Creek Watershed Representative Photographs

Plate 33. Anderson Creek. Location 1. Site 99162. Low instream cover. RNTR, BLTR, and MNWH.

Plate 34. Anderson Creek. Location 2. Site 99059. Beaver dams creating migration barriers. RNTR and BLTR.

Plate 35. Anderson Creek. Location 3. Site 99064. Low instream cover. RNTR.

Plate 36. Anderson Creek. Location 4. Site 99076. Large gravel dominant substrate. RNTR.
Appendix 1. Section 3. Anderson Creek Watershed Representative Photographs

Plate 37. Anderson Creek. Location 5. Site 99163. Undercut banks dominant cover. RNTR and BLTR.

Plate 38. Anderson Creek. Location 6. Site 99178. Undercut banks dominant cover. RNTR and BLTR.


Plate 40. Anderson Creek. Location 7. Site 99080. LWD dominant cover. RNTR and BLTR.
Appendix 1. Section 3. Anderson Creek Watershed Representative Photographs

Plate 41. Anderson Creek. Location 8. Site 99193. Undercut banks dominant cover. RNTR.

Plate 42. Anderson Creek. Location 9. Site 99078. Undercut banks dominant cover. RNTR.

Plate 43. Tributary #2. Location 12. Site 99077. Undercut banks dominant cover. NFC.

Plate 44. Tributary #2. Location 13. Site 99042. Undercut banks dominant cover. RNTR and BLTR.
Appendix 1. Section 3. Anderson Creek Watershed Representative Photographs

Plate 45. Tributary #2. Location 14. Site 99075. LWD dominant cover. RNTR and BLTR.

Plate 46. Tributary #2. Location 15. Site 99046. Rooted width of 3.3m. BLTR.

Plate 47. Tributary #3. Location 17. Site 99045. Terrestrial canopy dominant cover. RNTR.

Plate 48. Tributary #3. Location 18. Site 99079. Terrestrial canopy dominant cover. NFC.
Appendix 1. Section 3. Anderson Creek Watershed Representative Photographs

Plate 49. Tributary #4. Location 19. Site 99194. Undercut banks dominant cover. RNTR.

Plate 50. Tributary #4. Location 20. Site 99082. Beaver ponds angled only. NFC.
Appendix 1. Section 4. Upper Erith River Watershed Representative Photographs

Plate 51. Erith River. Location 1. Site 99144. Fines dominant substrate. RNTR.

Plate 52. Erith River. Location 2. Site 99197. Undercut banks dominant cover. RNTR and MNWH.

Plate 53. Erith River. Location 3. Site 99126. Surface turbulence dominant cover. RNTR and MNWH.

Plate 54. Erith River. Location 4. Site 99151. LWD dominant substrate. RNTR and BLTR.
Appendix 1. Section 4. Upper Erith River Watershed Representative Photographs

Plate 55. Erith River. Location 5. Site 99135. Undercut banks dominant cover. RNTR and BLTR.


Plate 57. Halpenny Creek. Location 7. Site 99147. Fines dominant substrate. LNSC, SPSV, TRPR, RNTR, PRDC and WHSC.

Plate 58. Halpenny Creek. Location 8. Site 99195. Large gravel dominant substrate. RNTR, SPSC and LNSC.
Appendix 1. Section 4. Upper Erith River Watershed Representative Photographs

Plate 59. Tributary to Halpenny Creek. Location 9. Site 99148. LWD dominant cover. RNTR.

Plate 60. Tributary to Halpenny Creek. Location 10. Site 99149. Large gravel dominant substrate. RNTR.

Plate 61. Bacon Creek. Location 11. Site 99145. LWD dominant cover. RNTR.

Plate 62. Bacon Creek. Location 12. Site 99196. Undercut banks dominant cover. RNTR.
Appendix 1. Section 4. Upper Erith River Watershed Representative Photographs

Plate 63. Tributary #1. Location 13. Site 99146. Fines dominant substrate. NFC.

Plate 64. Tributary #2. Location 14. Site 99141. Undercut banks dominant cover. RNTR.

Plate 65. Tributary to #2. Location 15. Site 99140. Terrestrial canopy dominant cover. NFC.

Plate 66. Tributary #3. Location 16. Site 99127. LWD dominant cover. RNTR.

Plate 68. Tributary #4. Location 18. Site 99084. Undercut banks dominant cover. RNTR.

Plate 69. Tributary #5. Location 19. Site 99015. Fines dominant substrate. NFC.

Plate 70. Tributary #6. Location 20. Site 99139. Undercut banks dominant cover. RNTR.
Appendix 1. Section 4. Upper Erith River Watershed Representative Photographs

Plate 71. Tributary #6. Location 21. Site 99137. LWD dominant cover. NFC.

Plate 72. Unnamed Creek. Location 22. Site 99138. Large gravel dominant substrate. RNTR.

Plate 73. Tributary #8. Location 23. Site 99153. Terrestrial canopy dominant cover. RNTR and BLTR.


Plate 76. Tributary #11. Location 26. Site 99112. Terrestrial canopy dominant substrate. NFC.