Canada Alberta Northwest Territories

Northern River Basins Study

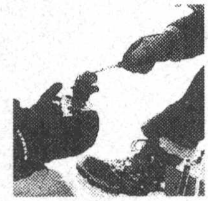











Date Due

Prepared for the
Northern River Basins Study
under Project 3121-B1

by
C. McLeod, and T. Clayton
R.L. & L. Environmental Services Ltd.

NORTHERN RIVER BASINS STUDY PROJECT REPORT NO. 11

FISH RADIO TELEMETRY DEMONSTRATION PROJECT

UPPER ATHABASCA RIVER MAY TO AUGUST, 1992

Published by the
Northern River Basins Study
Edmonton, Alberta, Canada
June, 1993

CANADIAN CATALOGUING IN PUBLICATION DATA

McLeod, C. (Curtiss)

Fish radio telemetry demonstration project,
Upper Athabasca River, May to August, 1992

(Northern River Basins Study project report;
ISSN 1192-3571 ; no. 11)
Includes bibliographical references.
ISBN 0-662-20765-3
DSS cat. no. R71-49/3-11E

1. Animal radio tracking -- Alberta --
Athabasca River. 2. Fishes -- Research --
Alberta -- Athabasca River.
I. Clayton, Terry.
II. Northern River Basins Study (Canada)
III. Title. IV. Series.

QL60.4M32 1933 597'.0072 C93-099609-7

PREFACE:

The Northern River Basins Study was initiated through the "Canada-Alberta-Northwest Territories Agreement Respecting the Peace-Athabasca-Slave River Basin Study, Phase II - Technical Studies" which was signed September 27, 1991. The purpose of the Study is to understand and characterize the cumulative effects of development on the water and aquatic environment of the Study Area by coordinating with existing programs and undertaking appropriate new technical studies.

This publication reports the method and findings of particular work conducted as part of the Northern River Basins Study. As such, the work was governed by a specific terms of reference and is expected to contribute information about the Study Area within the context of the overall study as described by the Study Final Report. This report has been reviewed by the Study Science Advisory Committee in regards to scientific content and has been approved by the Study Board of Directors for public release.

It is explicit in the objectives of the Study to report the results of technical work regularly to the public. This objective is served by distributing project reports to an extensive network of libraries, agencies, organizations and interested individuals and by granting universal permission to reproduce the material.

NORTHERN RIVER BASINS STUDY
PROJECT REPORT RELEASE FORM

This publication may be cited as:

McLeod, C., and Clayton, T., R.L. & L. Environmental Services Ltd., ***Northern River Basins Study Project Report No. 11, Fish Radio Telemetry Demonstration Project, Upper Athabasca River, May to August, 1992,*** **Edmonton, Alberta, Canada, June, 1993.**

Whereas the above publication is the result of a project conducted under the Northern River Basins Study and the terms of reference for that project are deemed to be fulfilled,
IT IS THEREFORE REQUESTED BY THE STUDY OFFICE THAT;
this publication be subjected to proper and responsible review and be considered for release to the public.

F. J. Wrona — 2 June 93
(Dr. F.J. Wrona, Ph.D., Science Director) (Date)

Whereas it is an explicit term of reference of the Science Advisory Committee "to review, for scientific content, material for publication by the Board",
IT IS HERE ADVISED BY THE SCIENCE ADVISORY COMMITTEE THAT;
this publication has been reviewed for scientific content and that the scientific practices represented in the report are acceptable given the specific purposes of the project and subject to the field conditions encountered.
SUPPLEMENTAL COMMENTARY HAS BEEN ADDED TO THIS PUBLICATION: [ ] Yes [ ] No

P. A. Larkin — 11 June 93
(Dr. P. A. Larkin, Ph.D., Chair) (Date)

Whereas it is the duty of the Operations Committee to attend to the day-to-day management of the Study on behalf of the Study Board,
IT IS THEREFORE RECOMMENDED BY THE OPERATIONS COMMITTEE THAT;
this publication be released to the public and it is reported that
THIS PUBLICATION HAS BEEN REVIEWED BY THE HEALTH ASSESSMENT COMMITTEE AND SUBSEQUENTLY FORWARDED TO APPROPRIATE HEALTH AUTHORITIES: [ ] Yes [ ] No

Whereas the Study Board is satisfied that this publication has been reviewed for scientific content and for immediate health implications,
IT IS HERE APPROVED BY THE BOARD OF DIRECTORS THAT;
this publication be released to the public, and that this publication be designated for: **[ ] STANDARD AVAILABILITY [ ] EXPANDED AVAILABILITY**

Bev Burns — 10/6/93
(Bev Burns, Co-chair) (Date)

P. Melnychuk — 22/06/93
(Peter Melnychuk, Co-Chair) (Date)

NRBS.005

FISH RADIO TELEMETRY DEMONSTRATION PROJECT
UPPER ATHABASCA RIVER
MAY TO AUGUST, 1992

STUDY PERSPECTIVE

The distribution and movement of fish species in the watersheds of the Peace, Athabasca, and Slave rivers are major areas of interest to the Northern River Basins Study. Determination of where fish spend their time (rearing, spawning and feeding) and when fish are most likely to be exposed to alterations in natural water quality are important to understanding the relationship between fish exposure, fish health, contaminant body burdens, and physiological changes. An understanding of the seasonal behaviour (eg. migrations and homing) of fish is an important component of recognizing contaminant pathways.

Related Study Questions

6) What is the distribution and movement of fish species in the watersheds of the Peace, Athabasca and Slave river? Where and when are they most likely to be exposed to changes in water quality and where are their important habitats?

12) What native traditional knowledge exists to enhance the physical science studies in all areas of enquiry?

13b) What are the cumulative effects of man made discharges on the water and aquatic environment?

14) What long term monitoring programs and predictive models are required to provide an ongoing assessment of the state of the aquatic ecosystems.

The size and length of the Peace, Athabasca and Slave rivers in addition to the limited baseline information on the fish community of these rivers, make the task monumental for identifying, monitoring and describing fish movement. Therefore, a preliminary investigation to technically assess and demonstrate the feasibility and potential benefits of radio telemetry, as a means for achieving these goals, was initiated on a small scale on the upper Athabasca River between Jasper National Park and the Windfall Bridge.

This report describes the technology used up to August 1, 1992 to obtain, implant transmitters and monitor several species (bull trout, mountain whitefish, burbot, rainbow trout, arctic grayling and lake whitefish) of radio tagged fish. Initial results confirm the practicality of using this technology as well as some of the method difficulties which can be encountered related to transmitter quality, battery life, and handling of small fish.

The experience gained provides a scientific basis for planning future initiatives. The technology has potential application for measuring the behavioural response of fish to effluent plumes, and for improving our understanding concerning the biological loss of contaminants from fish tissue and correlation with physiological response of fish moving from areas affected by contaminants to those areas not affected. Monitoring of tagged fish has continued and will be the subject of a subsequent report.

EXECUTIVE SUMMARY

A Fish Radio Telemetry Demonstration Project was undertaken on the upper reaches of the Athabasca River in spring and summer 1992. The general objective of the project was to describe and implement a technical assessment of underwater radio telemetry using representative fish species within the Athabasca River, and to assess the utility of this technique for use in the Northern River Basins Study (NRBS).

The study area encompassed 322 km of the mainstem Athabasca River, from the town of Whitecourt upstream to Athabasca Falls (Jasper National Park). In addition, the lower reaches of major tributaries also were included in the study area.

Thirty-five fish of six target species (mountain whitefish, bull trout, burbot, rainbow trout, lake whitefish and Arctic grayling) were implanted with high frequency (148.0 - 150.0 MHz) digitally encoded transmitters. These transmitters enabled identification of several individuals on a single frequency. Fish were collected from the mainstem Athabasca River by boat electrofishing, and a surgical procedure was utilized for transmitter implantation. Transmittered fish were released at four locations within the study area, during the period 24 May to 12 June 1992.

Fish movements and behaviour were systematically monitored by a fixed ground station and aircraft tracking. The fixed ground station was installed 11.5 km upstream of the Weldwood Mill in Hinton to continually monitor movements of fish past the site and enable evaluation of the effectiveness of this technique. Tracking information was downloaded from the station data logger on five occasions (bi-weekly) during the study. The remainder of the study area was surveyed using a single-engine fixed-wing aircraft, with aerial tracking conducted on eight flights between 20 June and 31 August.

Technical problems were encountered with some equipment (i.e., transmitters) and during initial equipment set-up; however, both the fixed ground station and aircraft tracking successfully detected and recorded signals from the target species. Home range territorial movements, significant spawning and feeding movements, and potential critical habitat locations were identified for bull trout, mountain whitefish and burbot in the study area. Bull trout spawning migrations of nearly 100 km, from release locations below Hinton upstream into Jasper National Park tributaries, were documented. Complex feeding movements of mountain whitefish also were identified, in addition to territorial habitat use by burbot. Additional tracking in fall and winter 1992/93 will be undertaken to more fully describe the behaviour and life history of the target species.

Because of its ability to provide multiple data points on the location and seasonal habitat used by fish, radio telemetry is uniquely suited for developing further information on food chain relationships of fish, and correlation of the behaviour of target fish species with important environmental parameters in the NRBS area.

TABLE OF CONTENTS

Page #

LIST OF TABLES . . . iii
LIST OF FIGURES . . . iv

1.0 INTRODUCTION . . . 1
1.1 STUDY AREA . . . 2

2.0 METHODS . . . 2
2.1 TELEMETRY EQUIPMENT AND TECHNIQUES . . . 2
2.1.1 System Design . . . 2
2.1.2 Transmitter and Frequency Selection . . . 2
2.2 FISH COLLECTION AND HANDLING PROCEDURES . . . 4
2.3 SURGICAL PROCEDURES . . . 5
2.3.1 Anesthesia . . . 5
2.3.3 Implant Procedure . . . 6
2.3.4 Recovery . . . 7
2.4 SURVEILLANCE SYSTEMS . . . 8
2.4.1 Fixed Station . . . 8
2.4.2 Aerial Surveys . . . 11
2.4.3 Ground Surveys . . . 12

3.0 RESULTS AND DISCUSSION . . . 13
3.1 SITE CONDITIONS AND FISH AVAILABILITY . . . 13
3.2 TRANSMITTER IMPLANTS . . . 15
3.3 FISH MOVEMENT DATA . . . 16
3.3.1 Data Collection . . . 16
3.3.2 Movement Patterns . . . 16
3.4 EQUIPMENT AND TECHNIQUES EVALUATION . . . 31
3.4.1 Transmitter Function . . . 31
3.4.2 Detection Systems . . . 31
3.4.3 Fish Handling and Operative Procedures . . . 35

4.0 SUMMARY AND RECOMMENDATIONS . . . 36
4.1 TECHNICAL ASSESSMENT . . . 36
4.2 UTILITY OF RADIO TELEMETRY FOR THE NRBS . . . 40

5.0 LITERATURE CITED . . . 41

LIST OF TABLES

Page #

Table 2.1 Stages of anaesthesia (modified from Summerfelt and Smith 1990). 6

Table 3.1 Summary of data from radio tagged fish, Athabasca River Telemetry Demonstration Project Area. 15

Table 3.2 Location and number of radio tagged fish released at each site. 15

Table 3.3 Summary of fish movements at the Fixed Station, Athabasca River (Km 1239) 25 May to 31 August 1992. 17

Table 3.4 Aerial tracking data for bull trout, Athabasca River, Telemetry Demonstration Project Area. 21

Table 3.5 Aerial tracking data for mountain whitefish, Athabasca River, Telemetry Demonstration Project Area. 25

Table 3.6 Aerial tracking data for burbot, Athabasca River, Telemetry Demonstration Project Area. 28

Table 3.7 Aerial tracking data for various species, Athabasca River, Telemetry Demonstration Project Area. 28

LIST OF FIGURES

Page #

Figure 1.1 Study area, Athabasca River Fish Radio Telemetry Demonstration Project 3

Figure 2.1 Location of antennae and fixed station area. 9

Figure 3.1 Fish collection period in relation to daily discharge, Athabasca River at Hinton (Stn. 07AD002) for the study period May to July 1992. 14

Figure 3.2 Example of a fixed station intercept of mountain whitefish (Code 20-12), illustrating rate of movement, and antennae differentiation to determine movement direction using relative signal strength (A) and percentage of signals received by each antennae over a 30 minute time period (B). 19

Figure 3.3 Signal acquisition and activity of a burbot (Code 1-2) near Km 1239 from 27 May (Day 1) to 13 July (Day 50), 1992. 20

Figure 3.4 Movement patterns of bull trout in the Athabasca River from 20 June to 31 August 1992, in relation to release location 22

Figure 3.5 Movements of a bull trout (Code 19-25) from the release location (Km 1227) in the Athabasca River, June to August 1992. 24

Figure 3.6 Movement patterns of selected mountain whitefish in the Athabasca River from 20 June to 31 August 1992, in relation to release location 26

Figure 3.7 Movement patterns of burbot in the Athabasca River from 20 June to 31 August 1992, in relation to release location. 29

Figure 3.8 Movement patterns of Arctic grayling, rainbow trout, and lake whitefish in the Athabasca River from 20 June to 31 August, in relation to release location 30

Figure 3.9 Example of signal interpretation of a bull trout (Code 19-25) moving upstream past the fixed station, prior to antennae repositioning. 33

Figure 3.10 Example of signal interpretation of a bull trout (Code 20-31) moving upstream past the fixed station, after antennae repositioning. 33

1.0 INTRODUCTION

Underwater biotelemetry is a useful technique to collect fisheries data on free-ranging fish and has undergone technological development for over two decades. International conferences on biotelemetry methods and research have been held since 1977 (e.g., Long 1977). Reviews of underwater telemetric methods have been published by Stasko and Pincock (1977), Ireland and Kanwisher (1978), and Winter et al. (1978). Telemetry systems are either ultrasonic or radio; the advantages of both are reviewed by Winter (1983). Radio telemetry is often utilized for freshwater fisheries investigations as it can be used to search large areas to find mobile species, antennas are portable, signals are little affected by thermoclines or ice cover, and many individuals can be monitored at the same time and location. Applications of radio telemetry, as summarized by J. Winter (Fish Tracking Techniques Workshop, Albuquerque, N.M., March 1992), are:

1. To describe activity patterns of fish (e.g., presence near a plume).
2. To collect home range data.
3. To identify habitat use, including:
    - dispersal
    - migration
    - behaviour relative to environmental parameters, and
4. To test assumptions in population estimates (i.e., are fish mixing randomly?).

A Fish Radio Telemetry Demonstration Project on the Athabasca River was requested to verify the cost-effectiveness and utility of radio telemetry prior to committing its utilization on a basin-wide scale. This technology may provide a means to describe fish behaviour due to environmental variables and thereby develop life history information on selected fish species. A knowledge of movements and habitats of target fish species within the Northern River Basins Study area is an essential part of the process required to understand food chain relationships and thus facilitate assessment of contaminant burdens in these fish.

R.L. & L. Environmental Services Ltd. was contracted to undertake the Demonstration Project, within the following general objectives (Terms of Reference, Sub-project 3121; Appendix A):

1. To describe appropriate techniques, equipment and protocols to be employed in capturing fish, implanting radio transmitters, and monitoring movements, and

2. To implement a field project during spring 1992 to undertake a technical assessment of radio telemetry using representative fish species (e.g., mountain whitefish, bull trout) within the Athabasca River.

Because of funding limitations, alterations to the Terms of Reference were necessary (e.g., deletion of one of two shore-based monitors). This alteration affected the intended scope of the program; however, it was decided that testing of at least one shore-based monitor (fixed station) was critical to determination of the utility of radio telemetry. A shore-based monitor was thus included, with time and costs shared with R.L. & L. Environmental Services Ltd.

1.1 STUDY AREA

The study was conducted in the upper reaches of the Athabasca River above Whitecourt (Figure 1.1), encompassing 322 km of mainstem river, with a priority area for transmitter implantations designated in the 30 km reach downstream of the Weldwood Mill at Hinton. The survey area extended upstream to Athabasca Falls (an impassable barrier to upstream fish movement) in Jasper National Park, and included lower reaches of major tributaries (i.e., Fiddle River, Snake Indian River, Rocky River, Snaring River) above Brule Lake. Lower reaches of several downstream tributaries (i.e., Solomon Creek, Oldman Creek, and the Berland River) also were surveyed (Appendix D, Table 12).

A site for the single fixed ground station was established near the location of Old Entrance, 11.5 km upstream of the Weldwood Mill effluent discharge at Hinton.

2.0 METHODS

2.1 TELEMETRY EQUIPMENT AND TECHNIQUES

2.1.1 System Design

In addition to in-house expertise (R.L. & L. Environmental Services Ltd. has undertaken several previous radio telemetry studies, dating from 1978 to present), system design and equipment characteristics were discussed with other individuals having radio telemetry experience, including Mr. S. McKinley (Ontario Hydro) and Mr. K. Chang-Kue (Fisheries and Oceans Canada). Two firms, Lotek Engineering Inc. and Advanced Telemetry Systems Inc., were contacted regarding equipment recommendations, specification and delivery. These firms were selected because of previous working experience with the companies and customer recommendations. The lack of study preparation time also restricted the number of firms contacted and equipment reviewed.

Equipment manufactured by Lotek Engineering Inc.[1] was utilized for the demonstration study; a representative of the company conducted a site inspection and provided initial instruction in operation of the equipment.

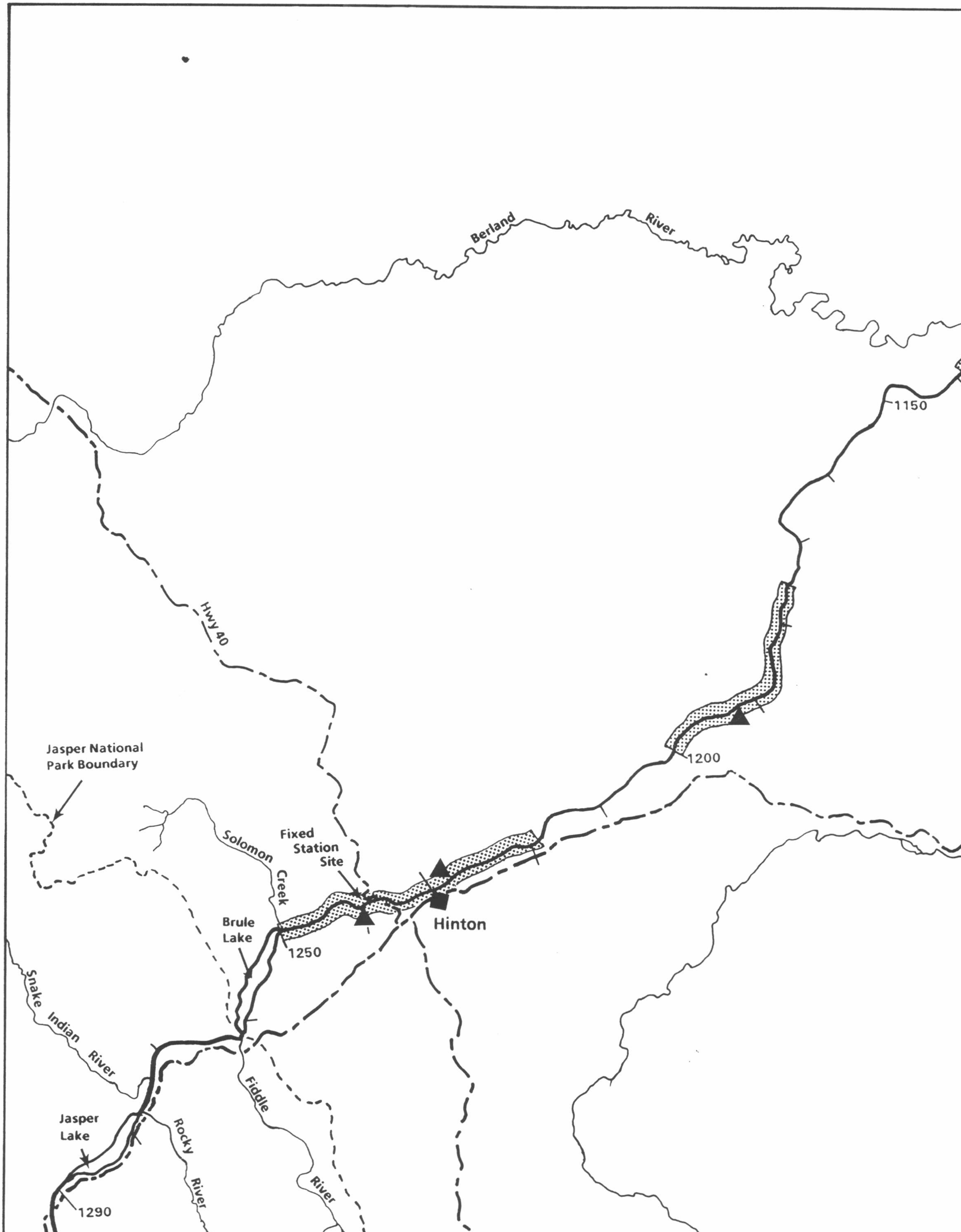
Photographs of system configuration, surgical equipment used, and the surgical procedure employed are provided in Appendix F, Photos 1 to 15.

2.1.2 Transmitter and Frequency Selection

Propagation losses of radio signals in water vary with frequency; lower frequencies generally have lower propagation losses. The best results are usually obtained at water depths <5 m and conductivities of <400 μS/cm. However, antennae and matching network efficiencies for higher frequencies are considerably higher and can offset these losses (Velle et al. 1979).

---

[1]Use of a company's name, or equipment identification does not constitute endorsement.


Berland
River
1150
Hwy 40
1200
Jasper National
Park Boundary
Solomon
Creek
Fixed
Station
Site
Brule
Lake
1250
Hinton
Snake
Indian
River
Fiddle
River
Jasper
Lake
Rocky
River
1290

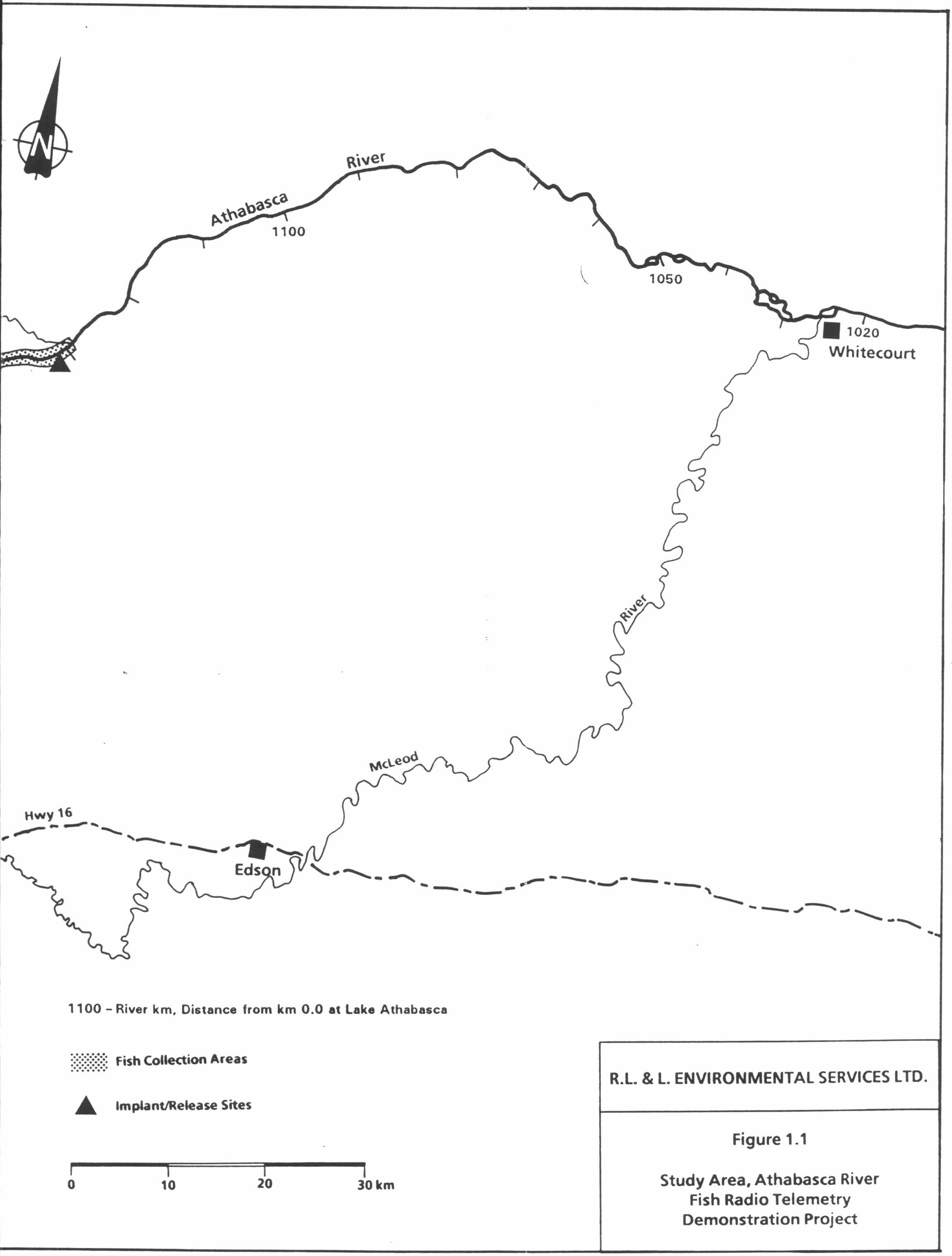


Figure 1.1

Study Area, Athabasca River Fish Radio Telemetry Demonstration Project

High frequency (148.0-150.0 MHz) transmitters were selected for this study. Primary reasons for use of high frequency, as opposed to low frequency, transmitters were:

1. The relatively shallow depths and low conductivity of waters in the upper Athabasca River are conducive to good signal reception from high frequency transmitters, and

2. Yagi antennae configurations for directional tracking, or fixed station set-up, are much more manageable (size-related) and efficient for high frequencies than for low frequencies.

Transmitters utilized were 4.2 cm x 1.4 cm in size, with a 45 cm trailing whip antennae and weighed 10.5 g in air (Photo # 5; Appendix F). These units utilize a 3-volt lithium battery, with a life expectancy of 270 days. Transmitters were digitally encoded, allowing up to 50 transmitters to be used on a single frequency. This feature reduces scan time and enables use of a larger sample size of fish, in addition to enhancing audible detection of signals from background noise (Lotek Engineering Inc., system information pamphlet).

The external capsule material was nalgene, designed not to bond to protein, and thus reduce the potential for rejection or expulsion of the transmitter from the body of the fish. Expulsion has been a problem in some surgical implant studies and has been previously discussed by several researchers (e.g., Summerfelt and Mosier 1984, Chisholm and Hubert 1985, Marty and Summerfelt 1986, Helm and Tyus 1992).

A transmitter range test was conducted at initiation of the study and each transmitter was tested in water for function and frequency selection prior to implantation. Transmitters were labelled with the address of the Northern River Basins Study office, for return in the event of fish capture by anglers. One transmitter was retained for use as a reference transmitter (receiver/antennae test) and to document life span.

2.2 FISH COLLECTION AND HANDLING PROCEDURES

All fish used for the telemetry study were collected by boat electrofishing. The collection system included a Smith Root Model SR-18 boat equipped with a GPP-5.0 electrofisher, and propelled by an outboard jet. The system operated with an output of 4 to 7 Amperes, and with a pulse rate and width (DC voltage) of 60 pps and 507 ms, respectively. The electrofishing procedure consisted of drifting downstream under minimum power, with the boat maintained near shore. In most instances, a single pass was made through a length of river, with the boat alternating between shores. Selection of the area to be electrofished was dependent on bank type, water depth, cover and crew experience in capturing the target species in similar habitats. Natural hazards (e.g., high velocity chutes and boulder gardens, sweepers and debris jams) were avoided or judiciously sampled.

During electrofishing the netters selected for larger adult specimens, and individuals of insufficient size were immediately returned to the river. Transmitter weight should ideally be no more than 1 to 2% of body weight of the fish used for surgical implantation, thus fish were required in the range of 525 to 1050 g minimum weight. Anatomy and body shape are also important considerations in the ability to implant transmitters.

Captured individuals were immediately placed in an onboard holding tank, equipped with a recirculating water and aeration system, to minimize holding stress. Prior to surgery, captured specimens were examined for signs of distress and physical injury. Fish were judged unsuitable for surgery if they exhibited any of the following external conditions:

1. Abnormal swimming behaviour (unable to maintain balance, inability to sound in the holding tank).
2. Severe haemorrhaging along the ventral surface (indicative of potential internal haemorrhaging), and
3. Other physical injury such as gashes (i.e., from predators), scale loss, blindness, or sores.

In general, the time between commencement of electrofishing and surgical implantation of transmitters was about four hours. To reduce the potential of electroshocking freshly-implanted specimens, the surgical component was not initiated until the area selected for the day's electrofishing was covered. The release site and immediate downstream areas ($\leq$1 km) also were avoided during subsequent sampling.

2.3 SURGICAL PROCEDURES

2.3.1 Anesthesia

Fish were anesthetized with Finquel (tricaine methane sulfonate), a registered trademark anesthetic sold by Argent Chemical Laboratories. Tricaine is a restricted drug in Canada requiring authorization by the Health and Welfare Bureau of Veterinary Drugs prior to purchase and submission of a follow-up report after use. The concentration used was 143 mg/L (5 g in 35 L H_20), which is within the 50-330 mg/L range reported by Schnick et al. (1986) to cause anesthesia within 1 to 40 minutes, and similar to the 150 mg/L recommended by Bidgood (1980).

The length of time the fish was immersed in the anesthetic solution was dependent on species and size. Each individual was observed as it progressed through a sequence of physiological stages, outlined in Table 2.1 (modified from Summerfelt and Smith 1990). When the subjects reached stage 5 (loss of reactivity; opercular movements slow and irregular; loss of all reflexes), they were judged suitable for surgery.

Tricaine has been noted to anesthetize salmonids more slowly with decreasing water temperature (Schoettger and Julin 1967 *In* Summerfelt and Smith (1990). In addition to considerations of anesthetic efficacy in changing water temperature, the shock of transfer from a relatively cool environment (river) to a warmer tank and then back to cooler water (post-operation) was a concern during this study. As such, the anesthetic solution was monitored regularly for temperature change, and a new solution was prepared when the difference between it and the river temperature exceeded 4°C.

Table 2.1 Stages of anaesthesia (modified from Summerfelt and Smith 1990).

STAGE	CONDITION
1	Slight loss of reactivity, equilibrium normal
2	Loss of reactivity, equilibrium normal
3	Increased opercular rate, equilibrium waning
4	Slow but regular opercular rate, equilibrium lost
5	Opercular movements slow and irregular
6	Opercular movements cease, cardiac arrest

2.3.2 Surgical Equipment

The surgical equipment included a surgical trough, instruments, and various chemical solutions. A complete list of surgical equipment and supplies is provided in Appendix B, Table 1. The surgical platform was a V-shaped trough, with adjustable width for fish size; for smaller individuals, foam was added to the trough base to raise the individual and facilitate surgery. The trough was lined with neoprene to retain moisture and restrict fish movement. A meter stick attached to the lip of the trough facilitated length measurements and reduced handling of the fish during collection of morphometric data.

Surgical instruments included haemostats, tissue forceps, scissors, knife, hypodermic needles, surgical blades and handles, hypodermic syringes and needles, and sutures swaged to cutting needles. Polydioxanone sutures were used; these retain their strength for four to six months before degrading. Permanent, non-degradable, suture material is used by many researchers; 6-lb monofilament fish line can substitute (J. Winter, Assistant Professor, Texas Tech. University, Lubbock, Texas, pers. commun.). Additional supplies included a sharps' container (for disposal of blades, needles, and other surgical refuse).

The solutions used included zephiran chloride, Betadine, distilled water, malachite green, and Liquamycin LP (a Roger/SIB trademark for oxytetracycline hydrochloride). Zephiran chloride was used as a pre-operative disinfectant since it is less of a tissue irritant than Betadine (which contains iodine), it is less corrosive to surgical instruments than alcohol, and is less costly than either alcohol or Betadine.

The equipment, instruments and most of the chemical solutions were transported within a 150 L Coleman brand cooler, which also doubled as an anesthetic tank or recovery tank as required. Photos #6 and #7 (Appendix F) illustrate the typical field set-up and equipment.

2.3.3 Implant Procedure

The surgical implantation procedure was a modification of techniques described by Bidgood (1980) and Knecht et al. (1981) and are detailed in the following paragraphs. Three persons were utilized during the operating procedure. These included the principal surgeon, an assistant, and a third person to record data and transfer fish to and from the anesthetic bath.

To the extent possible in field conditions, a sterile operating environment was maintained. Transmitters were disinfected with zephiran chloride and rinsed with distilled water prior to insertion, and all instruments were bathed in zephiran chloride prior to use. Personnel wore vinyl examination gloves during fish surgery and recovery.

Fish weight was taken on a digital scale immediately after the individual was removed from the anesthetic bath. The fish was then placed on its dorsum in the surgical trough, and its length recorded. Pre-soaked towelling was placed over the fish to keep it moist; an opening in the towelling facilitated surgery. For mountain whitefish and lake whitefish three to four rows of scales were removed prior to incision from an area between the ventral line and the distal ends of the ribs. Scale removal was not necessary for other species. The area was washed with distilled water prior to the incision being made.

A 3-4 cm longitudinal incision was made approximately 1-2 cm from the mid-ventral line, anterior to the pelvic fins (Photo # 8; Appendix F). A No.16 hypodermic needle was then inserted through a point in the body wall to the side and posterior to the incision. The transmitter antenna wire was inserted into the hollow needle, the needle removed, leaving the antenna wire exiting the body wall of the fish. The transmitter was then inserted into the body cavity, Liquamycin LP antibiotic was injected intraperitoneally (as recommended by McKinley et al. 1992), and the incision closed.

A simple interrupted suture pattern was used, selected because the knot is the weakest point and failure of a knot in this pattern would not allow opening of the total incision. A square knot, using an instrument tie, was used to secure the suture ends. All knots were double-tied.

Malachite green (a fungicide) was topically applied with a cotton swab to the outside of the incision and the antenna wound. Fish receiving transmitters on 11 and 12 June also had n-butyl cyanocrylate tissue adhesive (VetBond - a 3M Company trademark) applied to the incision.

Oxygenated water was directed over the gills during the surgical procedure. For mountain whitefish, ventilation usually began as soon as the incision was made in the individual, while for bull trout, it began after the transmitter was inserted. Manual ventilation consisted of fresh river water being directed over the gills from a plastic wash bottle.

All surgical needles, hypodermic needles, and scalpel blades were disposed of via the sharps' container. Pertinent data on the individual's time in the anesthetic solution, time on the operating table, recovery time, and the amount of prophylactic used were recorded during the operation.

2.3.4 Recovery

The post-operative recovery phase was continually modified over the period of study. The methodology that eventually resulted in the quickest recovery time involved removing the fish from the operating table directly to the holding tank on the electrofishing boat. The fish was then held under the stream of oxygenated water from the recirculating pump, and maintained in this position until opercular movements were judged sufficiently strong to allow the individual to gill on its own. The fish was subsequently moved to a holding cage in the river and monitored periodically.

An initial collection of fish (five individuals) was retained in the holding cage for 24 hours after surgery to determine short term health and vigour. However, subsequent fish were held for one to two hours and then released if exhibiting normal swimming behaviour and no disorientation. Minimal holding of surgically treated fish has been noted by several researchers (e.g., Hart and Summerfelt 1975) to cause less trauma.

2.4 SURVEILLANCE SYSTEMS

A fixed ground station and aircraft tracking were the principal techniques employed to systematically identify movements of tagged individuals within the project area. The equipment used and the procedures employed are detailed in the following sections.

2.4.1 Fixed Station

A fixed ground station enables collection of a large number of data records from within the area scanned and is often used in fisheries studies to determine the timing and rate of movement of fish past a specific location (e.g., upstream spawning migration). Associated costs of surveillance and downloading, as requested in the Terms of Reference, are presented in Appendix C.

Components

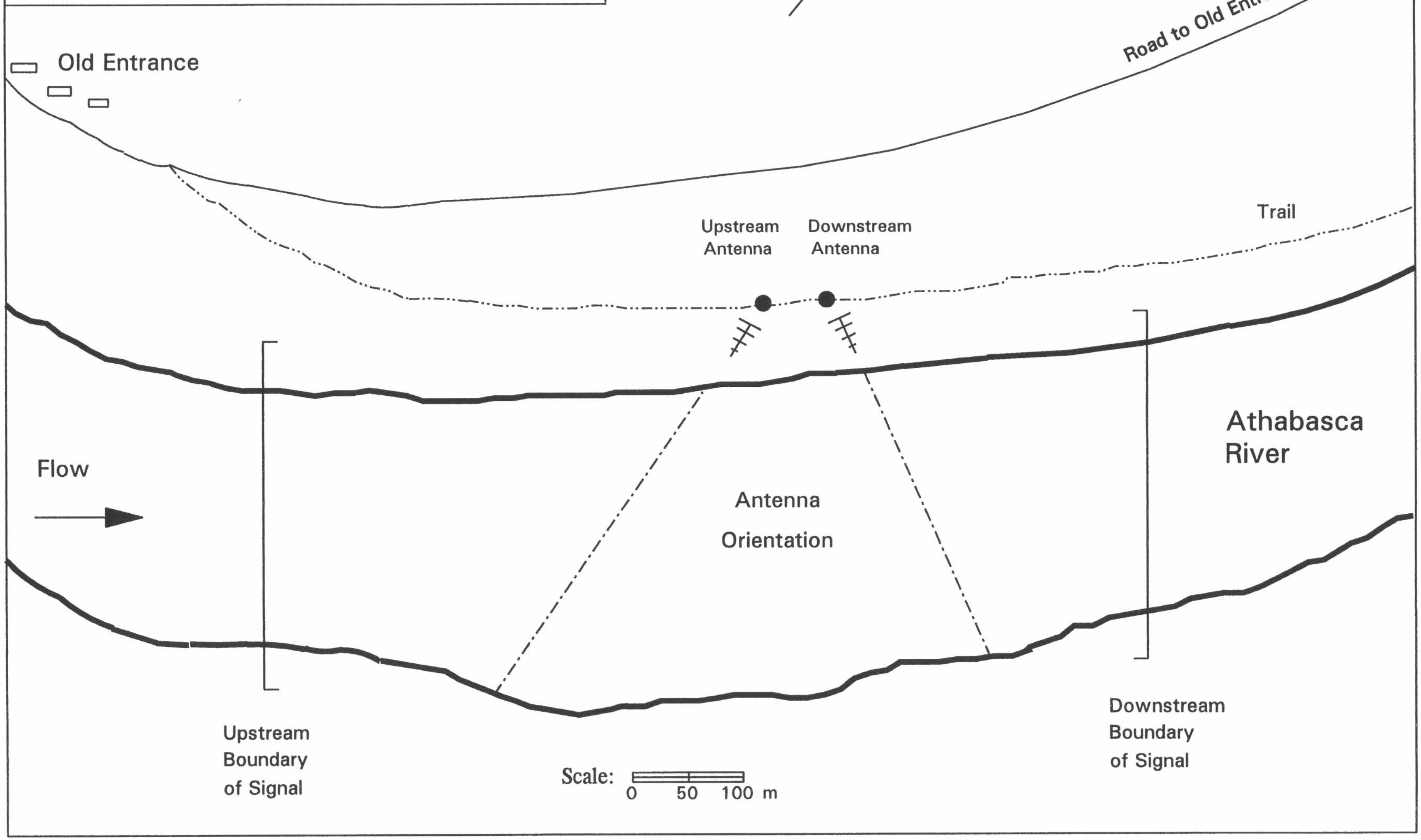
The fixed station consisted of two antennas, coaxial cable, a data logger, a locking steel cabinet, and two 12V recreational vehicle batteries. The antennas were identical nine-element Yagis, mounted on 6.1 m telescoping masts. Each mast was stabilized by guy wires anchored into the ground. The remote station set-up and antennae array are displayed in Figure 2.1 and Photos #1, #2 and #4 (Appendix F).

RG-58 coaxial cable was utilized to connect the antennas to the data logger and was buried approximately 8 cm into the soil to prevent damage by rodents and discourage vandalism. Conduit pipe was used to weather-proof and protect the cable along the lower 3 m of the masts and from the soil surface to the steel cabinet.

The data logger and batteries were housed in a lockable weather proof, steel, security cabinet. The data logger was a model SRX-400 Telemetry Receiver manufactured by Lotek Engineering Inc., with antennae switching to allow identification of upstream and downstream movements of fish. The switch box allows for switching to a maximum of eight antennas. Power requirements for the receiver and antennae switcher varies with operating conditions, but Lotek estimated that the SRX-400 receiver had an average current drain of 250mA, and that each antenna would drain an additional 100mA. A minimum of 11V was specified to power the receiver.

Two deep-cycle 120 ampere-hour 12-V recreational vehicle batteries, connected in parallel, were used to power the receiver and switch box. Each battery had an expected life of 343 hours (14.3 days). Batteries were replaced every two to three weeks to ensure continuous receiver operation. Voltages were recorded each time the batteries were changed, and drain, elapsed time and voltage readings are presented in Appendix C, Table 2.

R. L. & L. Environmental Services Ltd.
Figure 2.1
Location of antennae and fixed station area.



Station Set-up

The fixed station was located immediately east of Old Entrance (GPS reading 53°22'09.09" N, 117°42'46.1" W), 11.5 km upstream of the Weldwood Mill in Hinton. This site was selected for a number of reasons, including ease of access by vehicle (to Old Entrance), elevation above the river, clear line of site across river, narrow channel width, shallow depths, and secluded setting.

Access to the site is an important consideration since the equipment must be initially transported into the site, the batteries need servicing on a regular basis, data must be downloaded and the equipment must be removed when the project terminates. However, seclusion is also important to reduce potential for vandalism or the necessity to erect security fencing. Primary access to the site involves hiking from Old Entrance; boat access is also available from the Weldwood Bridge launch 13 km downstream.

Signal reception improves with increasing antenna height above the river. The combination of the high bank, approximately 18 m above river level, and the relative steepness of the bank (short horizontal distance to the water) provided excellent conditions for signal reception. The additional height of the masts resulted in total antenna height being approximately 24 m above river level. Signal reception is maximized if it travels unimpeded to the antennas (e.g., no trees), and the selected site offered a clear line of sight to the far bank.

Signal strengths of radio transmitters are maximized when emitted near the water surface, so that a site with shallow depths reduces the opportunity for a fish to sound and thus pass the site undetected. Depth recordings taken by sonar in late May indicated that the maximum depth in line with the antennas was approximately 2 m (river discharge $<200\ m^3s^{-1}$). Even with higher discharge (500-600 m^3s^{-1}) from the glacial meltwaters in June/July, the maximum depth at the site did not likely exceed 3.5 m. Discharges creating water depths in excess of 3 m (potentially affecting signal detection) were present from late May to early July (approximately 10% of the year). Another disadvantage of this site was that during high water, rapids and surface turbulence developed, thus tending to result in a greater scatter of the radio waves when exiting the water. However, depth and turbulence during this period did not likely compromise detection of transmittered fish. The time period did not coincide with the major migration period of any of the target species and migratory behaviour of these fish generally includes movement through the shallower, shore margin, water to avoid high velocities and to maintain visual cues.

During equipment testing and range evaluations, the antenna array was modified. At final set-up, the antenna were placed 57 m apart, with the downstream antenna at a 30° orientation to the river and the upper antenna at a 45° orientation. This placement allowed a longer reception time on the upstream antenna to maximize signal returns from fish travelling downstream, at or near the river velocity. Antennae were also oriented in the H-plane (elements vertical, as radio waves emitted from water are vertically polarized) and were adjusted by the guy wires to scan the river.

Data Acquisition

A scan cycle of 6 s was selected after testing; thus each frequency (channel) was scanned for 6 s on the downstream antennae, switched to the upstream antennae, and the process repeated. With the SRX-400 receiver CODE_LOG (data logging option) program, scan times can be set in 0.01 s increments up to ten minutes. A range of antennae switching options also are available.

Data from fish passing the fixed station were captured and stored in the data logger until downloading. Data were downloaded from the data logger into an IBM-compatible 386 notebook computer via a RS-232 null modem cable. The computer had 60 megabytes of available hard disk space, although a significant portion of that was filled with data manipulation programs. The data logger's storage banks hold a maximum of 280,000 bytes per bank. During the present demonstration project the amount of data stored never exceeded 400,000 bytes, and thus only 2 banks were used. After downloading the data, the data logger's memory banks were initialized (blanked), so that the maximum storage capability was available. The firmware's documentation indicates that 512,000 bytes are available for storage. The amount of storage capability is important in situations when changing of batteries cannot be done within relatively short intervals (e.g., less than three weeks), or the target species reside within reception range for extended periods.

2.4.2 Aerial Surveys

Aerial surveys allow for a large area to be searched in a relatively short time and facilitate tracking in areas inaccessible to vehicles.

Equipment

A Cessna 172 aircraft was utilized for aerial tracking; high-winged aircraft such as this are generally better suited than low-wing aircraft for attachment of antennae and tracking. The high-wing also allows easier viewing for the observer, since once a signal is acquired the fish's position must be determined. Quotations from Edmonton and area aircraft charter companies indicated that the lowest hourly charter rates were for the Cessna 172, and rates for fixed-wing aircraft were substantially lower than rates for rotary wing aircraft. Availability was also a consideration since it was desirable not to have to modify the equipment in the event that different aircraft charter firms were used.

A single four element Yagi antenna was mounted on the pilot's side of the aircraft in a forward-looking position. The position of the antenna relative to the horizon was modified throughout the survey period in order to determine optimum signal reception. Using correspondence received in July from Lotek Engineering Inc., the antenna was mounted at a 30° angle below the horizon (Photo # 3; Appendix F). Under ideal conditions this allowed the receiver to acquire the signals prior to the aircraft being directly over the fish's position and afforded the observer an opportunity to locate the kilometre designation on the map. However, to receive stronger signals and thus reduce the need for multiple passes over a site to acquire the fish code, the antennae was ultimately positioned at a 60° angle below the horizon. The antenna mount was attached to the wing strut with hose clamps and the coaxial cable connecting the antenna to the receiver was taped to the strut. Neoprene padding was used to avoid damaging the strut.

The receiver model used was similar to the one operated at the fixed station. Headphones were employed to monitor the signals acquired by the receiver. On a fully-configured receiver, the firmware allows the observer to alternate between the CODE_LOG program (data logging option) and EVENT_LOG program (a tracking option); the receiver used for aerial reconnaissance had only the tracking option. Under EVENT_LOG the receiver scans the table of frequencies and displays codes acquired on those frequencies. The codes are displayed for less than 30 seconds, after which time they are lost. Once the observer has determined the position of the fish on the topographic maps, the data on location and tag number can be entered into the receiver's non-volatile memory.

The observer had a complete set of topographic maps for the area to be searched which were marked with kilometre designations for the mainstem and significant tributaries. For stretches of river with few easily identifiable points (e.g., bridge crossings), locations of pipeline crossings, gas plants, etc. were recorded as reference points.

Tracking Procedures

During the Demonstration Project flights commenced between 07:30 and 08:15. In most instances the flight plan was Edmonton to Whitecourt, Whitecourt to Brule Lake (Hinton), refuel at the Jasper-Hinton airport, and return to Edmonton via Whitecourt. The final tracking flight went directly from Edmonton to Brule Lake, up to Athabasca Falls, and returned to the Jasper-Hinton airport with excursions up the major tributaries. After refuelling, the area searched was from Brule Lake to Whitecourt.

Prior to each flight, receiver and antennae function were checked with a reference transmitter. A noise scan of all frequencies was also done on the ground and shortly after lift-off to determine background noise levels. This was necessary to identify any severe electrical noise from the aircraft which could interfere with signal monitoring or acquisition, because the same aircraft was not always available for the survey (i.e., flying school aircraft).

Several flight speeds and altitudes were utilized throughout the project, with the objective being to identify which combination provided best signal reception on a single pass. Airspeeds flown ranged from 130 to 170 km/h, with slowest speeds being superior (thus increasing the reception and coding time available). Flight altitude varied from 150 to 425 m depending on the area searched (e.g., canyon, broad valley), weather conditions, and signal reception. Flights at higher altitudes increased the range at which audio signals could be detected, but in most instances low level passes were needed to acquire the transmitter code.

2.4.3 Ground Surveys

Ground surveys are often required to pin-point the location of individual fish and obtain specific habitat data.

In the present study, one ground survey was employed on the Rocky River. A hand-held four element Yagi antennae and tracking receiver were used from the high banks along the river valley to confirm and identify use of a side channel site by a radio tagged fish.

3.0 RESULTS AND DISCUSSION

3.1 SITE CONDITIONS AND FISH AVAILABILITY

Field programs were initiated 11 May 1992, with fixed station site selection; however, collection of fish and implantation of transmitters did not begin until 24 May, with completion on 12 June.

The Athabasca River is an unregulated river with a wide seasonal fluctuation in flow. Although spring snow melt results in some early increase in discharge, high flows in the study area are normally a result of glacial meltwater and rain in the mountain headwaters during June and July. The Athabasca River hydrograph at Hinton, for the period of study, is illustrated in Figure 3.1. During the fish collection and implantation period of the study, flows ranged from approximately 150 m^3s^{-1} to nearly 600 m^3s^{-1}. At initiation of the study, low flows created some launching and navigational difficulty; however, by early June high flows decreased sampling efficiency as a result of turbidity, velocities and shore-margin debris. These flows also altered the availability of holding habitat for fish. Water temperature during the fish collections ranged from approximately 10.5°C to 13.0°C. Conductivity of the river, although not measured at the time of fish collection, was 209 μS/cm in the lower portion of the survey area on 23 April (R.L. & L. Environmental Services Ltd. 1992a).

Collection locations reflected, in large part, access to the river and the availability of suitable-sized candidate fish. Within the priority study section the only launch for larger boats is at the Weldwood Bridge (Km 1227) below the Weldwood Mill in Hinton. Collections from Brule Lake (Km 1249) downstream to Km 1215 were based from this location. Other access points were located downstream at Obed Ford (Km 1192) and the Berland River Bridge (Km 1129).

All target fish for the study were sports or management-significant species. The primary target species were mountain whitefish (*Prosopium williamsoni*) and bull trout (*Salvelinus confluentus*). Mountain whitefish is one of the most abundant species in the study area; bull trout, although not abundant, is important as a top-predator and because of its "threatened" status in many east-slope drainages. The other recommended target species were burbot (*Lota lota*) and rainbow trout (*Oncorhynchus mykiss*). Burbot are locally common but were difficult to collect; rainbow trout were infrequent in the upper reaches and priority study section. Lake whitefish (*Coregonus clupeaformis*) and Arctic grayling (*Thymallus arcticus*) were included during the survey as "special interest" fish and because of lack of suitable-sized candidates of other species.

The availability of suitable-sized fish was a problem during the collection portion of this study; for some species due to distribution and habitat selection, but for others because of overall limited abundance. Although fish weight was used as the primary parameter for implantation, anatomy and body shape (i.e., species characteristic) were also significant. Fish with a deep body cavity (e.g., rainbow trout) can generally accept implantation of a transmitter at a smaller size than fusiform-shaped fish (e.g., mountain whitefish). However, heavier transmitters can affect fish buoyancy and also may result in transmitter loss (e.g., transintestinal transmitter expulsion). Summerfelt and Mosier (1984) noted that the retention rates of dummy transmitters surgically implanted in channel catfish were significantly higher for light implants (capsule in water weighing 1% of fish's weight in air) than for heavy implants (capsule weighing 2% of fish weight).

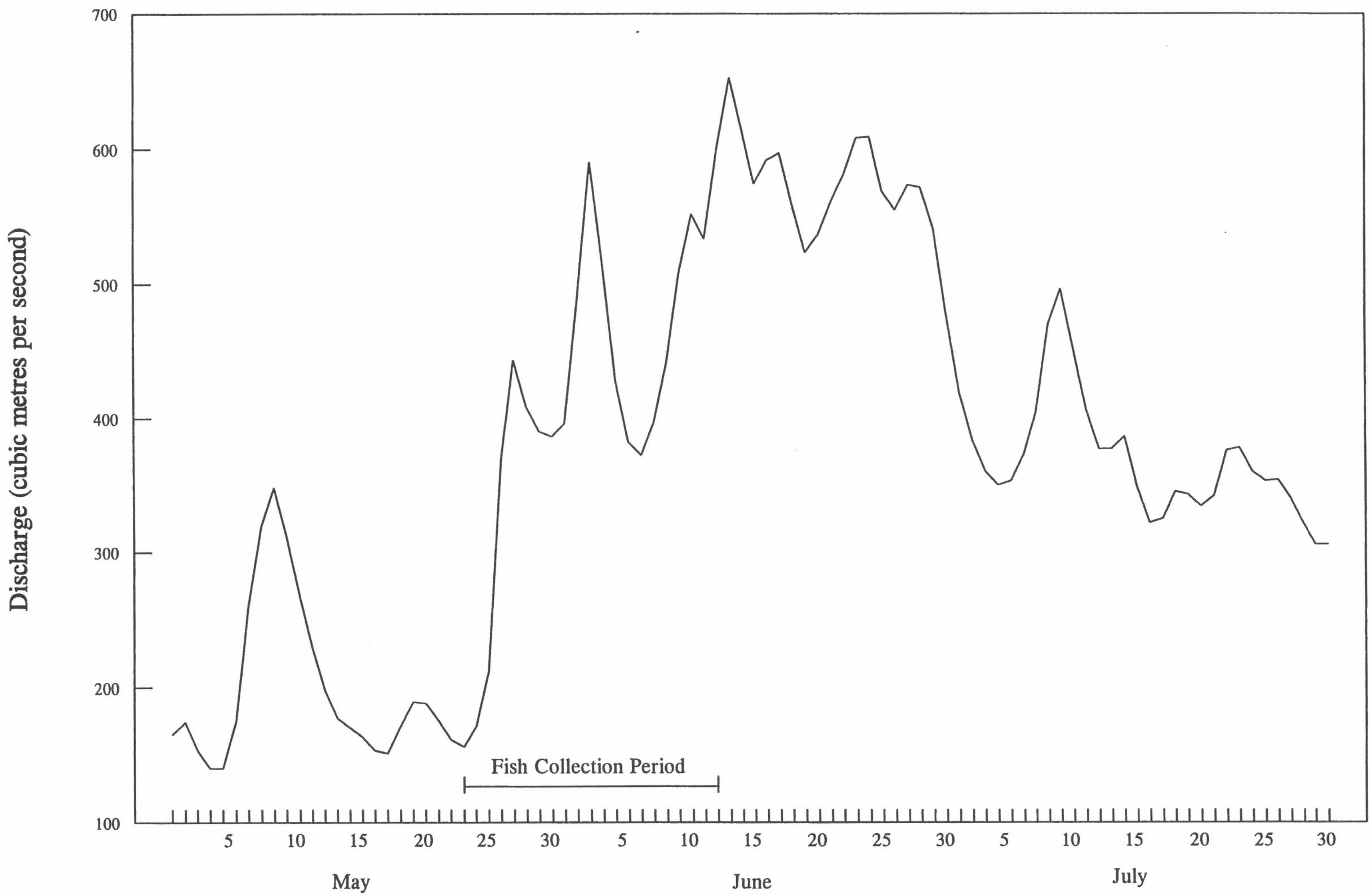


Figure 3.1. Fish collection period in relation to daily discharge, Athabasca R. at Hinton (Stn. 07AD002) for the study period May to July 1992.

(Water Survey of Canada preliminary data).

3.2 TRANSMITTER IMPLANTS

In total, 35 radio transmitters were implanted into adult fish of six species during late May and early June, 1992. Mountain whitefish (mean fork length 399 mm, mean weight 808 g) comprised the majority (17 fish) of target fish, followed by bull trout (9 fish) and burbot (5 fish). Rainbow trout collected were generally too small for tagging and only two fish were implanted with transmitters. Single specimens of lake whitefish and Arctic grayling were tagged. Species, numbers tagged, and size data for these species are indicated in Table 3.1. Transmitter codes, release date, and individual fish data are presented in Appendix D, Table 1.

Table 3.1 Summary of data from radio tagged fish, Athabasca River Telemetry Demonstration Project Area.

Species	Number	Fish Size	
		$\bar{x}$ Length/Range (mm)	$\bar{x}$ Weight/Range (g)
Mountain whitefish	17	399 (362-435)	808 (633-1205)
Bull trout	9	488 (385-570)	1287 (520-2070)
Burbot	5	692 (545-890)	2452 (910-5500)
Rainbow trout	2	348 (329-366)	507 (423-591)
Lake whitefish	1	501	-
Arctic grayling	1	304	369
All Species	35		

Fish were tagged and released at several locations in the study area to optimize collection of movement data and in order to demonstrate the operating and data logging features of the fixed station. With the exception of Old Entrance, these locations also reflected access to the river and the availability of suitable candidate fish. Twenty-three (66%) of the fish were released at Sites 2 and 3 within or near the 30 km priority area (downstream of the Hinton mill); the remaining fish were released at Old Entrance (Site 4) and near the Berland River (Site 1; Table 3.2).

Table 3.2 Location and number of radio tagged fish released at each site.

Site (Distance)[1]	Number of Fish
1. Upstream of Berland River (Km 1129)	3
2. Obed "Ford" (Km 1192)	11
3. Weldwood Bridge (Hinton) (Km 1227)	12
4. Old Entrance (Km 1239)	9

[1] Distance from Km 0.0 at confluence of Athabasca River and Lake Athabasca.

3.3 FISH MOVEMENT DATA

Movement data for the six target species were recorded by both the fixed station and aircraft surveillance over the late spring and summer period from June to August 1992. Although the study period for the Demonstration Project extended only to the end of July, data from survey extensions in August (10 and 31 August) are also included to facilitate the discussion and graphically illustrate the fish movement patterns during the summer.

Movement data for each species are discussed below; further data from survey extensions in fall and winter 1992 will be appended to the final report.

3.3.1 Data Collection

Fixed Station Surveillance

The fixed ground station was fully operational by 8 June 1992, and thereafter scanned the river 24-hours per day to intercept and document upstream or downstream movement of radio tagged fish. Tracking data was downloaded from the data logger on five occasions (20 June, 6 July, 23 July, 10 August, and 31 August).

During system testing transmittered fish were released just above the fixed station on 25 and 27 May. Localized movements were recorded on an intermittent basis for these fish until the fixed station was fully operational on 8 June. Some fish remained in the vicinity of the station for a considerable period of time before moving out of the range boundaries of the antennae.

Aerial Surveillance

Aerial tracking of the mainstem Athabasca River and major tributaries was initiated on 20 June, after all transmitters had been implanted. Seven tracking flights were flown between 20 June and the end of the initial study period on 29 July. Fall tracking commenced 31 August; data from this survey have been included in this discussion to more graphically illustrate the extent of movement and behaviour of the demonstration fish species. Aerial tracking results are described in Appendix D, Tables 4-11; coverage of the study area is indicated in Appendix D, Table 12.

3.3.2 Movement Patterns

Fixed Station Data

Fish movements at the fixed station are summarized in Table 3.3, and are briefly discussed below for each download period.

- *Download 1 (9 June to 20 June data)*

Movements and activity of four fish (one burbot, three bull trout) were documented in this period (Table 3.3). The burbot (Code 1-2) and two of the bull trout (Code 4-8 and Code 3-20) had been initially released in this area and displayed local home range or feeding-type movements. Bull trout Code 20-10, however, was migrating upstream. This fish had been released at Km 1226.7 (Weldwood Bridge) on 12 June and was intercepted moving upstream past the fixed station (Km 1239) on 20 June. Burbot Code 1-2, which had apparently moved out of range during the early portion of the survey period, was present again from 16 June on, remaining within the reception area. Similarly bull trout Code 4-8, which was present in the reception area from 25 May to 13 June, moved downstream out of range.

- *Download 2 (20 June to 6 July data)*

Mountain whitefish Code 4-2, was intercepted moving upstream past the station on 5 July. Released near the station at Km 1239 on 25 May, it had moved downstream after tagging, below the canyon as far as Km 1231 (2 July aerial tracking) before initiating what was probably an upstream summer-feeding movement.

Two bull trout were intercepted migrating upstream past the station during this period. Bull trout Code 19-20, released at the Weldwood Bridge on 12 June, moved past the station on 26 June; bull trout Code 19-25 released at the Weldwood Bridge on 9 June, moved past the station on 3 July. A third bull trout (Code 20-44) released at the bridge also moved upstream into the canyon near the Highway 40 bridge during this period and was recorded by the station in this area on 1-2 July, after which time it moved back downstream out of range.

Burbot Code 1-2 remained within the reception area throughout the full duration of the survey period.

Table 3.3 Summary of fish movements at the Fixed Station, Athabasca River (Km 1239) 25 May to 31 August 1992.

Species	Transmitter Code	Release		Station Interception	
		Date	Km	Date	Movement Direction
Burbot	1-2	25 May	1239	25 May-13 July	Localized/Upstream
Mountain whitefish	4-2	25 May	1239	25 May	Downstream
				5 July	Upstream
				26 August	Downstream
Mountain whitefish	4-5*	25 May	1239	25 May-2 June	Localized
Bull trout	4-8	25 May	1239	25 May-13 June	Localized/Downstream
				18-19 July	Upstream
Burbot	1-7	27 May	1239	27 May	Downstream
Bull trout	3-20*	27 May	1239	28 May-10 June	Localized
Burbot	5-9*	27 May	1239	28 May-1 June	Localized
Bull trout	5-14*	27 May	1239	28 May-5 June	Localized
Bull trout	19-20	12 June	1227	26 June	Upstream
Bull trout	19-25	9 June	1227	3 July	Upstream
Bull trout	20-10	12 June	1227	20 June	Upstream
Mountain whitefish	20-12	11 June	1192	12-13 July	Upstream
Bull trout	20-31	10 June	1192	30-31 July	Upstream
Bull trout	20-44	12 June	1227	1-2 July	Localized/Downstream
				7 July	Upstream

*Suspected faulty transmitter.

- *Download 3 (6 July to 23 July data)*

Three new intercepts (two bull trout and one mountain whitefish) were made during this period; all fish were moving upstream. Bull trout Code 4-8, which had moved downstream on 13 June (released near the station on 25 May), migrated upstream past the station on 18 and 19 July. Bull trout Code 20-44, which had approached the fixed station on 1 and 2 July, migrated past the site on 7 July. This fish entered the station reception area at 20:13h and continued upstream beyond range by 23:36h (Appendix D, Table 2).

Mountain whitefish Code 20-12, tagged and released 47 km downstream (Obed Ford) on 11 June, moved upstream through the site on 12 and 13 July (overnight). Figure 3.2 illustrates the signal intercept data, antennae differentiation to identify direction of movement, and time of movement through the antennae range. Although some signal overlap occurred on both antennae, the higher signal strength and greater percentage of signals received on the downstream antennae indicated the fish was below the fixed station and moving gradually upstream for nearly 900 min, before passing the site and moving out of upstream range approximately 1020 min after initial interception.

Burbot Code 1-2, which had resided within the reception area since mid-June, moved upstream and vacated the area on 13 July. Signal acquisition by the station, and documentation of home range territory and local activity for this individual are illustrated in Figure 3.3 and Appendix D, Table 3. After 14d of initial activity in the area of the station, this fish appeared to move downstream out of the reception area for 7d, and then moved back into the area to remain for approximately another 29d.

- *Download 4 (23 July to 10 August data)*

One fish, bull trout Code 20-31, moved upstream past the fixed station on 30 and 31 July. This fish had been captured below the Emerson Lakes Bridge at Km 1181 and released at Obed Ford (Km 1192) on 10 June.

Aerial Data

Aerial tracking results are summarized below for each target species. In total, 9 transmitters (25.7%) were lost or malfunctioned immediately and were never detected during the aerial surveys. Subsequent malfunctions of several other transmitters also occurred; equipment performance is discussed in later sections of this report.

- *Bull Trout*

Bull trout radio tagged (n=9; functioning transmitters = 6) during the demonstration study displayed substantial movements within the study area. After an initial period of localized movement, or fallback from the release site during recovery from the surgery, most fish began to slowly migrate upstream. Pronounced upstream movements were recorded by the fixed station and by aerial tracking during July. Tracking data and movements in relation to release locations are summarized in Table 3.4 and Figure 3.4. This movement pattern by bull trout is typical of mid-summer orientation towards spawning tributaries and is similar to bull trout spawning movements monitored by radio telemetry in the Peace River system (RL&L 1992b).

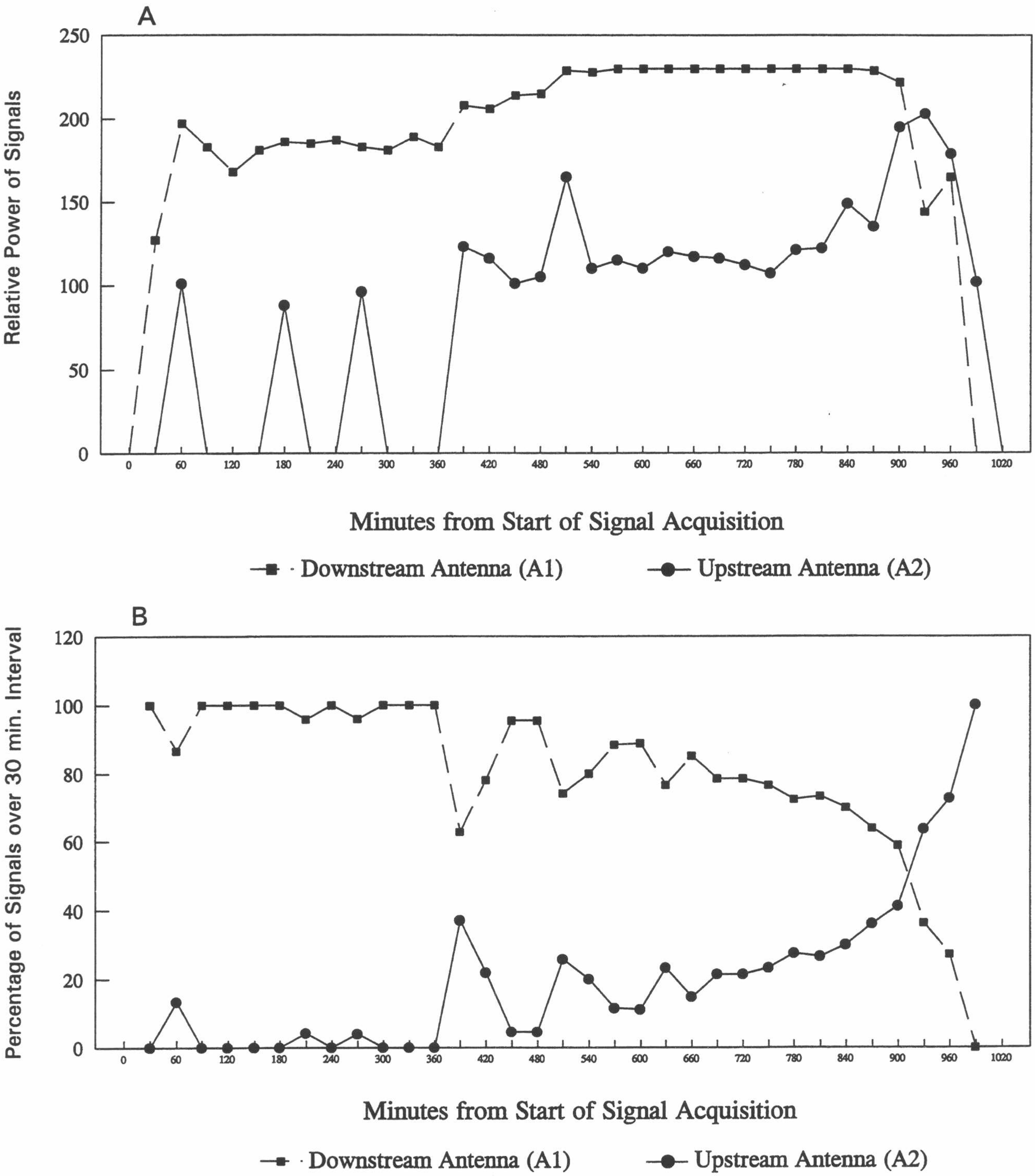


Figure 3.2. Example of a fixed station intercept of mountain whitefish (Tag 20-12), illustrating rate of movement, and antennae differentiation to determine movement direction using relative signal strength (A) and percentage of signals received by each antennae over a 30 minute time period (B).

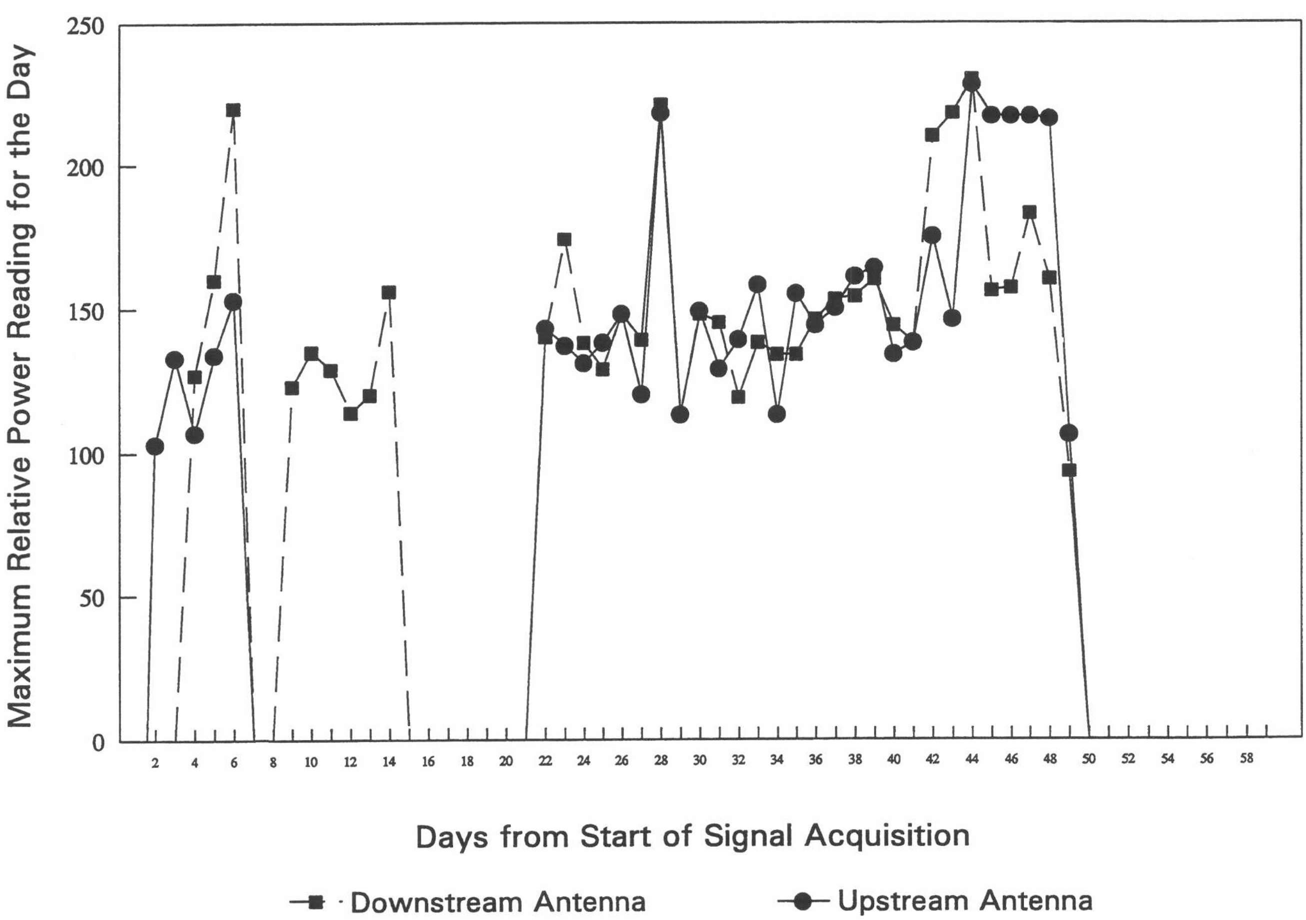


Figure 3.3. Signal acquisition and activity of a burbot (Tag 1-2) near Km 1239 from 27 May (Day 1) to 13 July (Day 50), 1992.

Table 3.4 Aerial tracking data for bull trout, Athabasca River, Telemetry Demonstration Project Area.

Fish Code	Release		TRACKING DATE, LOCATION (LOC), AND MOVEMENT (MOVE)															
			20 June		24 June		28 June		2 July		18 July		22 July		29 July		31 August	
	LOC (km)	Date	LOC[1] (km)	MOVE (km)	LOC (km)	MOVE (km)	LOC (km)	MOVE (km)	LOC (km)	MOVE (km)	LOC (km)	MOVE (km)	LOC (km)	MOVE (km)	LOC (km)	MOVE (km)	LOC (km)	MOVE (km)
3-20	1239	27-05	*	-	*	-	*	-	*	-	*	-	*	-	*	-	*	-
4-1	1239	25-05	*	-	*	-	*	-	*	-	*	-	*	-	*	-	*	-
4-8	1239	25-05	1235	-3.9	1235	-0.1	1229	-6.0	1228	-1.0	1239	+10.5	1260	+21.9	SN5.5[3]	+17.1	1246	-32.0
5-14	1239	27-05	*	-	*	-	*	-	*	-	*	-	*	-	*	-	*	-
19-20	1227	12-06	1228	+0.8	1229	+1.5	1247	+18.0	1249	+2.1	NS[2]	-	NS	-	NS	-	SN33.5	+66.0
19-25	1227	09-06	1220	-6.7	1223	+3.0	1234	+11.0	1232	-2.0	NS	-	NS	-	SN20.5	+53.0	SN20.5	0.0
20-10	1227	12-06	1239	+12.3	NS	-	1262	+22.8	1262	0.0	*[5]							
20-31	1192	10-06	1190	-2.0	1190	0.0	1190	0.0	1190	0.0	1205	+15.0	1219	+13.5	1234	+15.9	RK1.0[4]	+42.0
20-44	1227	12-06	1226	-0.7	1226	0.0	1238	+12.0	1238	0.0	1267	+28.9	1264	-2.9	1264	0.0	1264	0.0
	Detection (%)		67		56		67		67		38		38		50		63	

[1]Locations identified to nearest Km; movements downstream (-), upstream (+).
[2]NS - No signal received.
[3]SN - Snake Indian River.
[4]RK - Rocky River.
[5]20-10 Angler capt. 5 July/Fiddle River.
*Lost/malfunctioned transmitter; never detected during aerial tracking.

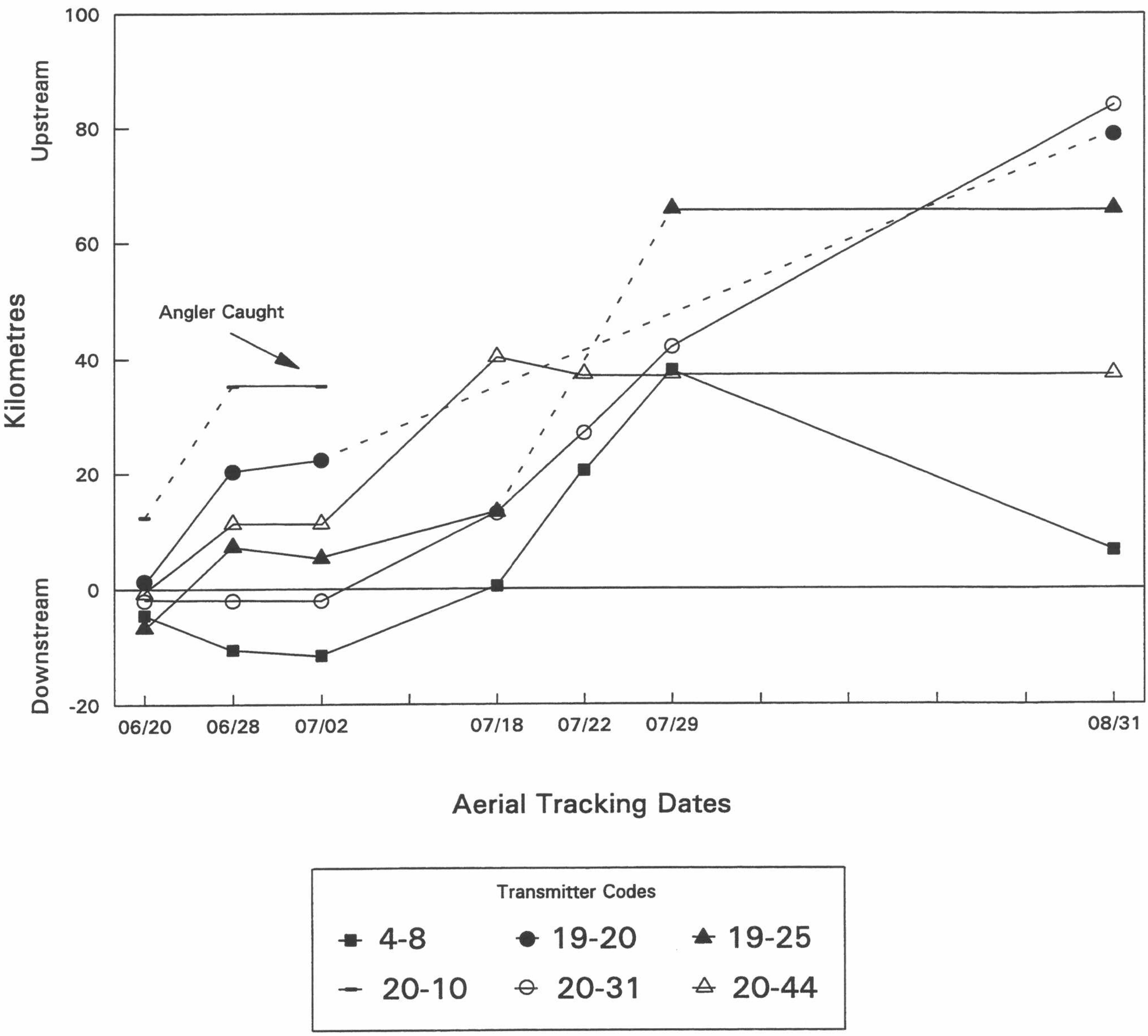


Figure 3.4. Movement patterns of bull trout in the Athabasca River from 20 June to 31 August 1992, in relation to release location.

Rate of upstream migration by some bull trout was very rapid. Bull trout Code 19-20 migrated 18 km through the canyon area above Hinton and past the fixed station in just four days. Another fish (Code 19-25) entered the range of the fixed station at 14:30:51 on 3 July and moved through the range of the station (estimated range 800 m) in 68 min. Movements of this fish during the survey period are illustrated in Figure 3.5.

All of the bull trout successfully monitored during the survey moved upstream through the canyon above Hinton, through Brule Lake and into Jasper National Park. One fish (Code 20-10) was captured by an angler near the Fiddle River before it could complete its migration. Three bull trout (Code 4-8, 19-20, and 19-25) moved into the Snake Indian River (Figure 3.4); probable spawning sites were located near Km 20.5 and Km 33.5 above the confluence with the Athabasca River. An impassable falls at Km 36.5 prevents further upstream migration in this system. A fourth bull trout (Code 20-31) moved upstream into the Rocky River, again likely for spawning purposes. This fish had originally been captured on 10 June near the outlet of Emerson Creek (local name) 95 km downstream from the Rocky River.

- *Mountain Whitefish*

In total, 12 of 17 mountain whitefish receiving radio transmitters were successfully tracked. Mountain whitefish movements, in most cases, appeared to be related to feeding behaviour or home territory. Home territory movements of generally less than 10 km were displayed by all fish tracked until July (Table 3.5). However, substantial, rapid, upstream movements were undertaken by several radio tagged fish in July (Figure 3.6). Fish Code 4-2 moved upstream past the fixed station on 5 July, through Brule Lake, and was next located above Jasper Lake (55 km upstream of the fixed station) on the 29 July aerial survey. However, by 26 August this individual passed the fixed station again, enroute downstream (Figure 3.6).

Two other mountain whitefish also moved a considerable distance during this period. Between 2-18 July, fish Code 20-12 moved upriver 82 km to the Rocky River in Jasper National Park, where it was located in a side-channel near the confluence of the Rocky and Athabasca rivers. Fish Code 19-27 moved upstream 32 km at the same time, and then remained near this point for the remaining surveys. These long-distance summer movements displayed by some of the radio tagged fish are most likely feeding related. Davies and Thompson (1976) found that most adult mountain whitefish in the Sheep River (southwestern Alberta) were migratory, with complex movement patterns including upstream summer feeding movements in the mainstem river when stream discharges/turbidities decreased and food abundance increased. Similar mechanisms likely influence the distribution and movement of mountain whitefish in the upper Athabasca River. Distinct spawning-related movements of some of the demonstration fish can be expected in the fall.

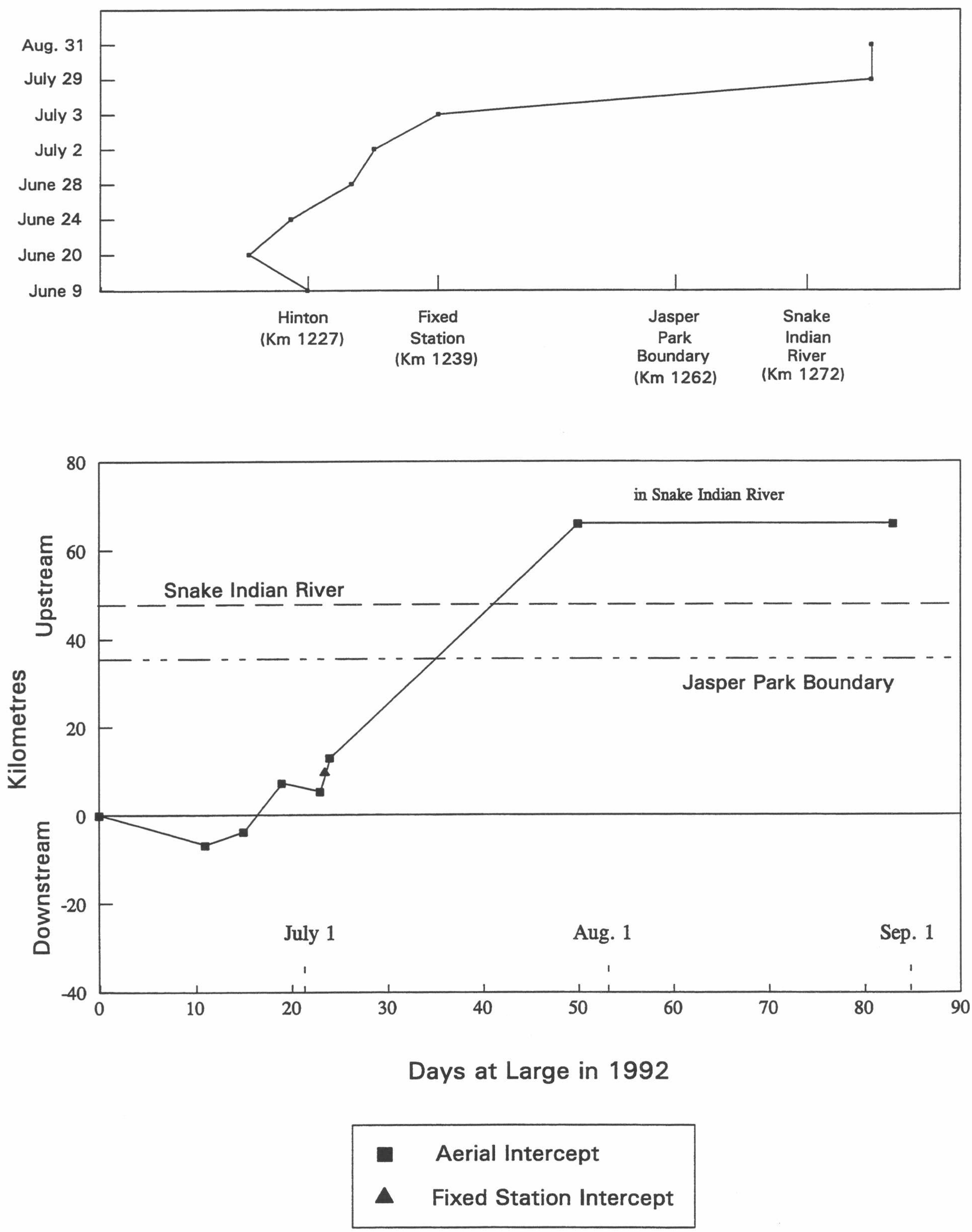


Figure 3.5. Movements of a bull trout (Code 19-25) from the release location (Km 1227) in the Athabasca River, June to August 1992.

Table 3.5 **Aerial tracking data for mountain whitefish, Athabasca River, Telemetry Demonstration Project Area.**

Fish Code	Release		TRACKING DATE, LOCATION (LOC)[1], AND MOVEMENT (MOVE)															
			20 June		24 June		28 June		2 July		18 July		22 July		29 July		31 August	
	LOC (km)	Date	LOC[1] (km)	MOVE (km)	LOC (km)	MOVE (km)	LOC (km)	MOVE (km)	LOC (km)	MOVE (km)	LOC (km)	MOVE (km)	LOC (km)	MOVE (km)	LOC (km)	MOVE (km)	LOC (km)	MOVE (km)
1-3	1129	29-05	1119	-10.3	1119	0.0	1119	0.0	1118	-1.0	1118	0.0	1118	0.0	1118	0.0	1118	0.0
2-11	1227	28-05	*		*		*		*		*		*		*		*	
3-22	1227	28-05	1225	-1.7	NS		NS		NS		NS		NS		NS		NS	
4-2[2]	1239	25-05	NS	-	1235	-4.5	1236	1.0	1231	-5.5	1239[2]	+8.0	NS	-	1294	+54.7	1239[2]	-55.0
4-3	1227	28-05	NS	-	1217	-9.7	1217	0.0	1216	-1.0	NS	-	NS	-	NS	-	NS	-
4-4	1227	28-05	1223	-3.7	1224	+1.0	1223	-1.0	1225	+2.0	1221	-4.0	1223	+2.0	1222	-1.0	1217	-5.0
4-5	1239	25-05	1238	-1.5	1238	0.0	1238	0.0	1238	0.0	NS	-	NS	-	NS	-	NS	-
4-7	1227	28-05	*		*		*		*		*		*		*		*	
6-15	1192	11-06	*		*		*		*		*		*		*		*	
19-23	1192	11-06	1187	-5.0	1184	-3.0	1184	0.0	1186	+2.0	1178	-8.4	1178	0.0	1177	-1.0	1187	+10.0
19-26	1192	11-06	*		*		*		*		*		*		*		*	
19-27	1192	11-06	1192	0.0	1191	-1.0	1192	+1.0	1192	0.0	1224	+32.2	1224	0.0	1223	-1.0	1222	-1.0
19-33	1192	10-06	1192	0.0	1191	-1.0	1192	+1.0	1192	0.0	1192	0.0	1192	0.0	1192	0.0	1193	+1.0
20-11	1227	09-06	NS	-	1219	-7.7	1219	0.0	1219	0.0	NS	-	1219	0.0	NS	-	NS	-
20-12	1192	11-06	1192	0.0	1191	-1.0	1192	1.0	1192	0.0	1274	+82.0	1276	+2.4	1276	0.0	1276	0.0
20-24	1192	10-06	1192	0.0	1191	-1.0	1192	+1.0	1192	0.0	1193	+1.0	1193	0.0	1200	+6.5	1214	+14.0
20-43	1192	10-06	1192	0.0	1191	-1.0	1192	+1.0	1192	0.0	1192	0.0	1191	-1.0	1192	+1.0	NS	-
	Detection (%)		59		71		71		71		47		53		53		41	

[1]Locations identified to nearest Km; movements downstream (-), upstream (+).
[2]Code 4-2 (Fixed station data) - 5 July and 26 August. Fish not located during aerial surveys on 18 July and 31 August.
* Lost/malfunctioned transmitter; never detected during aerial tracking.
NS - No signal received.

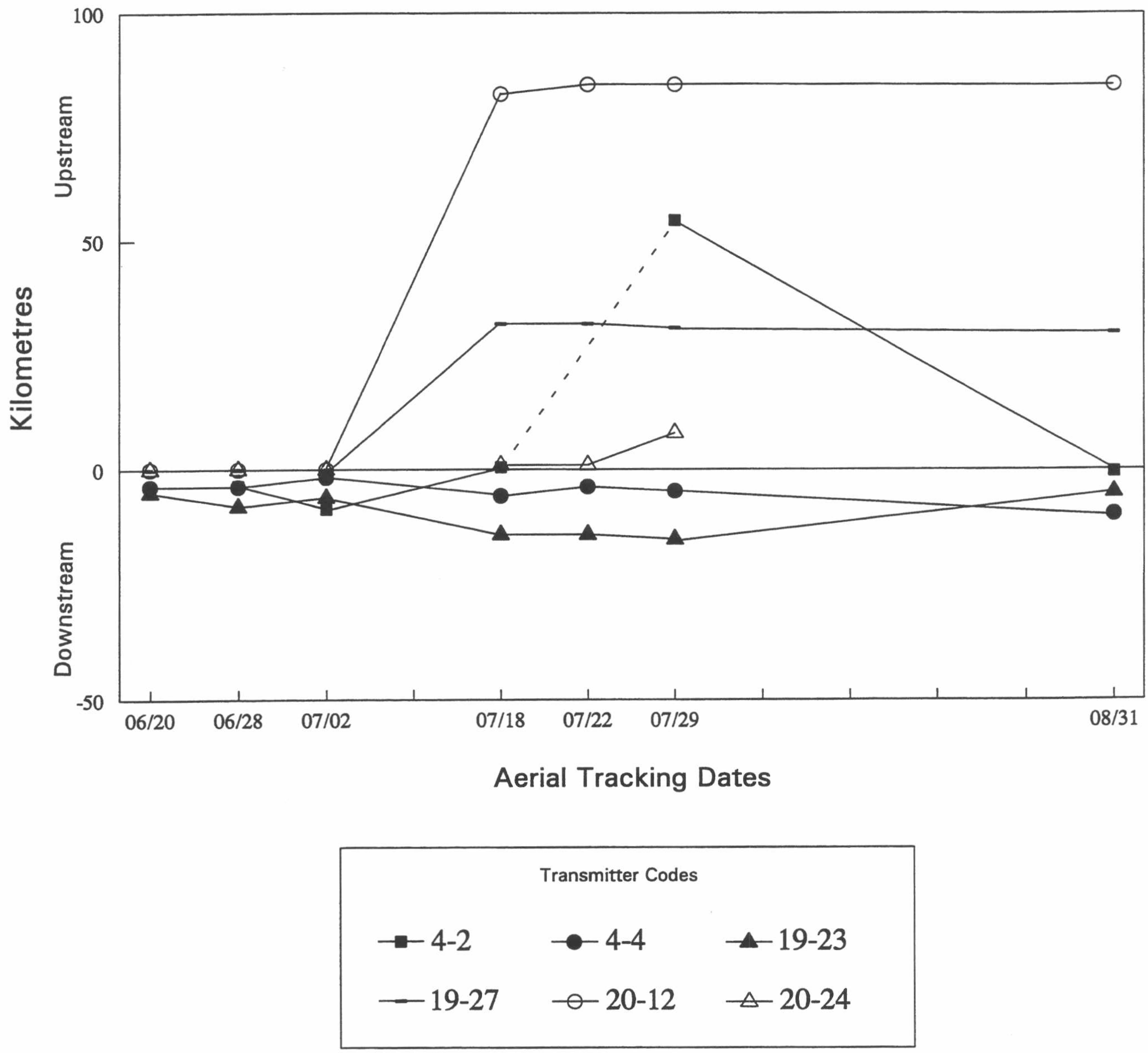


Figure 3.6. Movement patterns of selected mountain whitefish in the Athabasca River from 20 June to 31 August 1992, in relation to release location.

- *Burbot*

Five burbot were implanted with transmitters, however two units failed shortly after initiation of the study. Movements of the three burbot tracked to-date have been short with the maximum distance travelled from the release site being 6 km (Table 3.6; Figure 3.7). These movements are undoubtedly feeding or home territory related; more extensive movements may occur in late fall and winter in response to spawning. Possible spawning or feeding-related movements of up to 280 km distance were recorded for a radio-tagged burbot in the lower Slave River during winter (R.L. & L./EMA 1985a).

- *Rainbow Trout*

Short, territorial, movements were displayed by the two rainbow trout tagged (Table 3.7; Figure 3.8). Fish Code 4-6, moved upstream 8.2 km shortly after release, moving back into a large pool habitat located near its point of capture. It remained within this area during the summer. The fish was not located, however, on the 31 August re-initiation survey and it is suspected that it may have been captured by an angler or predator. The second rainbow trout (Code 19-28) also moved upstream to its home territory shortly after release and has remained in this vicinity (Table 3.7). Well-defined spawning movements into small tributaries, similar to those described by radio telemetry on the upper Peace River, B.C. (R.L. & L. Environmental Services Ltd. 1992b) can be expected in spring 1993 but transmitter life will not be sufficient to continue monitoring until this period.

- *Arctic Grayling*

The Arctic grayling (Code 20-26) remained in the vicinity of its release location until late June at which time it exhibited a sudden 35 km downstream movement. No subsequent movement has been detected (Table 3.7; Figure 3.8).

- *Lake Whitefish*

After implantation of the radio transmitter this fish (Code 5-15) moved downstream approximately 6 km and has displayed only short distance (±1 km) movements between surveys throughout the summer (Table 3.7; Figure 3.8). As spawning season nears in the fall, more extensive movement is likely.

Table 3.6 Aerial tracking data for burbot, Athabasca River, Telemetry Demonstration Project Area.

Fish Code	Release		TRACKING DATE, LOCATION (LOC), AND MOVEMENT (MOVE)															
			20 June		24 June		28 June		2 July		18 July		22 July		29 July		31 August	
	LOC (km)	Date	LOC[1] (km)	MOVE (km)	LOC (km)	MOVE (km)	LOC (km)	MOVE (km)	LOC (km)	MOVE (km)	LOC (km)	MOVE (km)	LOC (km)	MOVE (km)	LOC (km)	MOVE (km)	LOC (km)	MOVE (km)
1-2	1239	25-05	NS	-	1240	1.0	1239	-1.0	1234	0.0	1244	+5.0	1244	0.0	1244	0.0	1245	+1.0
1-7	1239	27-05	NS	-	1238	-1.5	NS	-	NS	-	1238	0.0	1237	-1.0	1237	0.0	1238	+1.0
2-13	1129	29-05	*		*		*		*		*		*		*		*	
3-24	1227	28-05	1225	-2.0	1224	-1.0	1225	+1.0	1227	+2.0	NS	-	1222	-5.0	1221	-1.0	NS	-
5-9	1239	27-05	*		*		*		*		*		*		*		*	
	Detection (%)		20		60		40		40		40		60		60		40	

[1]Locations identified to nearest Km; movements downstream (-), upstream (+).
* Lost/malfunctioned transmitter; never detected during aerial tracking.

Table 3.7 Aerial tracking data for various species, Athabasca River, Telemetry Demonstration Project Area.

Species	Fish Code	Release		TRACKING DATE, LOCATION (LOC), AND MOVEMENT (MOVE)															
				20 June		24 June		28 June		2 July		18 July		22 July		29 July		31 August	
		LOC (km)	Date	LOC[1] (km)	MOVE (km)	LOC (km)	MOVE (km)	LOC (km)	MOVE (km)	LOC (km)	MOVE (km)	LOC (km)	MOVE (km)	LOC (km)	MOVE (km)	LOC (km)	MOVE (km)	LOC (km)	MOVE (km)
Arctic grayling	20-26	1192	11-06	1189	-3.0	1153	-1.0	1153	-35.0	1153	0.0	1153	0.0	1153	0.0	1153	0.0	1153	0.0
Rainbow trout	4-6	1129	29-05	1138	+9.0	1137	-1.0	1138	-1.0	1138	0.0	1138	0.0	1138	0.0	1138	0.0	NS	-
Rainbow trout	19-28	1192	10-06	NS	-	1191	-1.0	1195	+4.0	1195	0.0	1194	-1.0	1194	0.0	1194	0.0	1195	+1.0
Lake whitefish	5-15	1227	28-05	NS	-	1221	-6.0	1220	-1.0	1220	0.0	1220	0.0	1221	+1.0	1220	-1.0	1220	0.0
		Detection (%)		50		100		100		100		100		100		100		75	

[1]Locations identified to nearest Km; movements downstream (-), upstream (+).
NS - No signal received.

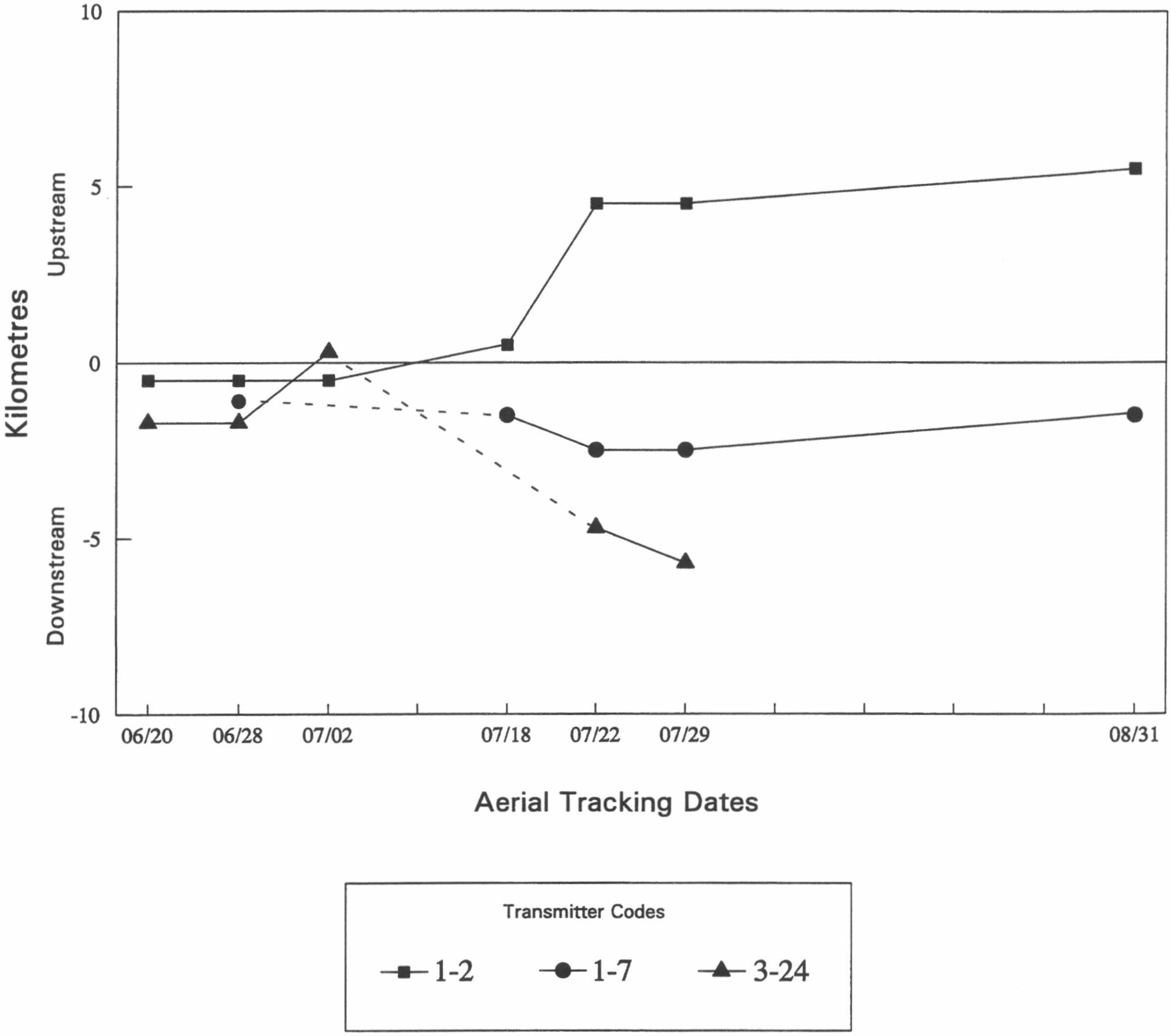


Figure 3.7. Movement patterns of burbot in the Athabasca River from 20 June to 31 August 1992, in relation to release location.

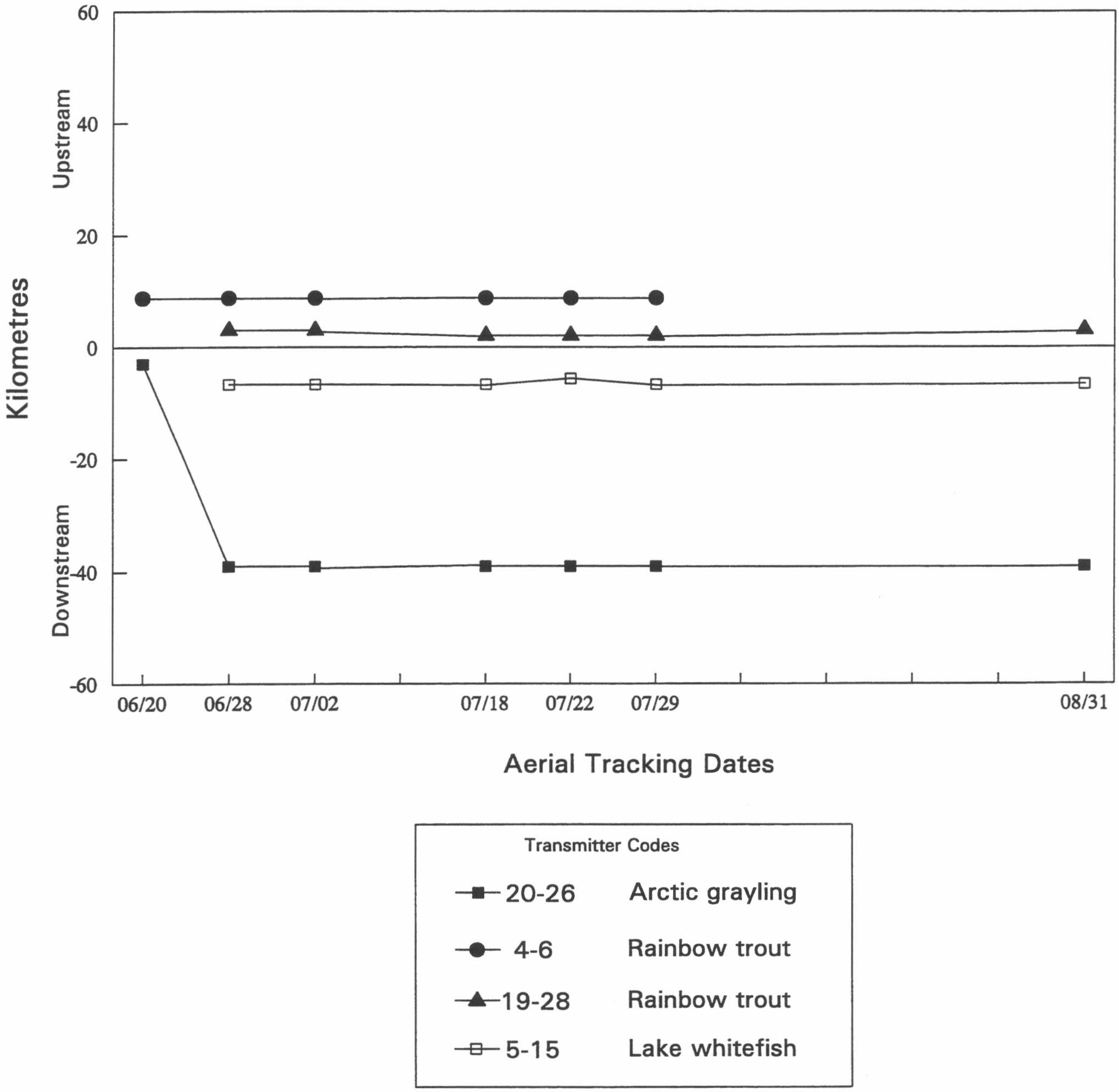


Figure 3.8. Movement patterns of Arctic grayling, rainbow trout, and whitefish in the Athabasca River from 20 June to 31 August 1992, in relation to release location.

3.4 EQUIPMENT AND TECHNIQUES EVALUATION

3.4.1 Transmitter Function

Transmitter function was tested in air and water prior to utilization. During range testing at the remote station a serious malfunction was noted in transmitters from the initial shipment when used for several hours at the ambient river water temperatures of 9°-13°C. This problem was apparently related to tuning of the crystal (controlling the frequency). Upon advice from Lotek, transmitters were tested overnight (±10 h) in iced water. Units not functioning after this test (12 transmitters) were returned to Lotek, while the remainder were presumed to be operative and were retained for use in order to avoid further delays to the study. However, subsequent performance of some of the retained transmitters suggests that 40-50% of these were also faulty.

Transmitters received after this occurrence (re-manufactured or replaced units) showed a much better reliability with only two (12.5%) of 16 units appearing to malfunction. This rate is closer to normal; previous experience has indicated that up to 10% of the transmitters will probably fail.

In total, after all transmitters were implanted, we appeared to have had at least a 33% failure rate. This is clearly unacceptable. Although quality control was responsible at the manufacturing level, some of the problem originated as a result of the study process for the Northern Rivers Basin programs. Transmitters cannot normally be delivered in the timeline established by NRBS for the Demonstration Study (these are custom built, not in-stock items). Normal supply time from most telemetry equipment manufacturers is 6-8 weeks. An initial portion of the transmitters and other equipment ordered for this study was received within 4 weeks of order; however, the remainder required an additional 2 weeks before delivery. Lotek attempted to meet the deadline using on-hand crystals left from a previous (1991) order; however, procedures for tuning were apparently set for 1992 manufactured crystals and this was not identified during the urgency to provide these transmitters.

3.4.2 Detection Systems

Fixed Ground Station

- *Calibration*

At the ground station maximum coverage was determined by manually positioning a transmitter in the water, at a depth of 0.5 m, at varying distances on each shore upstream and downstream of the antennae. Because of the shallow depths (generally ≤2 m) in the area and difficulty due to river velocities, transmitters were not range tested at other depths. A test was also conducted to establish reception time span by drifting a transmitter beneath a float, past the fixed station. Reception ranges at the fixed ground station were primarily a function of antennae position and signal gain adjustments. It was ultimately found to be necessary to orient the upstream antennae at a greater upstream angle, in order to capture the signal earlier and compensate for the velocity of the river and speed of movement if the fish was migrating downstream. During the initial set-up the upstream antennae achieved a range of approximately 750 m, with the downstream antennae (position more directly across the river) having an estimated range of 550 m. However, downloads from the fixed station indicated substantial signal overlap was occurring between the antennae at their position and gain settings. Gains were subsequently reduced approximately 15% and the downstream antennae was moved farther away from the upstream antennae. Although the range boundaries were reduced (indicated in Figure 2.1) signal interpretation was improved. Figures 3.9 and 3.10 illustrate the difference in signal interpretation as a result of these changes. Fixed station intercepts and direction of movement, at least for upstream migrating fish, was relatively easy to interpret after these changes. Downstream intercepts may, however, encounter some difficulty. Fish moving at the velocity of the river will be in range for about only five minutes and, because of frequency scan time and antennae switching, the signal would only be intercepted a maximum of 4-5 times while in range.

- *Data Storage and Manipulation*

Data storage capability is important in situations when changing of batteries cannot be done within relatively short intervals or the target species reside within reception range for extended periods. Fish species with relatively slow movement patterns will stay within range for longer periods of time and thus both increase the amount of data stored and reduce battery life. For example, in one 24 h period (08 July) there were 1,784 records (signal acquisitions) from one burbot (Code 1-2; Appendix D, Table 3).

During the fixed station monitoring it was found that a large number of records could present problems in data manipulation, as well as with battery life. A data bank full of records and accompanying environmental information (e.g., signal strength, gain, etc.) represents more than 9,000 records. The most commonly used spreadsheet program available (i.e., Lotus 1-2-3, Lotus Development Corp.) will only import a maximum of 8,192 records into a worksheet, so that additional records are simply lost. Care must be taken to ensure that all records have been loaded, since this spreadsheet program does not prompt the user that not all of the records have been loaded. There are, however, other spreadsheet programs that have greater data import capabilities. For example, Excel V4.0 (Microsoft Corp.) will import 16,384 records.

Another method of ensuring all the data records are available is to edit the data prior to importing it into the spreadsheet. Since the data are in ASCII format, a text editor can be employed to remove extraneous data. Again, care must be taken to ensure that the selected editor is capable of importing all the records prior to editing. In this demonstration, it was found that WordStar V1.0 could successfully read all the data. Other text editors such as WordPerfect 5.1 also successfully read the data, but programs such as these occupied too much hard disk space on the notebook computer used to download the data. The early version of WordStar occupied only approximately 360 000 bytes of hard disk space. In the present study, after manipulation with a text editor to remove environmental information and data on battery strength, the edited file was saved in its ASCII format and imported into Lotus 1-2-3. The records were then sorted, so that records for each transmitter were located in contiguous groups.

Another potential problem with a large data set was demonstrated when one full data bank (i.e., approximately 280,000 bytes) was sorted and manipulated with the spreadsheet program. Although only one new subset of data was generated from the original imported data set (i.e., date conversion from the firmware's Julian date to the "year/month/day" format), the resulting spreadsheet was over 1.6 megabytes in size. Since a high density 3.5 inch diskette can hold only 1.44 megabytes, the file could not be transferred between computers without first "condensing" it to a smaller size (archival program PKZIP/PKUNZIP was found to be useful for this purpose).

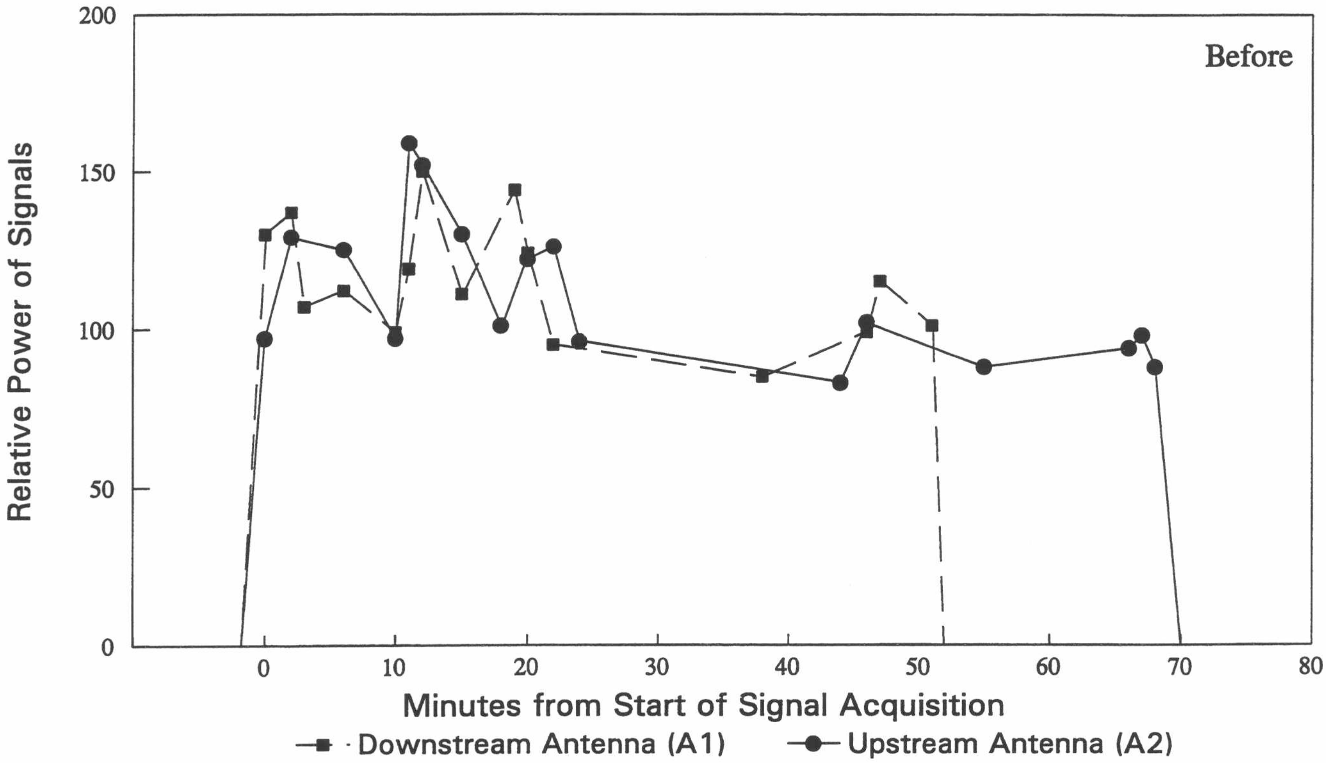


Figure 3.9. Example of signal interpretation of a bull trout (Code 19-25) moving upstream past the fixed station, prior to antennae repositioning. (Gain A1=72, A2=75; distance between antennae = 44.5 m).

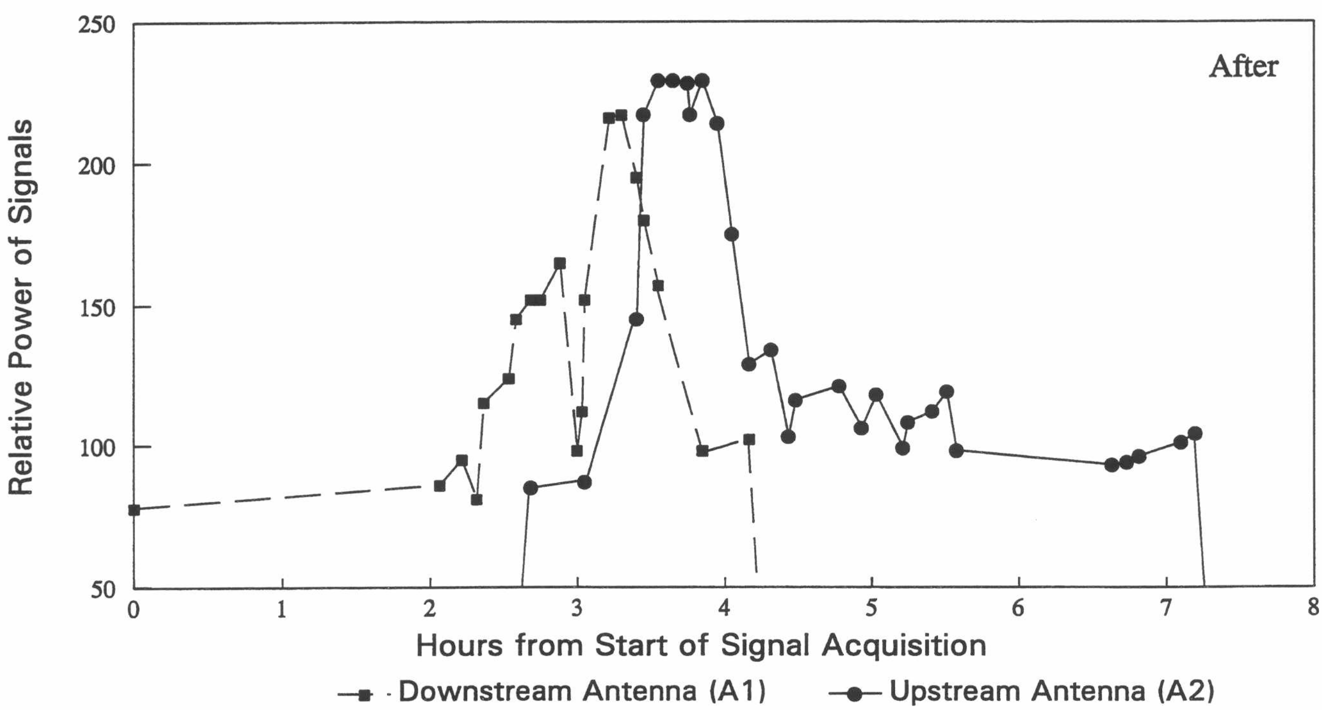


Figure 3.10. Example of signal interpretation of a bull trout (Code 20-31) moving upstream past the fixed station, after antennae repositioning. (Gain A1=60, A2=65; distance between antennae = 57 m).

.Furthermore, for individuals with a large number of records, the data could not be concatenated into a single file. For example, there were nearly 19 000 records for a single burbot from 27 May to 13 July (Appendix D, Table 3). It was difficult to manipulate and interpret that much data.

It is also important to be able to manipulate the data in the field. During the demonstration project, knowing which fish had passed the fixed station aided in ground truthing the locations of tagged fish. Being able to download and view the data is also important during the setup and range testing phase.

- *Costs*

Costs associated with placement and servicing of a fixed ground station are itemized in Appendix C, Table 1. Costs of the current battery-operated station and estimated costs of providing solar panel battery charging, to reduce potential servicing costs are provided. Complete automation is also possible with a telephone link whereby data can be transferred to an in-house computer and program parameters (e.g., antennae gain) can be adjusted from the desk top.

The present system, involving battery replacement and manual downloading, does however provide some assurances on site security and any physical damages to equipment. In the present study, very high winds shifted the antennae orientation; this problem was observed during the regular servicing schedule and corrected.

Aircraft Monitoring

Reception range and efficiency was not specifically determined for the transmitters because of the variability due to receiver gain, aircraft noise, altitude and antennae set-up. However, an initial test was conducted in Chickakoo Lake near Edmonton, to determine signal strength required for decoding. A reference transmitter was manually positioned from a boat at depths of 0.5, 1.0, and 3.0 m, while reception was monitored during several passes over the lake with an aircraft at an altitude of approximately 200 m. At depths of 3.0 m difficulty was experienced decoding the transmitter signal. The conductivity of Chickakoo Lake water (197 μS/cm, RL&L 1987) is similar to that of the Athabasca River, and therefore did not bias the results.

During aerial tracking, a number of factors contributed to efficiency of signal reception. The terrain definitely influenced reception; for example, it was difficult to acquire signals in areas such as the canyon at the Highway 40 bridge near Hinton. On some flights, numerous passes were made over the canyon in an attempt to isolate the code of a fish utilizing that habitat. A second factor was the number of radio tagged fish near a given location. At some locations in the vicinity of release points, dispersal had yet to occur, resulting in fish on different frequencies inhabiting essentially the same area. The procedure in these areas required multiple passes, each on a different frequency. When the observer determined that a fish(s) on a given frequency was present but could not positively identify the individual (i.e., code not displayed), subsequent passes had to be conducted. A third factor affecting signal reception was noise; some areas had high levels of background noise (e.g., Hinton urban area). The receiver often acquired and displayed a noise code, which could only be overridden by a transmitter code of sufficient strength. In some cases, multiple passes at various altitudes again were required before the transmitter code was successfully received.

Another factor potentially influencing signal reception was individual transmitter signal strength. This factor could not be quantitatively or qualitatively evaluated, since it would require capturing a representative proportion of the radio tagged fish and testing the transmitters.

Three main areas of concern arise from problems with signal acquisition; these are costs, lost data, and observer fatigue and motion sickness. Firstly, each multiple pass over an area increases the amount of flight time, thus increasing the cost for each radio telemetry flight. Secondly, failure to acquire the transmitter code may result in lost data. With sufficient planning, it is possible to limit the number of tags of a given frequency in a particular area. If tags on a specific frequency are spaced relatively far apart and the code cannot be acquired from a transmitter, it may be possible after review of previous tracking flights to identify which fish on that frequency was at the location. Similarly, if the locations of all the other fish on a frequency are known, the code for the unidentified tag can be deduced. Finally, fatigue and motion sickness may detract from the efficiency of the tracking operation. Gilmer et al. (1981) suggested that two hours was the limit an individual could be expected to effectively monitor the receiver and perform the associated tasks of navigation and data recording. As they noted, weather and turbulence are important factors in tracking efficiency. Average flight time for the present study area was about 5½ hours.

In the present tracking area, a large portion of the terrain is mountainous creating turbulent flying conditions on most surveys. Build-up of weather fronts and storms in the mountain foothills area occurred frequently, reducing the coverage of the study area on several flights and resulting in loss of potential data from areas which could not be surveyed on that date. It is thus important that contingencies be built into any aerial survey program.

3.4.3 Fish Handling and Operative Procedures

Pre-Operative Evaluation

Fish were examined for injury (i.e., gill damage, haemorrhaging) or abnormal behaviour both before and during the operation and rejected if signs of distress were noted.

Mountain whitefish was the only species exhibiting substantial signs of distress, however, none of the individuals captured suffered immediate mortality. Of the total number of adult mountain whitefish captured, approximately 50% were judged unsuitable for surgery. Electrofishing damage ("burn" mark where the fish was likely in contact with the anode) was noted on one bull trout, but did not affect its immediate or subsequent migratory behaviour.

Handling of the fish was minimized, in particular for mountain whitefish, in an attempt to reduce stress. After the initial implants, where all morphometric data were collected, weights were taken only from representative fish and Floy tagging also was discontinued.

Post-Operative Evaluation

Data on induction and recovery times for each of the individuals undergoing surgery are presented in Appendix E, Table 1. There was a higher correlation between mean weight and induction time (r^2=0.92) than for mean length and induction time (r^2=0.72), indicating that fish weight is a better predictor of time to stage 5 anesthesia than length. The mean time for mountain whitefish in the anesthetic solution was relatively short in comparison to the other species, since it was observed that increasing the time until the fish had reached stage 5 resulted in most individuals also reaching stage 6 (cessation of opercular movements followed by cardiac arrest). In some instances, mountain whitefish removed from the anesthetic after stage 4 (total loss of equilibrium) progressed to stage 6. With additional field testing, it was found that removing this species after a maximum of 95 seconds in the anesthetic resulted in the highest rate of recovery and surgical success.

An initial collection of fish (five individuals) was retained in the holding cage for 24 h after surgery to determine short term health and vigour. Four individuals appeared to have fully recovered and exhibited no signs of distress, buoyancy or balance difficulty. However, one fish (a mountain whitefish) had split or snagged its sutures (probably on the material of the holding cage) and had to be sacrificed. Subsequent fish were held for only one to two hours and then released if exhibiting normal swimming behaviour and no disorientation. Minimal holding of surgically treated fish has been noted by several researchers (e.g., Hart and Summerfelt 1975) to cause less trauma and reduce the risk of injury.

Subsequent recovery of one radio tagged bull trout (Code 20-10) by an angler on 5 July (23 days after surgery) indicated complete recovery and healing had occurred by this time, with no signs of abrasion or infection of the suture or antennae exit location.

4.0 SUMMARY AND RECOMMENDATIONS

4.1 TECHNICAL ASSESSMENT

The primary objective of this study was the technical evaluation of equipment, protocols, and telemetry techniques. The results of this assessment have been presented in the forgoing sections; specific points are discussed below.

Transmitters

- *Frequency Selection*

The high frequencies utilized (148-149 Mhz) for this study appeared to be generally suitable for the conditions experienced in the study area, and for the purposes required. However, these frequencies may not necessarily be suitable for conditions or all sites selected in other parts of the NRBS area. High frequency transmitters may not be the best selection in rivers exhibiting depths of >3 m. High frequency transmitters do allow the use of more efficient and directional antennae systems; however the high gains employed to capture signals also may result in interception of considerable background noise. The fish species, tracking method, site conditions, and purpose of the study all need careful consideration prior to selection of frequency. If the sole purpose of the study is to examine home territory movements of a bottom feeding species, rather than intercepting spawning movements of a highly-migratory species at one location, then a low frequency rather than high frequency may be more suitable. Many salmonids tend to migrate in shallow margins of the river, and in turbid systems fish often move in shallow depths or near the surface, thus enhancing use of high frequencies in these cases.

Background noise conditions should be evaluated, particularly for fixed station installations in high noise urban locations. Ideally, noise levels should be known prior to ordering transmitters and receivers and sufficient planning time should be available to do this. A noise scan was not performed prior to ordering materials for this study as the time frame for optimum collection/implantation of fish was very short, equipment was unavailable on short notice, and the remote setting of most of the study area reduced potential noise sources. After the data logger was received, a noise scan of the tentative fixed station location was conducted to determine background conditions and potential sources of interference, prior to installation. For aerial tracking, a majority of the noise and electrical interference is likely to originate from the aircraft itself. For many charters, the specific aircraft is unknown prior to the flight; in the case of this study, noise conditions were evaluated on the ground after antennae hookup, and again shortly after lift-off to ensure no major problems existed. With the SRX-400 receiver, the noise floor of the environment can be determined and performance optimized by adjusting the noise blank level and gain levels.

Transmitters utilized for the present study were equipped with the manufacturers unique time-interval coding system, which theoretically enabled up to 50 transmitters to be employed on one specific frequency. This has obvious advantages if a very large number of target fish are required (i.e., 200 fish could be monitored on only four frequencies). Standard pulse-coded systems usually assign a maximum of 2-3 transmitters per frequency. In the present study, a number of problems developed which limited the usefulness and reliability of the coded transmitters supplied by the manufacturer. In addition to the manufacturing problem previously identified, the transmitters also illustrated the following problems:

- although the frequency could be identified audibly, the specific transmitter code could not be identified if signal strength was not sufficiently strong.
- if fish (transmitters) were not sufficiently dispersed then difficulty was experienced scanning and coding individual frequencies.

These latter problems contributed to inefficiency in aerial tracking and loss of some potential data.

- *Transmitter Size and Life Span*

Transmitter size is a function of battery size; battery size/capacity usually determines the life span of the transmitter. In the present Demonstration Project the transmitters were selected to provide the life span requested for monitoring through autumn 1992 and thus allow the opportunity to collect information on fall spawning activities of bull trout and mountain whitefish, and overwintering habitat selection. To provide this life span, the transmitters utilized a 3-volt battery, with a package weight of 10.5 g. As published protocols recommend transmitter weights of $\leq 2\%$ of fish weight, this limited the size range of fish to approximately 525 g or larger. This size limitation has implications for some fish species, if long-term data are desired. The next available size of coded transmitter used a larger battery package and weighed 29 g in air. This transmitter exhibited a longer life span (or significantly greater signal strength over the same life span) but would require a fish weighing 1450 g or larger.

Again, the objectives of the study have to be clearly determined before selection of a transmitter size and life span. Size and availability of fish in all seasons must be known in advance. During the Demonstration Project time period difficulty was experienced in obtaining fish of sufficient size for some of the proposed target species, although during other seasons and with more sampling effort this problem could possibly be overcome. However, this latter option is not generally available on a contract study. It is also obvious from published studies that transmitter loading rate (weight relative to body weight) can be an important factor in the success of the program. In surgical implant studies in which loss or expulsion of transmitters was not a problem, the transmitter weight to fish weight was generally less than 1% (e.g., 0.6%, Hart and Summerfelt 1974; 0.35%, Pitlo 1978, and 0.25%, Miller 1982; *In* Summerfelt and Mosier 1984). McKinley et al. 1992 recommended a tag weight not exceeding 0.5-1% of the fish's total body weight for body cavity implants. In the Demonstration Project, although most target fish (32 of 35 fish) met the 2% weight criteria, only 34% (12 fish) met the 1% limit. This may have affected the results achieved for some fish; however, tracking data indicated most difficulties existed with a total loss of signal, not a stoppage in movement which would be indicative of tag expulsion.

Monitoring Techniques

- *Fixed Station*

The information collected to-date indicates that the remote (fixed) ground station has been highly successful in monitoring fish movements and determining direction of movement and migratory behaviour (i.e., rate of movement, home territory movements). No major problems have been encountered with the equipment at the fixed station, other than insufficient time allowance for system set-up. Reliability during winter conditions will be tested during winter 1992-1993.

At initiation of any subsequent study, sufficient time should be allowed for system design and set-up. Factors to consider in site selection include property tenure (private or crown) and time required to obtain permission for use. This is not an insignificant item and has to receive priority in the initial stages of the study. Other factors (access, security) have been previously identified and are also important considerations.

Site conditions are obviously critical in the success of a monitoring station and the following conditions should be present, to the extent possible, to enhance signal reception:

1) elevation of antennae as high as practical above the river level,
2) shallow river channel depths, e.g., $\leq$3 m,
3) repose, rather than undercut, banks to reduce signal loss from fish moving along the margins,
4) laminar flows, rather than rapids to reduce radio wave refractions and improve reception,
5) slower velocities to maximize the number of signals received if the intent is to monitor downstream migrations, and
6) singular river channels; if braided channels are selected then multiple stations will likely be required. Very wide channels may also require stations on both sides of the channel.

Costs, especially downloading and maintenance, will vary with the location and system utilized. For the Demonstration Project the downloading and servicing costs were approximately $ 2800.00/month (Appendix C; Table 1). If available, a remote telephone link/solar battery charger would reduce this to an estimated $ 1650.00/month.

Purchase of a remote data-logger/fixed station system should not assume receipt of a "turn-key" operation. This was a problem during set-up of the present system. Although the radio-telemetry manufacturer was able to provide technically advanced transmitters and receivers, knowledge of station and antennae set-up and influencing parameters were less than satisfactory, resulting in considerable additional time to achieve final operational status.

- *Aircraft Tracking*

Aerial tracking during the Demonstration Project provided new information on the movement patterns and location of critical habitats of target fish species within the study area. Without this component of the study, the upstream extent of migration, critical habitat locations (e.g., bull trout spawning) and degree of movements/utilization of the mainstem Athabasca River and selected tributaries in Jasper National Park, by fish originating (at the time of this study) from downstream of Hinton would not be known.

As indicated previously, however, the efficiency of aircraft tracking in this upstream portion of the Athabasca River system is often reduced by weather conditions which develop over the mountains in a short period of time. A high risk factor also exists for fixed-wing flying at low levels in mountain areas.

In summary, the aerial tracking and fixed ground station monitoring both provided useful data. These techniques can be supportive of each other and selection of an individual method for future studies will again depend on the objectives of the study. Aircraft tracking can provide data on the range, movement patterns and critical habitat locations of fish. For these purposes it is indispensable. Remote (fixed) stations can be used to define the limits of a study area or identify the time, rate, and extent of movements in specific areas. For example, because of the multi-antennae capability of the present system, a monitor located at an effluent source could identify utilization of the site by target species and/or avoidance and movement through the monitoring area. With both techniques, further ground (shore or boat based) tracking may be needed to pin-point the location of specific habitats utilized.

Collection and Attachment Protocols

Collection techniques resulting in the least physical damage to the target fish species are important to reduce stress and increase the probability of recovery from transmitter attachment. Unfortunately not all techniques are equally as efficient or stress-limited on all species. During the present study electrofishing was the sole technique utilized due to study time commitments and river flow conditions. Late spring flow levels (Figure 3.1) and high turbidity resulted in fish being subjected to the electric field for a longer period of time than normal before they were observed and captured. Damage was most apparent to mountain whitefish, a species which does not seem to react well to capture or handling stress. Study timing should ensure that collections are completed before peak flows begin. Lower flows and shallow river conditions generally increase electrofishing efficiency, enable use of lower power settings, and optimize netting success.

Surgical implantation techniques were successful for all species, and eliminated potential problems of entanglement, drag, abrasion, and regurgitation faced with external or stomach inserted transmitters. However, for short term movement studies of some large species, stomach insertions are definitely quicker and may result in less short term stress to the fish. This was illustrated by a very successful telemetry study of spawning migrations of inconnu conducted on the Slave River (RLL/EMA 1985b).

During the surgical procedure mountain whitefish were very sensitive to the degree of anaesthesia and several mortalities occurred. This may also have been related to the low tolerance by this species to handling or the physiological stress and damage from electrofishing. Further use of mountain whitefish should include additional evaluation of collection techniques and implantation/transmitter attachment stress.

4.2 UTILITY OF RADIO TELEMETRY FOR THE NRBS

The present study has demonstrated the value of radio telemetry in the upper Athabasca River drainage for identifying the location of target fish species and developing a further understanding of the basic ecology and behaviour of these species. Previously undocumented information on the movements and exchange of fish between upstream reaches of the Athabasca River has been reported. An understanding of the seasonal behaviour of these target species (e.g., migrations and homing) is an important component of recognizing contaminant pathways and dispersal from core areas.

As the present study was a demonstration of techniques and procedures for radio tagging, several fish species were utilized. However, application of this methodology for future studies should be confined to a small number of species, size-classes, sex, or locations, in order to focus on and answer one question or hypothesis.

Because of some technical difficulties (i.e., initial failure of transmitters) which were not anticipated, the cost effectiveness of the study is difficult to evaluate. Similar equipment has been used on other large-scale studies, with apparently few problems encountered. U.S. Fish and Wildlife Service has to date deployed more than 2000 coded transmitters on the Snake River, Idaho. However, overriding all of the above assessments and recommendations is the need to allow a sufficient amount of time for study planning and equipment supply.

Conventional tagging of fish normally gives only two locations - the release site and the recapture site; generally conclusions about fish movement patterns are based on data from recaptures of 3-10% of the fish (Matthews and Reavis 1990). Use of radio telemetry in the NRBS area has the ability to provide multiple data points to better categorize the behaviour of target species and thus enable correlation with important environmental parameters.

5.0 LITERATURE CITED

BIDGOOD, B.F. 1980. Field surgical procedure for implantation of radio tags in fish. Alberta Fish and Wildlife Div., Fish. Res. Rep. 20, Edmonton, AB.

CHISHOLM, I.M., AND W.A. HUBERT. 1985. Expulsion of dummy transmitters by rainbow trout. Trans. Am. Fish. Soc. 114: 766-767.

DAVIES, R.W., AND G.W. THOMPSON. 1976. Movements of mountain whitefish (*Prosopium williamsoni*) in the Sheep River watershed, Alberta. J. Fish. Res. Bd. Can. 33: 2395-2401.

GILMER, D.S., L.M. COWARDIN, R.L. DUVAL, L.M. MECHLIN, C.W. SHAIFFER, AND V.B. KWECHLE. 1981. Procedures for the use of aircraft in wildlife biotelemetry studies. Resource Publ. 140, U.S. Fish and Wildl. Serv. 19 p.

HART, L.G., AND R.C. SUMMERFELT. 1975. Surgical procedures for implanting ultrasonic transmitters into flathead catfish (*Pylodictus olivaris*). Trans. Am. Fish. Soc. 104:56-59.

HELM, W.T., AND H.M. TYUS. 1992. Influence of coating type on retention of dummy transmitters implanted in rainbow trout. N. Am. J. Fish. Manage. 12:257-259.

IRELAND, L.C., AND J.S. KANWISHER. 1978. Underwater acoustic biotelemetry: procedures for obtaining information on the behaviour and physiology of free-swimming aquatic animals in their natural environments. Pages 341-379 *In* D.I. Mostofsky [ed.] The behavior of fish and other aquatic animals. Academic Press, New York, NewYork, USA.

KNECHT, C.D., A.R. ALLEN, D.J. WILLIAMS, AND J.H. JOHNSON. 1981. Fundamental techniques in veterinary surgery. 2nd edition. W.B. Saunders Co., Philadelphia, PA.

LONG, F.M. [ed]. 1977. Proceedings First International Conference on Wildlife Biotelemetry. Univ. of Laramie, Wyoming.

MARTY, G.D. AND R.C. SUMMERFELT. 1986. Pathways and mechanisms for expulsion of surgically implanted dummy transmitters from channel catfish. Trans. Am. Fish. Soc. 115: 577-589.

MATTHEWS, K.R. AND R.H. REAVIS. 1990. Underwater tagging and visual recapture as a technique for studying movement patterns of rockfish. AFS Symposium - Fish Tagging Techniques. 7:108-172.

MCKINLEY, R.S., G. POWER, AND H.E. KOWALYK. 1992. Transmitter attachment/implant - laboratory manual. Ontario Hydro Research, Environmental Research Department and Univ. Waterloo, Biol. Dept., unpubl. paper, 16p.

R.L.&L./EMA. 1985a. Burbot movements and domestic utilization in the Slave River, N.W.T. Report prep. for Slave River Hydro Study Group by RLL/EMA Slave River Joint Venture.

R.L. & L./EMA. 1985b. Fall fish spawning habitat survey, 1983-1985. Prep. for Slave River Hydro Study Group by RLL/EMA Slave River Joint Venture. 102 p. + Appendices.

R.L. & L. ENVIRONMENTAL SERVICES LTD. 1987. County of Parkland Fisheries Inventory - Chickakoo Lake. Prep. for Alberta Fish and Wildlife Div. and Alberta Recreation, Parks and Wildlife Foundation. 54 p.

R.L. & L. ENVIRONMENTAL SERVICES LTD. 1992a. Athabasca River - general fish inventories. Spring 1992 Component. Sub-Project 3111. Report prep. for Northern River Basins Study Group.

R.L. & L. ENVIRONMENTAL SERVICES LTD. 1992b. Peace River Site C hydroelectric development, pre-construction fisheries studies. Data summary report. Report prep. for B.C. Hydro, Environmental Resources Division.

SCHNICK, R.A., F.P. MEYER, AND D.F. WALSH. 1986. Status of fishery chemicals in 1985. Prog. Fish-Cult. 48: 1-17.

STASKO, A.B., AND D.G. PINCOCK. 1977. Review of underwater biotelemetry, with emphasis on ultrasonic techniques. J. Fish. Res. Bd. Can. 34: 1261-1285.

SUMMERFELT, R.C., AND D. MOSIER. 1984. Transintestinal expulsion of surgically implanted dummy transmitters by channel catfish. Trans. Am. Fish. Soc. 113: 760-766.

SUMMERFELT, R.C. AND L.S. SMITH. 1990. Anesthesia, surgery, and related techniques. Pages 213-272. *In* C. B. Schreck and P.B. Moyle [eds.] Methods for fish biology. American Fisheries Society, Bethesda, Maryland.

WINTER, J.D., V.B KUECHLE, D.B. SINIFF, AND J.R. TESTER. 1978. Equipment and methods for radio tracking freshwater fish. University of Minnesota Agricultural Experiment Station, Miscellaneous Report Number 152.

WINTER, J.D. 1983. Underwater biotelemetry. Pages 371-395. *In* Nielsen, L.A., and D.L. Johnson. [ed.]. Fisheries techniques. American Fisheries Society, Bethesda, Maryland. 468 p.

VELLE, J.I., J.E. LINDSAY, R.W. WEEKS, AND F.M. LONG. 1979. An investigation of the loss mechanisms encountered in propagation from a submerged fish telemetry transmitter. Pages 238-247. *In* F.M. Long [ed.]. Proceedings Second International Conference on Wildlife BioTelemetry. Univ. Wyoming, Laramie, Wyoming. Publ. by International Conference on Wildlife BioTelemetry.

APPENDIX A

TERMS OF REFERENCE

NORTHERN RIVER BASINS STUDY

TERMS OF REFERENCE - SCHEDULE A
PROJECT 31 FISH/FISH HABITAT INVENTORIES

SUB-PROJECT 3121 - RADIO TELEMETRY - REPRESENTATIVE REACH

Objective

A. To describe appropriate techniques, equipment, and protocols, to be employed in capturing fish, implanting radio tags in fish, and monitoring the daily and seasonal movements of the radio-tagged fish.

B. To implement a field project during the spring season to undertake a technical assessment of the above-mentioned techniques, equipment, and protocols on adult specimens of representative species (e.g., mountain whitefish, bull trout) within the Athabasca River, downstream of Jasper Lake to Whitecourt.

Contractor will:

1. Consult with representatives of radio-telemetry equipment supply companies and other persons with experience in the technique (e.g., S. McKinley - Ontario Hydro; K. Chang-Kue - Department of Fisheries and Oceans, Winnipeg) and solicit their participation in system design and field testing.

2. Select transmitter frequencies most suitable for the water depths, interference, and background noise levels to be encountered. Transmitter life should be sufficient to permit monitoring through the summer and autumn should a decision be made to do so.

3. Design a transmitter detection system and aircraft flight schedule to monitor the movements of radio-tagged fish within the Athabasca River Project area. The design should incorporate at least two remote stations (i.e., upstream of Hinton on the Athabasca River, and near the Berland River).

4. Surgically implant unique identification frequency-coded transmitters into 25-40 fish captured between the Weldwood Mill at Hinton and Whitecourt following the provided protocol for anaesthetizing and implanting.

    - The fish species recommended for tagging include mountain whitefish, bull trout, rainbow trout, and burbot.

    - The priority area for tagging includes the 30 km reach downstream of the Hinton mill but excluding major tributary mouths.

    - Identify situations where a departure from the provided protocols was necessitated.

5. Describe the low stress-inducing capture techniques and fish handling procedures used. Report on fish mortalities arising from capture, handling and tagging.

6. Evaluate each fish both before and after surgery for health and vigour to ensure confidence of recovery and the highest probability of normal behaviour.

7. Monitor and describe the movement patterns of individual radio-tagged fish using fixed-wing aircraft. Flights should be undertaken 2-3 times per week during the first two weeks, then weekly for the life of the transmitter batteries.

8. Develop a cost schedule for each individual remote station including the cost of down-loading and maintenance.

9. Provide a document detailing the telemetry design, remote station set-up including the antenna array (with photos), system set-up, testing by remote and aerial reconnaissance, site selection, water quality parameters considered, background noise determinations and levels, river cross-sections for remote site selection, flight altitude selected and aircraft antenna design, frequency selection, coding detection limits, and scanning details.

10. Progress reports, final manuscripts, electronic data files, samples, and photographic materials are to be delivered to the Study Office as per Schedule B. The format for the final report will follow the editorial style of the Canadian Journal of Fisheries and Aquatic Sciences.

11. Develop a photographic record of equipment and techniques to capture and process fish samples. As appropriate, take close-up photographs of fish exhibiting internal and/or external abnormalities. Use 35 mm, 200 ASA Fuji slide film in a camera having a 50-55 mm lens. Maintain records to associate photographs with sample material.

APPENDIX B

SURGICAL EQUIPMENT

Appendix B, Table 1. Equipment employed during surgical implantation of radio transmitters.

	Equipment	Description
1 -	Operating table	122cm x 60cm plywood with 70cm high metal legs
1 -	Operating trough	adjustable V-shaped neoprene-lined trough inside 78cm x 24cm x 20cm deep UHMW plastic box
2 -	Pieces open pore sponge	50cm x 15cm x 5cm thick
1 -	Container/Anesthetic tank	150L Coleman-brand marine cooler
1 -	Holding pen	125cm x 60cm x 50cm deep, c/w 1.9cm Vexar-brand plastic mesh
1 -	Anesthetic tank	75cm x 43cm x 30cm deep, marked for 35L
1 -	Recovery tank	Boat live well, 142cm x 48cm x 36cm deep, with recirculating pump
1 -	Surgical Box	
1 -	Plastic bucket	10L
2 -	Instrument trays	35cm x 22cm x 5 cm deep
6 doz	Sutures	69cm Ethicon 2.0 (metric) polydioxanone sutures swaged to cutting CP-2 needle
2 -	Haemostats	
1 -	Tissue forceps	
1 -	Hypodermic needle	16 gauge, 10cm length
1 doz	Syringes and needles	6mL size
3 doz	Scalpel blades	No. 12, disposable
3 -	Scalpel handles	
1 -	Scissors	
1 -	Knife	
1 -	Sharps' container	
5 doz	Cotton swabs and balls	
2 box	Surgical gloves	
1 -	Bottle Anesthetic	100g tricaine methane sulfonate (MS-222), weighed in 5g vials
3 -	Disinfectant	Zephiran chloride in 1:750 concentration, 4 L containers
1 -	Surgical Scrub	Betadine brand, 10% povidone iodine, 1% available iodine
3 -	Distilled water	4 L containers
2 -	Wash bottles	1 filled with distilled water, the other with river water
1 -	Malachite Green	20mL, 0.75% active
1 -	Liquamycin LP	750mL, oxytetracycline hydrochloride
1 -	VetBond	3mL, 3M trademark
2 -	Dip nets	
1 -	Stop watch	
1 -	Pocket thermometer	

APPENDIX C

FIXED STATION COST SCHEDULE
AND SERVICING DATA

Appendix C. Table 1. Estimated costs associated with installation of a fixed station.

EQUIPMENT

Fixed Station	Cost with GST
Data Logger	$10 780.25
Security Cabinet and Lock	267.50
Dolly Rental	21.40
Batteries	462.07
Antennas	930.90
Masts	165.10
Guy Wires & Turnbuckles	57.73
Station Equipment (e.g., Rebar)	79.06
RG-58 Cable	306.23
SubTotal	**$13 070.24**
Notebook Computer	$2 300.50
3.5" diskettes	21.38
Null Modem Cable	21.35
Miscellaneous	20.55
SubTotal	**$2 363.78**

LABOUR

Option 1 Labour	
Mobilization	$1 280.00
Travel	1 156.14
Antenna	1 030.41
Site Selection	2 544.46
Range Test	1 672.41
Removal	2 186.55
SubTotal	**$9 869.97**

Option 2 Labour	
All Option 1 Labour Costs	$9 869.97
Solar Power Installation & Testing	800.36
Remote Transmission Set-Up & Test	915.92
Security Fencing Installation	1 030.41
SubTotal	**$12 616.66**

TOTALS

Equipment	Option 1*	Option 2*
Fixed Station	$13 070.24	$13 070.24
Computer	2 363.78	363.80
Data Transmission & Solar Panels	0.00	1 634.00
SubTotal	$15 434.02	$15 068.04
10% (monthly)	1 543.40	1 506.80
Labour Site (one-time)	$9 869.97	$12 616.66
Labour Downloading (monthly)	1 244.00	150.00
Long Distance Charges (monthly)	0.00	20.00

SUMMARY

	Option 1*	Option 2*
One-time	**$9 869.97**	**$12 616.66**
Monthly	**$2 787.40**	**$1 676.80**

* - Option 1 refers to manual replacemnt of batteries and downloading of data
Option 2 refers to remote data transmission and solar power for station.

Appendix C, Table 2. Data on Battery Servicing and Mean Daily Voltage Drain

Battery Installation Date	Charged Reading (V)	Battery Replacement Date	Discharged Reading (V)	Elapsed Time (d)	Mean Daily Drain (V)
June 8	12.55	June 20	12.19	12	0.03
June 20	12.88	July 6	12.24	16	0.04
July 6	12.70	July 23	11.81	17	0.05
July 23	12.60	Aug. 10	11.68	18	0.05
Aug. 10	12.83	Aug. 31	11.63	20	0.06
Aug. 31	12.82	Sept. 15	11.87	15	0.06
Sept. 15	12.53	Oct. 2	11.86	17	0.04
Oct. 2	12.77	Oct. 26	11.50	24	0.05
Oct. 26	12.62	Nov. 24	5.33	29	0.25
Nov. 24	13.03	Dec. 16	11.60	22	0.07
Dec. 16	12.69	Jan. 4	10.03	19	0.14
Jan. 4	12.37	Jan 22	8.35	18	0.22
Jan. 22	12.67	Feb. 11	11.49	20	0.06
Feb. 11	12.28	Feb. 21	11.17	10	0.11
Feb. 27	12.04	Mar. 11	8.61	12	0.29
Mar. 21	12.33	Mar. 31	11.97	10	0.04

APPENDIX D

FISH MOVEMENT DATA

Appendix D, Table 1. List of radio transmitters and associated fish data.

Species	Channel	Code	Frequency	Length (mm)	Weight (g)	Release Date	Release Km	Release Location
Burbot	1	2	148.850	545	910	25-May-92	1239.5	Fixed Station
Mountain Whitefish	1	3	148.850	393	n.d.*	29-May-92	1129.3	Berland River
Burbot	1	7	148.850	890	5500	27-May-92	1239.5	Fixed Station
Mountain Whitefish	2	11	148.950	429	n.d.*	28-May-92	1226.7	Weldwood Bridge
Burbot	2	13	148.950	580	n.d.*	29-May-92	1129.3	Berland River
Bull Trout	3	20	149.015	413	687	27-May-92	1239.5	Fixed Station
Mountain Whitefish	3	22	149.015	396	n.d.*	28-May-92	1226.7	Weldwood Bridge
Burbot	3	24	149.015	870	n.d.*	28-May-92	1226.7	Weldwood Bridge
Bull Trout	4	1	149.071	524	1458	25-May-92	1239.5	Fixed Station
Mountain Whitefish	4	2	149.071	393	787	25-May-92	1239.5	Fixed Station
Mountain Whitefish	4	3	149.071	407	n.d.*	28-May-92	1226.7	Weldwood Bridge
Mountain Whitefish	4	4	149.071	430	n.d.*	28-May-92	1226.7	Weldwood Bridge
Mountain Whitefish	4	5	149.071	403	911	25-May-92	1239.5	Fixed Station
Rainbow Trout	4	6	149.071	366	591	29-May-92	1129.3	Berland River
Mountain Whitefish	4	7	149.071	365	n.d.*	28-May-92	1226.7	Weldwood Bridge
Bull Trout	4	8	149.071	519	1470	25-May-92	1239.5	Fixed Station
Burbot	5	9	149.251	573	946	27-May-92	1239.5	Fixed Station
Bull Trout	5	14	149.251	491	1400	27-May-92	1239.5	Fixed Station
Lake Whitefish	5	15	149.251	501	n.d.*	28-May-92	1226.7	Weldwood Bridge
Mountain Whitefish	6	15	149.340	362	633	11-Jun-92	1192.0	Obed/Ford
Bull Trout	19	20	149.680	460	1040	12-Jun-92	1226.7	Weldwood Bridge
Mountain Whitefish	19	23	149.680	391	711	11-Jun-92	1192.0	Obed/Ford
Bull Trout	19	25	149.680	557	1749	09-Jun-92	1226.7	Weldwood Bridge
Mountain Whitefish	19	26	149.680	410	812	11-Jun-92	1192.0	Obed/Ford
Mountain Whitefish	19	27	149.680	385	647	11-Jun-92	1192.0	Obed/Ford
Rainbow Trout	19	28	149.680	329	423	10-Jun-92	1192.0	Obed/Ford
Mountain Whitefish	19	33	149.680	398	821	10-Jun-92	1192.0	Obed/Ford
Bull Trout	20	10	149.700	385	520	12-Jun-92	1226.7	Weldwood Bridge
Mountain Whitefish	20	11	149.700	381	760	09-Jun-92	1226.7	Weldwood Bridge
Mountain Whitefish	20	12	149.700	390	744	11-Jun-92	1192.0	Obed/Ford
Mountain Whitefish	20	24	149.700	435	1205	10-Jun-92	1192.0	Obed/Ford
Arctic Grayling	20	26	149.700	304	369	11-Jun-92	1192.0	Obed/Ford
Bull Trout	20	31	149.700	570	2070	10-Jun-92	1192.0	Obed/Ford
Mountain Whitefish	20	43	149.700	415	858	10-Jun-92	1192.0	Obed/Ford
Bull Trout	20	44	149.700	476	1186	12-Jun-92	1226.7	Weldwood Bridge

n.d.* - These fish released without weights or Floy tags to reduce handling stress and operating time.

Appendix D, Table 2. 1992 data on a bull trout (Tag 20-44; frequency 149.700) moving upstream past fixed station.

Channel	Code	Date	Hr	Min	Sec	Power	Ant	Drift
20	44	07-07	20	13	3	139	1	
20	44	07-07	20	18	16	119	1	
20	44	07-07	20	24	49	107	1	
20	44	07-07	20	24	55	103	2	
20	44	07-07	20	27	27	87	1	
20	44	07-07	20	30	3	87	1	
20	44	07-07	20	31	22	90	1	
20	44	07-07	20	39	10	92	1	
20	44	07-07	20	40	29	101	1	
20	44	07-07	20	41	48	101	1	
20	44	07-07	20	41	55	87	2	
20	44	07-07	20	45	43	135	1	
20	44	07-07	20	45	50	94	2	
20	44	07-07	20	47	5	58	1	4
20	44	07-07	20	51	0	122	1	
20	44	07-07	20	52	20	128	1	
20	44	07-07	20	53	40	141	1	
20	44	07-07	20	54	59	106	1	
20	44	07-07	20	56	18	155	1	
20	44	07-07	20	56	25	115	2	
20	44	07-07	20	57	39	185	1	
20	44	07-07	20	57	45	138	2	
20	44	07-07	20	59	0	138	1	
20	44	07-07	21	0	19	154	1	
20	44	07-07	21	2	57	95	1	
20	44	07-07	21	3	4	105	2	
20	44	07-07	21	4	18	111	1	
20	44	07-07	21	4	24	116	2	
20	44	07-07	21	5	38	178	1	
20	44	07-07	21	5	45	118	2	
20	44	07-07	21	6	57	126	1	
20	44	07-07	21	7	4	89	2	
20	44	07-07	21	8	19	163	1	
20	44	07-07	21	9	38	193	1	
20	44	07-07	21	10	57	161	1	
20	44	07-07	21	12	17	182	1	
20	44	07-07	21	12	24	110	2	
20	44	07-07	21	13	38	163	1	
20	44	07-07	21	14	59	123	1	
20	44	07-07	21	16	18	170	1	
20	44	07-07	21	17	36	166	1	
20	44	07-07	21	18	55	163	1	
20	44	07-07	21	20	14	140	1	
20	44	07-07	21	21	32	153	1	
20	44	07-07	21	22	51	188	1	
20	44	07-07	21	24	10	172	1	
20	44	07-07	21	25	29	181	1	
20	44	07-07	21	26	49	186	1	
20	44	07-07	21	28	8	189	1	
20	44	07-07	21	32	3	177	1	
20	44	07-07	21	33	22	195	1	
20	44	07-07	21	34	41	204	1	
20	44	07-07	21	36	0	109	1	
20	44	07-07	21	37	19	171	1	
20	44	07-07	21	38	39	160	1	
20	44	07-07	21	39	58	132	1	
20	44	07-07	21	42	35	196	1	
20	44	07-07	21	43	54	188	1	
20	44	07-07	21	45	13	170	1	
20	44	07-07	21	46	32	116	1	
20	44	07-07	21	46	39	86	2	
20	44	07-07	21	47	53	190	1	
20	44	07-07	21	49	12	202	1	
20	44	07-07	21	50	31	177	1	
20	44	07-07	21	51	52	173	1	
20	44	07-07	21	53	13	189	1	
20	44	07-07	21	54	32	142	1	
20	44	07-07	21	55	51	181	1	
20	44	07-07	21	57	10	183	1	
20	44	07-07	21	58	29	176	1	
20	44	07-07	21	59	48	190	1	
20	44	07-07	22	1	7	196	1	
20	44	07-07	22	2	27	189	1	
20	44	07-07	22	5	6	192	1	
20	44	07-07	22	5	7	199	1	
20	44	07-07	22	6	26	211	1	
20	44	07-07	22	7	45	192	1	
20	44	07-07	22	7	52	120	2	
20	44	07-07	22	9	5	228	1	
20	44	07-07	22	9	12	158	2	
20	44	07-07	22	10	25	217	1	
20	44	07-07	22	10	32	129	2	
20	44	07-07	22	11	45	229	1	
20	44	07-07	22	11	51	128	2	
20	44	07-07	22	13	5	229	1	
20	44	07-07	22	13	11	129	2	
20	44	07-07	22	14	25	228	1	
20	44	07-07	22	14	32	164	2	
20	44	07-07	22	15	45	222	1	
20	44	07-07	22	15	52	163	2	
20	44	07-07	22	17	5	216	1	
20	44	07-07	22	17	12	175	2	
20	44	07-07	22	18	26	217	1	
20	44	07-07	22	18	32	216	2	
20	44	07-07	22	19	46	178	1	
20	44	07-07	22	19	53	228	2	
20	44	07-07	22	21	6	197	1	
20	44	07-07	22	21	13	228	2	
20	44	07-07	22	22	28	174	1	
20	44	07-07	22	22	34	228	2	
20	44	07-07	22	23	48	161	1	
20	44	07-07	22	23	54	215	2	
20	44	07-07	22	25	8	117	1	
20	44	07-07	22	25	15	228	2	
20	44	07-07	22	26	33	167	2	
20	44	07-07	22	27	46	178	1	
20	44	07-07	22	27	53	174	2	
20	44	07-07	22	29	8	121	1	
20	44	07-07	22	29	14	185	2	
20	44	07-07	22	30	28	128	1	
20	44	07-07	22	30	34	172	2	
20	44	07-07	22	31	54	109	2	
20	44	07-07	22	33	13	143	2	
20	44	07-07	22	35	45	119	1	
20	44	07-07	22	35	52	129	2	
20	44	07-07	22	37	7	113	1	
20	44	07-07	22	37	13	134	2	
20	44	07-07	22	38	27	80	1	
20	44	07-07	22	39	52	117	2	
20	44	07-07	22	41	11	72	2	4
20	44	07-07	22	42	30	156	2	
20	44	07-07	22	43	43	97	1	
20	44	07-07	22	45	8	115	2	
20	44	07-07	22	46	22	92	1	
20	44	07-07	22	50	23	113	2	
20	44	07-07	22	51	42	127	2	
20	44	07-07	22	56	52	98	1	
20	44	07-07	22	59	37	92	2	
20	44	07-07	23	0	57	105	2	
20	44	07-07	23	2	16	148	2	
20	44	07-07	23	3	36	114	2	
20	44	07-07	23	3	37	94	2	
20	44	07-07	23	4	56	114	2	
20	44	07-07	23	8	52	128	2	
20	44	07-07	23	10	11	107	2	
20	44	07-07	23	12	47	100	2	
20	44	07-07	23	36	18	84	2	
	end of records							

Appendix D, Table 3. Daily fixed station data for a burbot (Tag 1-2; frequency 148.850), from 27 May to 23 July 1992.

Date	Days at Large	Antenna 1 (downstream orientation) Mean Pwr Reading	Records on Antenna 1	Percentage of Records	Antenna 2 (upstream orientation) Mean Pwr Reading	Records on Antenna 2	Percentage of Records	Total Records
27-May-92	2	0	0	0	103	1	100	1
28-May-92	3	0	0	0	107	8	100	8
29-May-92	4	104	9	60	101	6	40	15
30-May-92	5	117	176	89	106	22	11	198
31-May-92	6	142	211	84	104	40	16	251
01-Jun-92	7	0	0	0	0	0	0	0
02-Jun-92	8	0	0	0	0	0	0	0
03-Jun-92	9	96	41	100	0	0	0	41
04-Jun-92	10	102	322	100	0	0	0	322
05-Jun-92	11	100	244	100	0	0	0	244
06-Jun-92	12	98	82	100	0	0	0	82
07-Jun-92	13	101	23	100	0	0	0	23
08-Jun-92	14	92	976	100	0	0	0	976
09-Jun-92	15	0	0	0	0	0	0	0
10-Jun-92	16	0	0	0	0	0	0	0
11-Jun-92	17	0	0	0	0	0	0	0
12-Jun-92	18	0	0	0	0	0	0	0
13-Jun-92	19	0	0	0	0	0	0	0
14-Jun-92	20	0	0	0	0	0	0	0
15-Jun-92	21	0	0	0	0	0	0	0
16-Jun-92	22	112	35	49	114	37	51	72
17-Jun-92	23	92	364	49	93	372	51	736
18-Jun-92	24	90	135	53	92	118	47	253
19-Jun-92	25	104	104	45	102	129	55	233
20-Jun-92	26	92	94	57	92	72	43	166
21-Jun-92	27	92	90	51	92	88	49	178
22-Jun-92	28	148	93	45	142	114	55	207
23-Jun-92	29	88	133	48	88	144	52	277
24-Jun-92	30	99	107	51	100	103	49	210
25-Jun-92	31	89	78	52	91	72	48	150
26-Jun-92	32	101	20	49	101	21	51	41
27-Jun-92	33	96	84	49	94	89	51	173
28-Jun-92	34	88	110	52	86	102	48	212
29-Jun-92	35	93	326	51	92	315	49	641
30-Jun-92	36	106	323	51	104	311	49	634
01-Jul-92	37	108	527	49	108	543	51	1070
02-Jul-92	38	103	336	48	102	366	52	702
03-Jul-92	39	96	303	49	98	320	51	623
04-Jul-92	40	92	266	50	93	263	50	529
05-Jul-92	41	95	389	49	95	403	51	792
06-Jul-92	42	153	481	73	90	181	27	662
07-Jul-92	43	182	1119	86	95	184	14	1303
08-Jul-92	44	112	761	43	159	1023	57	1784
09-Jul-92	45	98	300	20	171	1166	80	1466
10-Jul-92	46	98	316	22	157	1102	78	1418
11-Jul-92	47	104	612	35	180	1149	65	1761
12-Jul-92	48	99	190	47	147	214	53	404
13-Jul-92	49	84	10	45	89	12	55	22
14-Jul-92	50	0	0	0	0	0	0	0
15-Jul-92	51	0	0	0	0	0	0	0
16-Jul-92	52	0	0	0	0	0	0	0
17-Jul-92	53	0	0	0	0	0	0	0
18-Jul-92	54	0	0	0	0	0	0	0
19-Jul-92	55	0	0	0	0	0	0	0
20-Jul-92	56	0	0	0	0	0	0	0
21-Jul-92	57	0	0	0	0	0	0	0
22-Jul-92	58	0	0	0	0	0	0	0
23-Jul-92	59	0	0	0	0	0	0	0
TOTALS			9790			9090		18880

Appendix D, Table 4. Summary of radio telemetry flight on 20 June 1992.

Day	Month	Year	Freq	Chan	Code	Km	Species	Comment
20	6	92	148.850	1	3	1119.0	MW	
20	6	92	149.015	3	22	1225.0	MW	
20	6	92	149.015	3	24	1225.0	LING	
20	6	92	149.071	4	4	1223.0	MW	
20	6	92	149.071	4	5	1237.5	MW	
20	6	92	149.071	4	6	1137.5	RT	
20	6	92	149.071	4	8	1235.1	DV	
20	6	92	149.680	19	20	1227.5	DV	
20	6	92	149.680	19	23	1187.0	MW	
20	6	92	149.680	19	25	1220.0	DV	
20	6	92	149.680	19	27	1192.0	MW	
20	6	92	149.680	19	33	1192.0	MW	
20	6	92	149.700	20	10	1239.0	DV	
20	6	92	149.700	20	12	1192.0	MW	
20	6	92	149.700	20	24	1192.0	MW	
20	6	92	149.700	20	26	1188.5	AG	
20	6	92	149.700	20	31	1190.0	DV	
20	6	92	149.700	20	43	1192.0	MW	
20	6	92	149.700	20	44	1226.0	DV	
		Total Fish Tracked		19				

sort by species, channel, code

Day	Month	Year	Freq	Chan	Code	Km	Species
20	6	92	149.700	20	26	1188.5	AG
20	6	92	149.071	4	8	1235.1	DV
20	6	92	149.680	19	20	1227.5	DV
20	6	92	149.680	19	25	1220.0	DV
20	6	92	149.700	20	10	1239.0	DV
20	6	92	149.700	20	31	1190.0	DV
20	6	92	149.700	20	44	1226.0	DV
20	6	92	149.015	3	24	1225.0	LING
20	6	92	148.850	1	3	1119.0	MW
20	6	92	149.015	3	22	1225.0	MW
20	6	92	149.071	4	4	1223.0	MW
20	6	92	149.071	4	5	1237.5	MW
20	6	92	149.680	19	23	1187.0	MW
20	6	92	149.680	19	27	1192.0	MW
20	6	92	149.680	19	33	1192.0	MW
20	6	92	149.700	20	12	1192.0	MW
20	6	92	149.700	20	24	1192.0	MW
20	6	92	149.700	20	43	1192.0	MW
20	6	92	149.071	4	6	1137.5	RT

Species Recorded:	No.	Total	%
Arctic grayling	1	1	100
Bull trout	6	9	67
Burbot	1	5	20
Lake Whitefish	0	1	0
Mountain Whitefish	10	17	59
Rainbow Trout	1	2	50
Total	19	35	54

Appendix D, Table 5. Summary of radio telemetry flight on 24 June 1992.

Day	Month	Year	Freq	Chan	Code	Km	Species	Comment
24	6	92	148.850	1	2	1240.0	LING	
24	6	92	148.850	1	3	1119.0	MW	
24	6	92	148.850	1	7	1238.0	LING	
24	6	92	149.015	3	24	1224.0	LING	
24	6	92	149.071	4	2	1235.0	MW	
24	6	92	149.071	4	3	1217.0	MW	
24	6	92	149.071	4	4	1224.0	MW	
24	6	92	149.071	4	5	1238.0	MW	
24	6	92	149.071	4	6	1137.0	RT	
24	6	92	149.071	4	8	1235.0	DV	
24	6	92	149.251	5	15	1221.0	LW	
24	6	92	149.680	19	20	1229.0	DV	
24	6	92	149.680	19	23	1184.0	MW	
24	6	92	149.680	19	25	1223.0	DV	
24	6	92	149.680	19	27	1191.0	MW	
24	6	92	149.680	19	28	1191.0	RT	
24	6	92	149.680	19	33	1191.0	MW	
24	6	92	149.700	20	11	1219.0	MW	
24	6	92	149.700	20	12	1191.0	MW	
24	6	92	149.700	20	24	1191.0	MW	
24	6	92	149.700	20	26	1188.0	AG	
24	6	92	149.700	20	31	1190.0	DV	
24	6	92	149.700	20	43	1191.0	MW	
24	6	92	149.700	20	44	1226.0	DV	
		Total Fish Tracked		24				

sort by species, channel, code

Day	Month	Year	Freq	Chan	Code	Km	Species
24	6	92	149.700	20	26	1188.0	AG
24	6	92	149.071	4	8	1235.0	DV
24	6	92	149.680	19	20	1229.0	DV
24	6	92	149.680	19	25	1223.0	DV
24	6	92	149.700	20	31	1190.0	DV
24	6	92	149.700	20	44	1226.0	DV
24	6	92	148.850	1	2	1240.0	LING
24	6	92	148.850	1	7	1238.0	LING
24	6	92	149.015	3	24	1224.0	LING
24	6	92	149.251	5	15	1221.0	LW
24	6	92	148.850	1	3	1119.0	MW
24	6	92	149.071	4	2	1235.0	MW
24	6	92	149.071	4	3	1217.0	MW
24	6	92	149.071	4	4	1224.0	MW
24	6	92	149.071	4	5	1238.0	MW
24	6	92	149.680	19	23	1184.0	MW
24	6	92	149.680	19	27	1191.0	MW
24	6	92	149.680	19	33	1191.0	MW
24	6	92	149.700	20	11	1219.0	MW
24	6	92	149.700	20	12	1191.0	MW
24	6	92	149.700	20	24	1191.0	MW
24	6	92	149.700	20	43	1191.0	MW
24	6	92	149.071	4	6	1137.0	RT
24	6	92	149.680	19	28	1191.0	RT

Species Recorded:	No.	Total	%
Arctic grayling	1	1	100
Bull trout	5	9	56
Burbot	3	5	60
Lake Whitefish	1	1	100
Mountain Whitefish	12	17	71
Rainbow Trout	2	2	100
Total	24	35	69

Appendix D, Table 6. Summary of radio telemetry flight on 28 June 1992.

Day	Month	Year	Freq	Chan	Code	Km	Species	Comment
28	6	92	148.850	1	2	1239.0	LING	
28	6	92	148.850	1	3	1118.6	MW	
28	6	92	149.015	3	24	1225.0	LING	
28	6	92	149.071	4	2	1236.0	MW	
28	6	92	149.071	4	3	1217.0	MW	
28	6	92	149.071	4	4	1223.0	MW	
28	6	92	149.071	4	5	1237.5	MW	
28	6	92	149.071	4	6	1138.0	RT	
28	6	92	149.071	4	8	1229.0	DV	
28	6	92	149.251	5	15	1220.0	LW	
28	6	92	149.680	19	20	1247.0	DV	
28	6	92	149.680	19	23	1184.0	MW	
28	6	92	149.680	19	25	1234.0	DV	
28	6	92	149.680	19	27	1192.0	MW	
28	6	92	149.680	19	28	1194.5	RT	
28	6	92	149.680	19	33	1192.0	MW	
28	6	92	149.700	20	10	1261.8	DV	Fiddle R. mouth
28	6	92	149.700	20	11	1219.0	MW	
28	6	92	149.700	20	12	1192.0	MW	
28	6	92	149.700	20	24	1192.0	MW	
28	6	92	149.700	20	26	1153.0	AG	
28	6	92	149.700	20	31	1190.0	DV	
28	6	92	149.700	20	43	1192.0	MW	
28	6	92	149.700	20	44	1238.0	DV	
		Total Fish Tracked		24				

sort by species, channel, code

Day	Month	Year	Freq	Chan	Code	Km	Species	
28	6	92	149.700	20	26	1153.0	AG	
28	6	92	149.071	4	8	1229.0	DV	
28	6	92	149.680	19	20	1247.0	DV	
28	6	92	149.680	19	25	1234.0	DV	
28	6	92	149.700	20	10	1261.8	DV	Fiddle R. mouth
28	6	92	149.700	20	31	1190.0	DV	
28	6	92	149.700	20	44	1238.0	DV	
28	6	92	148.850	1	2	1239.0	LING	
28	6	92	149.015	3	24	1225.0	LING	
28	6	92	149.251	5	15	1220.0	LW	
28	6	92	148.850	1	3	1118.6	MW	
28	6	92	149.071	4	2	1236.0	MW	
28	6	92	149.071	4	3	1217.0	MW	
28	6	92	149.071	4	4	1223.0	MW	
28	6	92	149.071	4	5	1237.5	MW	
28	6	92	149.680	19	23	1184.0	MW	
28	6	92	149.680	19	27	1192.0	MW	
28	6	92	149.680	19	33	1192.0	MW	
28	6	92	149.700	20	11	1219.0	MW	
28	6	92	149.700	20	12	1192.0	MW	
28	6	92	149.700	20	24	1192.0	MW	
28	6	92	149.700	20	43	1192.0	MW	
28	6	92	149.071	4	6	1138.0	RT	
28	6	92	149.680	19	28	1194.5	RT	

Species Recorded:	No.	Total	%
Arctic grayling	1	1	100
Bull trout	6	9	67
Burbot	2	5	40
Lake Whitefish	1	1	100
Mountain Whit	12	17	71
Rainbow Trout	2	2	100
Total	24	35	69

Appendix D, Table 7. Summary of radio telemetry flight on 2 July 1992.

Day	Month	Year	Freq	Chan	Code	Km	Species	Comment
2	7	92	148.850	1	2	1239.0	LING	
2	7	92	148.850	1	3	1118.4	MW	
2	7	92	149.015	3	24	1226.5	LING	
2	7	92	149.071	4	2	1230.3	MW	
2	7	92	149.071	4	3	1216.0	MW	
2	7	92	149.071	4	4	1225.0	MW	
2	7	92	149.071	4	5	1238.0	MW	
2	7	92	149.071	4	6	1137.5	RT	
2	7	92	149.071	4	8	1228.0	DV	
2	7	92	149.251	5	15	1220.0	LW	
2	7	92	149.680	19	20	1249.1	DV	
2	7	92	149.680	19	23	1186.0	MW	
2	7	92	149.680	19	25	1232.0	DV	
2	7	92	149.680	19	27	1191.8	MW	
2	7	92	149.680	19	28	1194.5	RT	
2	7	92	149.680	19	33	1191.8	MW	
2	7	92	149.700	20	10	1261.8	DV	Fiddle R. mouth
2	7	92	149.700	20	11	1219.0	MW	
2	7	92	149.700	20	12	1192.0	MW	
2	7	92	149.700	20	24	1192.0	MW	
2	7	92	149.700	20	26	1153.0	AG	
2	7	92	149.700	20	31	1190.0	DV	
2	7	92	149.700	20	43	1192.0	MW	
2	7	92	149.700	20	44	1238.0	DV	
		Total Fish Tracked		24				

sort by species, channel, code

Day	Month	Year	Freq	Chan	Code	Km	Species	
2	7	92	149.700	20	26	1153.0	AG	
2	7	92	149.071	4	8	1228.0	DV	
2	7	92	149.680	19	20	1249.1	DV	
2	7	92	149.680	19	25	1232.0	DV	
2	7	92	149.700	20	10	1261.8	DV	Fiddle R. mouth
2	7	92	149.700	20	31	1190.0	DV	
2	7	92	149.700	20	44	1238.0	DV	
2	7	92	148.850	1	2	1239.0	LING	
2	7	92	149.015	3	24	1226.5	LING	
2	7	92	149.251	5	15	1220.0	LW	
2	7	92	148.850	1	3	1118.4	MW	
2	7	92	149.071	4	2	1230.3	MW	
2	7	92	149.071	4	3	1216.0	MW	
2	7	92	149.071	4	4	1225.0	MW	
2	7	92	149.071	4	5	1238.0	MW	
2	7	92	149.680	19	23	1186.0	MW	
2	7	92	149.680	19	27	1191.8	MW	
2	7	92	149.680	19	33	1191.8	MW	
2	7	92	149.700	20	11	1219.0	MW	
2	7	92	149.700	20	12	1192.0	MW	
2	7	92	149.700	20	24	1192.0	MW	
2	7	92	149.700	20	43	1192.0	MW	
2	7	92	149.071	4	6	1137.5	RT	
2	7	92	149.680	19	28	1194.5	RT	

Species Recorded:	No.	Total	%
Arctic grayling	1	1	100
Bull trout	6	9	67
Burbot	2	5	40
Lake Whitefish	1	1	100
Mountain Whitefish	12	17	71
Rainbow Trout	2	2	100
Total	24	35	69

Appendix D, Table 8. Summary of radio telemetry flight on 18 July 1992.

Day	Month	Year	Freq	Chan	Code	Km	Species	Comment
18	7	92	148.850	1	2	1243.5	LING	
18	7	92	148.850	1	3	1118.4	MW	
18	7	92	148.850	1	7	1238.0	LING	
18	7	92	149.071	4	4	1221.0	MW	
18	7	92	149.071	4	6	1137.7	RT	
18	7	92	149.071	4	8	1238.5	DV	
18	7	92	149.251	5	15	1220.0	LW	
18	7	92	149.680	19	23	1177.6	MW	
18	7	92	149.680	19	27	1224.0	MW	
18	7	92	149.680	19	28	1194.0	RT	
18	7	92	149.680	19	33	1192.0	MW	
18	7	92	149.700	20	12	1273.6	MW	
18	7	92	149.700	20	24	1193.0	MW	
18	7	92	149.700	20	26	1152.8	AG	
18	7	92	149.700	20	31	1205.0	DV	
18	7	92	149.700	20	43	1192.0	MW	
18	7	92	149.700	20	44	1266.9	DV	
		Total Fish Tracked		17				

sort by species, channel, code

Day	Month	Year	Freq	Chan	Code	Km	Species
18	7	92	149.700	20	26	1152.8	AG
18	7	92	149.071	4	8	1238.5	DV
18	7	92	149.700	20	12	1273.6	MW
18	7	92	149.700	20	31	1205.0	DV
18	7	92	149.700	20	44	1266.9	DV
18	7	92	148.850	1	2	1243.5	LING
18	7	92	148.850	1	7	1238.0	LING
18	7	92	149.251	5	15	1220.0	LW
18	7	92	148.850	1	3	1118.4	MW
18	7	92	149.071	4	4	1221.0	MW
18	7	92	149.680	19	23	1177.6	MW
18	7	92	149.680	19	27	1224.0	MW
18	7	92	149.680	19	33	1192.0	MW
18	7	92	149.700	20	24	1193.0	MW
18	7	92	149.700	20	43	1192.0	MW
18	7	92	149.071	4	6	1137.7	RT
18	7	92	149.680	19	28	1194.0	RT

Species Recorded:	No.	Total	%
Arctic grayling	1	1	100
Bull trout	4	8	50
Burbot	2	5	40
Lake Whitefish	1	1	100
Mountain Whitefish	7	17	41
Rainbow Trout	2	2	100
Total	17	34	50

Appendix D, Table 9. Summary of radio telemetry flight on 22 July 1992.

Day	Month	Year	Freq	Chan	Code	Km	Species	Comment
22	7	92	148.850	1	2	1243.5	LING	
22	7	92	148.850	1	3	1118.2	MW	
22	7	92	148.850	1	7	1238.0	LING	
22	7	92	149.015	3	24	1221.5	LING	
22	7	92	149.071	4	4	1223.0	MW	
22	7	92	149.071	4	6	1138.1	RT	
22	7	92	149.071	4	8	1260.4	DV	
22	7	92	149.251	5	15	1221.0	LW	
22	7	92	149.680	19	23	1177.8	MW	
22	7	92	149.680	19	27	1224.0	MW	
22	7	92	149.680	19	28	1194.0	RT	
22	7	92	149.680	19	33	1192.2	MW	
22	7	92	149.700	20	11	1218.5	MW	
22	7	92	149.700	20	12	1277.6	MW	ROCKY R. side channel
22	7	92	149.700	20	24	1193.0	MW	
22	7	92	149.700	20	26	1152.8	AG	
22	7	92	149.700	20	31	1218.5	DV	
22	7	92	149.700	20	43	1191.1	MW	
22	7	92	149.700	20	44	1264.0	DV	
		Total Fish Tracked		19				

sort by species, channel, code

Day	Month	Year	Freq	Chan	Code	Km	Species	
22	7	92	149.700	20	26	1152.8	AG	
22	7	92	149.071	4	8	1260.4	DV	
22	7	92	149.700	20	31	1218.5	DV	
22	7	92	149.700	20	44	1264.0	DV	
22	7	92	148.850	1	2	1243.5	LING	
22	7	92	148.850	1	7	1238.0	LING	
22	7	92	149.015	3	24	1221.5	LING	
22	7	92	149.251	5	15	1221.0	LW	
22	7	92	148.850	1	3	1118.2	MW	
22	7	92	149.071	4	4	1223.0	MW	
22	7	92	149.680	19	23	1177.8	MW	
22	7	92	149.680	19	27	1224.0	MW	
22	7	92	149.680	19	33	1192.2	MW	
22	7	92	149.700	20	11	1218.5	MW	
22	7	92	149.700	20	12	1277.6	MW	ROCKY R. side channel
22	7	92	149.700	20	24	1193.0	MW	
22	7	92	149.700	20	43	1191.1	MW	
22	7	92	149.071	4	6	1138.1	RT	
22	7	92	149.680	19	28	1194.0	RT	

Species Recorded:	No.	Total	%
Arctic grayling	1	1	100
Bull trout	3	8	38
Burbot	3	5	60
Lake Whitefish	1	1	100
Mountain Whitefish	9	17	53
Rainbow Trout	2	2	100
Total	19	34	56

Appendix D, Table 10. Summary of radio telemetry flight on 29 July 1992.

Day	Month	Year	Freq	Chan	Code	Km	Species	Comment
29	7	92	148.850	1	2	1244.0	LING	
29	7	92	148.850	1	3	1118.2	MW	
29	7	92	148.850	1	7	1237.5	LING	
29	7	92	149.015	3	24	1221.0	LING	
29	7	92	149.071	4	2	1294.2	MW	Hwy 16 Bridge
29	7	92	149.071	4	4	1222.0	MW	
29	7	92	149.071	4	6	1138.1	RT	
29	7	92	149.071	4	8	1272.0	DV	5.5 km up Snake Indian R.
29	7	92	149.251	5	15	1220.0	LW	
29	7	92	149.680	19	23	1177.0	MW	
29	7	92	149.680	19	25	1272.0	DV	20.5 km up Snake Indian R.
29	7	92	149.680	19	27	1223.0	MW	
29	7	92	149.680	19	28	1193.5	RT	
29	7	92	149.680	19	33	1192.2	MW	
29	7	92	149.700	20	12	1277.6	MW	ROCKY R. side channel
29	7	92	149.700	20	24	1199.5	MW	
29	7	92	149.700	20	26	1152.8	AG	
29	7	92	149.700	20	31	1234.4	DV	
29	7	92	149.700	20	43	1192.0	MW	
29	7	92	149.700	20	44	1264.0	DV	
		Total Fish Tracked		20				

sort by species, channel, code

Day	Month	Year	Freq	Chan	Code	Km	Species	
29	7	92	149.700	20	26	1152.8	AG	
29	7	92	149.071	4	8	1272.0	DV	5.5 km up Snake Indian R.
29	7	92	149.680	19	25	1272.0	DV	20.5 km up Snake Indian R.
29	7	92	149.700	20	31	1234.4	DV	
29	7	92	149.700	20	44	1264.0	DV	
29	7	92	148.850	1	2	1244.0	LING	
29	7	92	148.850	1	7	1237.5	LING	
29	7	92	149.015	3	24	1221.0	LING	
29	7	92	149.251	5	15	1220.0	LW	
29	7	92	148.850	1	3	1118.2	MW	
29	7	92	149.071	4	2	1294.2	MW	Hwy 16 Bridge
29	7	92	149.071	4	4	1222.0	MW	
29	7	92	149.680	19	23	1177.0	MW	
29	7	92	149.680	19	27	1223.0	MW	
29	7	92	149.680	19	33	1192.2	MW	
29	7	92	149.700	20	12	1277.6	MW	ROCKY R. side channel
29	7	92	149.700	20	24	1199.5	MW	
29	7	92	149.700	20	43	1192.0	MW	
29	7	92	149.071	4	6	1138.1	RT	
29	7	92	149.680	19	28	1193.5	RT	

Species Recorded:	No.	Total	%
Arctic grayling	1	1	100
Bull trout	4	8	50
Burbot	3	5	60
Lake Whitefish	1	1	100
Mountain Whitefish	9	17	53
Rainbow Trout	2	2	100
Total	20	34	59

Appendix D, Table 11. Summary of radio telemetry flight on 31 August 1992.

Day	Month	Year	Freq	Chan	Code	Km	Species	Comment
31	8	92	148.850	1	2	1245.0	LING	
31	8	92	148.850	1	3	1118.2	MW	
31	8	92	148.850	1	7	1237.5	LING	
31	8	92	149.071	4	4	1217.0	MW	
31	8	92	149.071	4	8	1246.0	DV	
31	8	92	149.251	5	15	1220.0	LW	
31	8	92	149.680	19	20	1272.0	DV	33.5 km up Snake Indian R
31	8	92	149.680	19	23	1187.0	MW	
31	8	92	149.680	19	25	1272.0	DV	20.5 km up Snake Indian R
31	8	92	149.680	19	27	1222.0	MW	
31	8	92	149.680	19	28	1195.0	RT	
31	8	92	149.680	19	33	1193.0	MW	
31	8	92	149.700	20	12	1277.6	MW	ROCKY R. side channel
31	8	92	149.700	20	24	1214.0	MW	
31	8	92	149.700	20	26	1152.8	AG	
31	8	92	149.700	20	31	1277.6	DV	ROCKY R. side channel
31	8	92	149.700	20	44	1264.0	DV	
		Total Fish Tracked =			17			

sort by species, channel, code

Day	Month	Year	Freq	Chan	Code	Km	Species	
31	8	92	149.700	20	26	1152.8	AG	
31	8	92	149.071	4	8	1246.0	DV	
31	8	92	149.680	19	20	1272.0	DV	33.5 km up Snake Indian R
31	8	92	149.680	19	25	1272.0	DV	20.5 km up Snake Indian R
31	8	92	149.700	20	31	1277.6	DV	ROCKY R. side channel
31	8	92	149.700	20	44	1264.0	DV	
31	8	92	148.850	1	2	1245.0	LING	
31	8	92	148.850	1	7	1237.5	LING	
31	8	92	149.251	5	15	1220.0	LW	
31	8	92	148.850	1	3	1118.2	MW	
31	8	92	149.071	4	4	1217.0	MW	
31	8	92	149.680	19	23	1187.0	MW	
31	8	92	149.680	19	27	1222.0	MW	
31	8	92	149.680	19	33	1193.0	MW	
31	8	92	149.700	20	12	1277.6	MW	ROCKY R. side channel
31	8	92	149.700	20	24	1214.0	MW	
31	8	92	149.680	19	28	1195.0	RT	

Species Recorded:	No.	Total	%
Arctic grayling	1	1	100
Bull trout	5	8	63
Burbot	2	5	40
Lake Whitefish	1	1	100
Mountain Whitefish	7	17	41
Rainbow Trout	1	2	50
Total	17	34	50

Appendix D, Table12. Summary of Athabasca River mainstem and tributary distances (kilometers) surveyed during radio telemetry flights, June to August 1992. Not all areas surveyed on any given date due to weather conditions and aircraft fuel capacity.

Survey Date	Mainstem	Tributaries										
	Athabasca River	Berland River	Oldman Creek	Solomon Creek	Fiddle River	Moosehorn River	Snake Indian River	Rocky River	Snaring River	Maligne River	Miette River	Whirlpool River
20-Jun-92	234											
24-Jun-92	213											
28-Jun-92	227	2		2	5							
02-Jul-92	271				5	2	5	5				
18-Jul-92	236	2										
22-Jul-92	252						5	5				
29-Jul-92	231				12		23	8	5	3	12	
31-Aug-92	286	6	10				36	8			25	25

APPENDIX E

SURGICAL DATA

Appendix E, Table 1. Data on surgical implantation, Athabasca River, 1992.

SPECIES	TAGGING DATE	CHAN.	CODE	FLOY TAG	LENGTH (mm)	WEIGH (g)	ANESTH. (1) TIME (min:sec)	REC. (2) TIME (min:sec)	OP. (3) TIME (min:sec)	LP (4 (ml)
MW	24-May-92	4	5	3072	403	911	1:45	10:00		0.0
MW	24-May-92	4	2	3076	393	787	1:30	5:30		0.4
DV	24-May-92	4	8	3078	519	1470	2:23	5:00		0.4
DV	24-May-92	4	1	3074	524	1458	2:15	2:20		0.5
LING	24-May-92	1	2	3075	545	910	4:25	1:20		0.5
LING	27-May-92	1	7	3083	890	5500	5:15	15:00		1.0
DV	27-May-92	5	14	3081	491	1400	2:00	2:21		0.9
LING	27-May-92	5	9	3084	573	946	3:15	1:06		0.9
DV	27-May-92	3	20	3082	413	687	2:00	2:00		0.0
MW	28-May-92	2	11	(5)	429	(6)	1:43	3:27		0.0
MW	28-May-92	4	7	(5)	365	(6)	1:25	3:30		0.0
MW	28-May-92	4	4	(5)	430	(6)	1:30	2:23		0.0
MW	28-May-92	4	3	(5)	407	(6)	1:30	2:00		0.0
LW	28-May-92	5	15	3086	501	(6)	1:36	1:00		0.0
MW	28-May-92	3	22	(5)	396	(6)	1:30	1:10		0.0
LING	28-May-92	3	24	3088	870	(6)	4:40	6:00		1.0
RT	29-May-92	4	6	(5)	366	591	1:55	2:15		0.0
MW	29-May-92	1	3	(5)	393	(6)	1:44	4:15		0.0
LING	29-May-92	2	13	(5)	580	(6)	3:06	1:20		0.0
DV	09-Jun-92	19	25	3097	557	1749	3:00	2:00		0.5
MW	09-Jun-92	20	11	3098	381	760	1:30	3:00	7:30	0.5
DV	10-Jun-92	20	31	(5)	570	2070	2:20	3:18	8:00	0.5
MW	10-Jun-92	20	24	(5)	435	1205	2:00	5:00	6:33	0.5
MW	10-Jun-92	20	43	(5)	415	858	1:22	n.d.	6:55	0.0
MW	10-Jun-92	19	33	(5)	398	821	1:39	4:00	6:57	0.5
RT	10-Jun-92	19	28	(5)	329	423	1:49	1:02	6:30	0.0
MW	11-Jun-92	20	12	(5)	390	744	1:33	5:50	6:47	0.0
MW	11-Jun-92	19	23	(5)	391	711	1:34	4:50	6:22	0.0
MW	11-Jun-92	19	26	(5)	410	812	1:25	2:20	6:13	0.0
MW	11-Jun-92	2	15	(5)	362	633	1:26	1:50	5:39	0.0
MW	11-Jun-92	19	27	(5)	385	647	1:50	1:29	6:55	0.0
AG	11-Jun-92	20	26	(5)	304	369	1:40	2:00	5:56	0.0
DV	12-Jun-92	20	10	(5)	385	520	1:28	2:05	7:15	0.5
DV	12-Jun-92	19	20	3457	460	1040	2:13	1:50	7:12	0.5
DV	12-Jun-92	20	44	3458	476	1186	2:55	1:30	7:58	0.6

(1) - Anesthetic Time is from when first immersed in MS-222 bath to when removed from bath.

(2) - Recovery Time is from when initially returned to fresh water to free swimming.

(3) - Operating Time is from when first immersed in anesthetic to when returned to fresh water.

(4) - LP (Liquamycin) is a Rogar/STB registered trademark for oxytetracycline hydrochloride.

(5) - Fish not Floy tagged to reduce handling time and stress.

(6) - Fish not weighed to reduce handling time and stress.

Species Abbreviations

AG	Arctic grayling
DV	Bull trout
LING	Burbot
LW	Lake whitefish
MW	Mountain whitefish
RT	Rainbow trout

APPENDIX F

PHOTOS

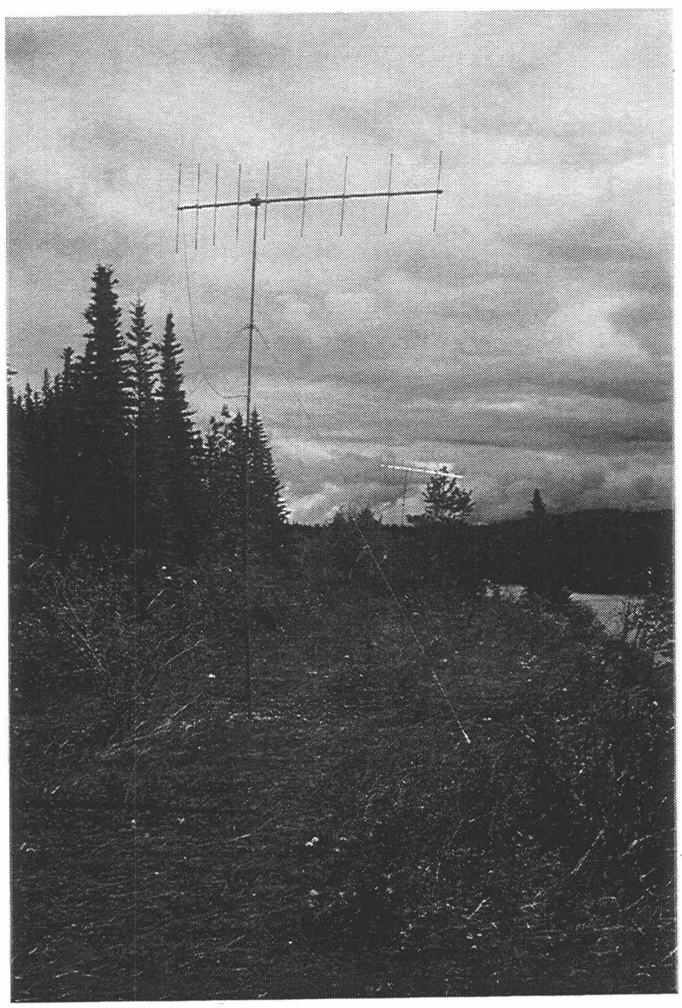


Photo #1 Ground station antennas indicating distance between antennas, distance to river bank, and height above river.

Photo #2 Fixed station antenna indicating height above river.

Photo #3 Yagi antenna mounted on Cessna 172.

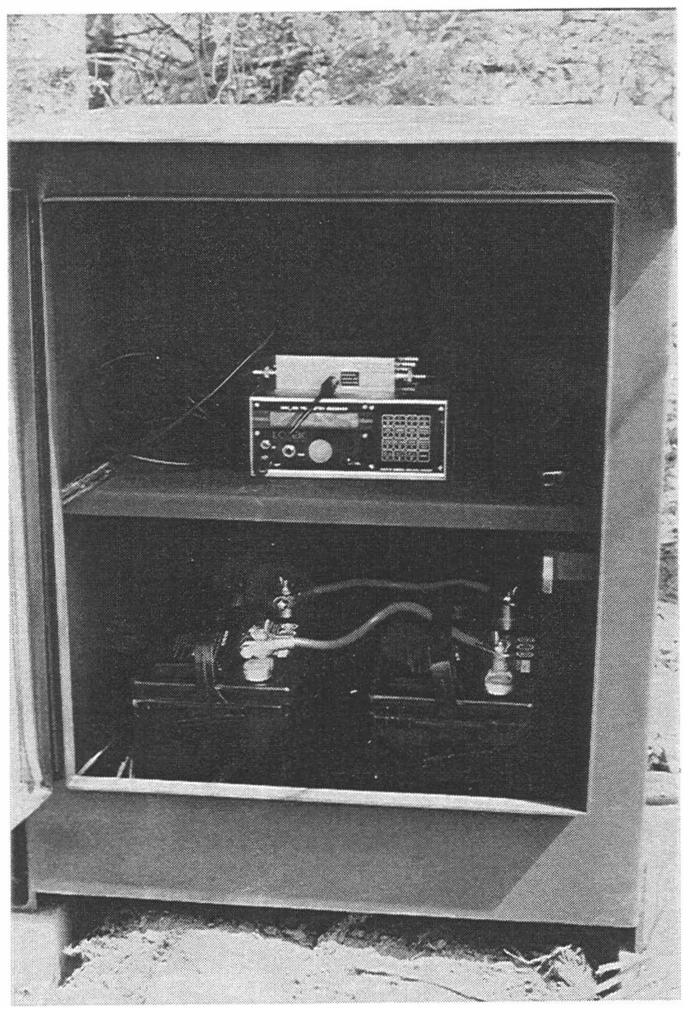


Photo #4 Fixed (ground) station equipment; data logger on top, and 12 volt batteries underneath.

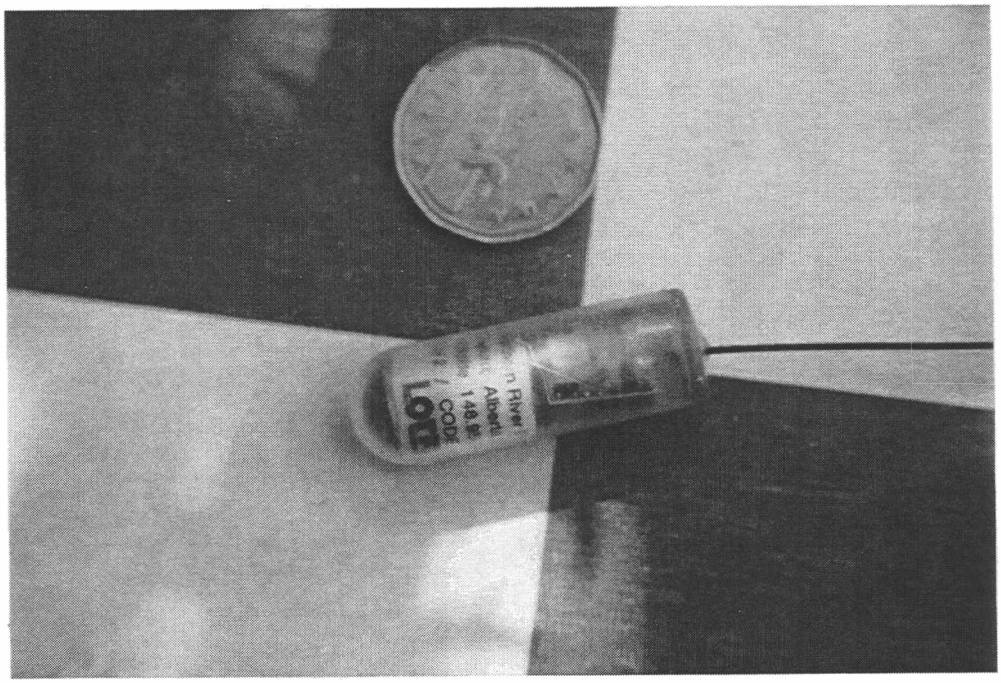


Plate #5 Transmitter used in demonstration study; illustration of size and transmitter identification.

Photo #6 Field surgical set-up for radio tag implantation. Live well on boat and cage beside boat used for post-operative recovery.

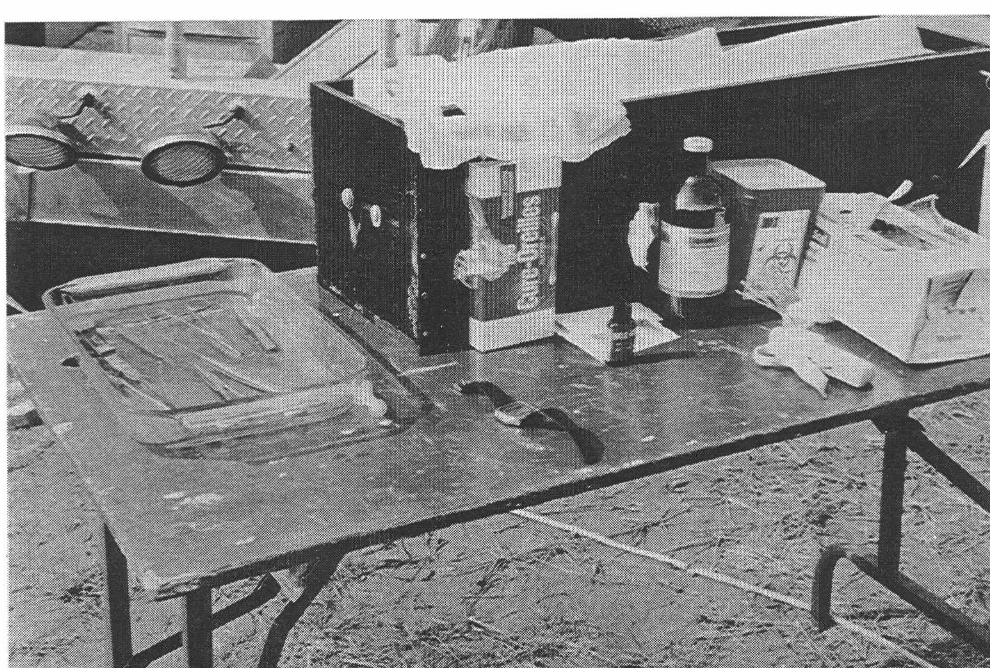


Photo #7 Surgical instruments used for radio tag implantation.

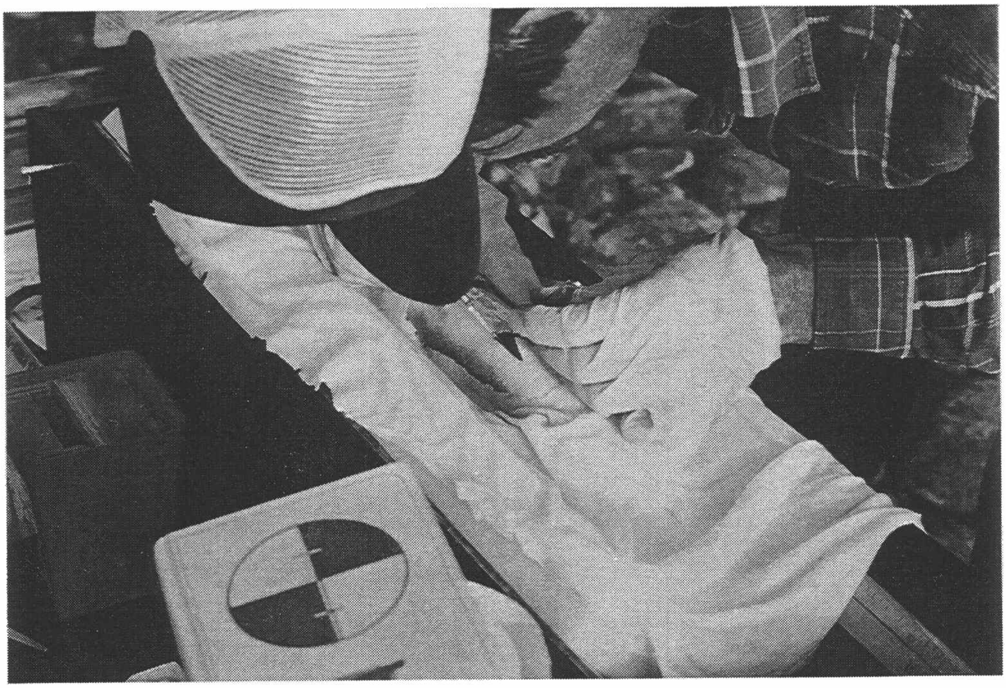


Photo #8 Surgical incision in a bull trout, prior to radio tag implantation.

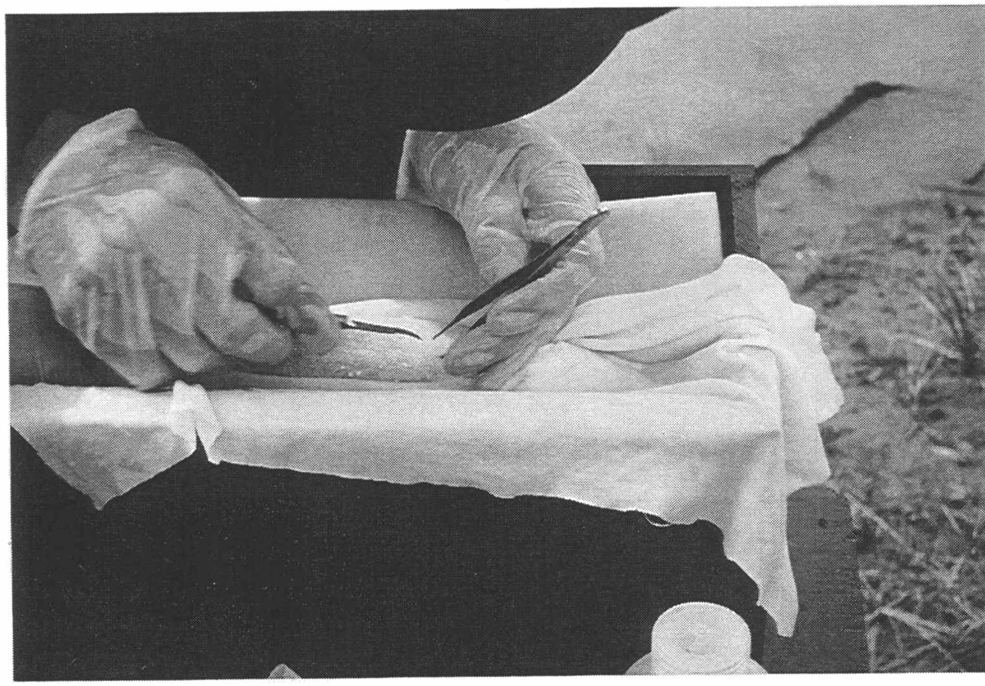


Photo #9 Preparation for incision on a mountain whitefish, after removal of several rows of scales on the ventral surface.

Photo #10 Antenna wire alignment during surgery.

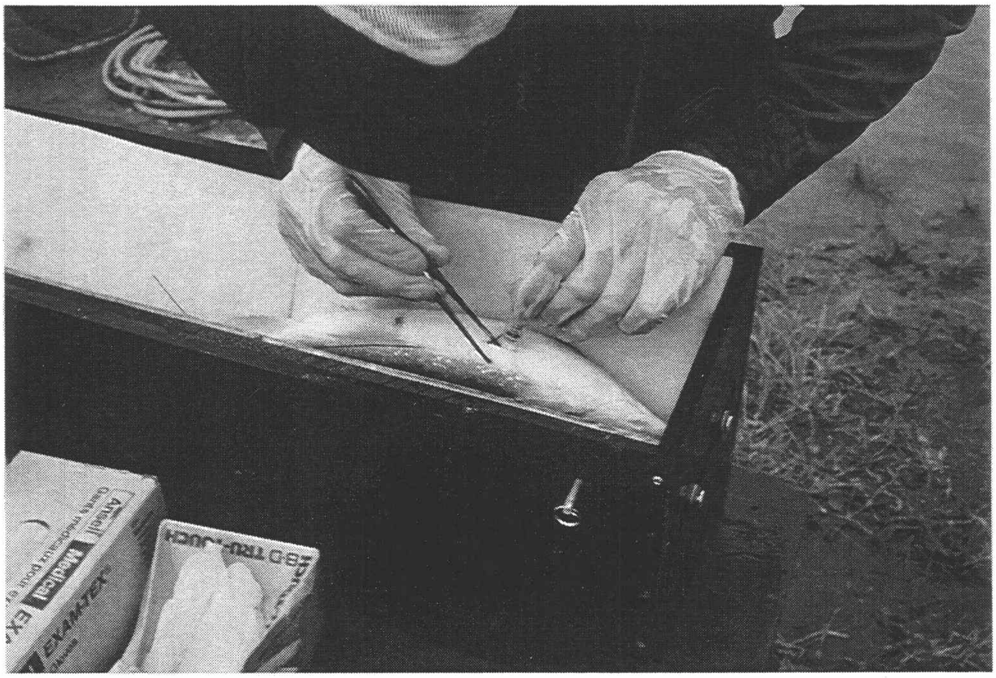


Photo #11 Radio transmitter insertion into a mountain whitefish.

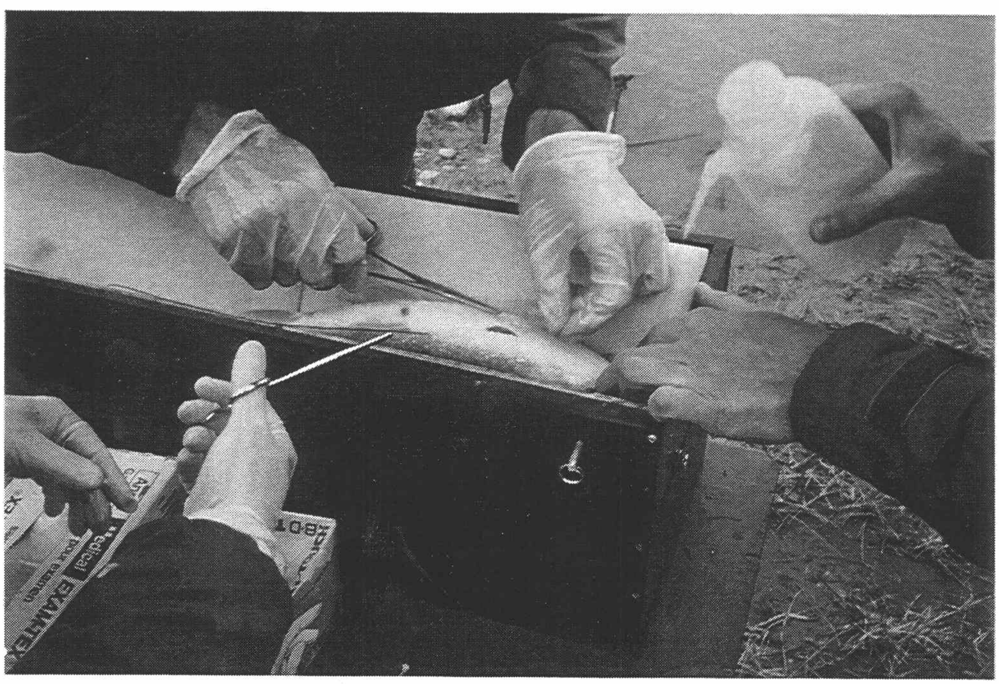


Photo #12 Suturing procedure on a mountain whitefish; wash bottle utilized to bath and aerate gills during final stages of suturing.

Photo #13 Post-operative care of a burbot; equilibrium maintained until fish able to swim on its own. Fish later transferred to holding cage.

Photo #14 Release of fish from in-river holding cage.

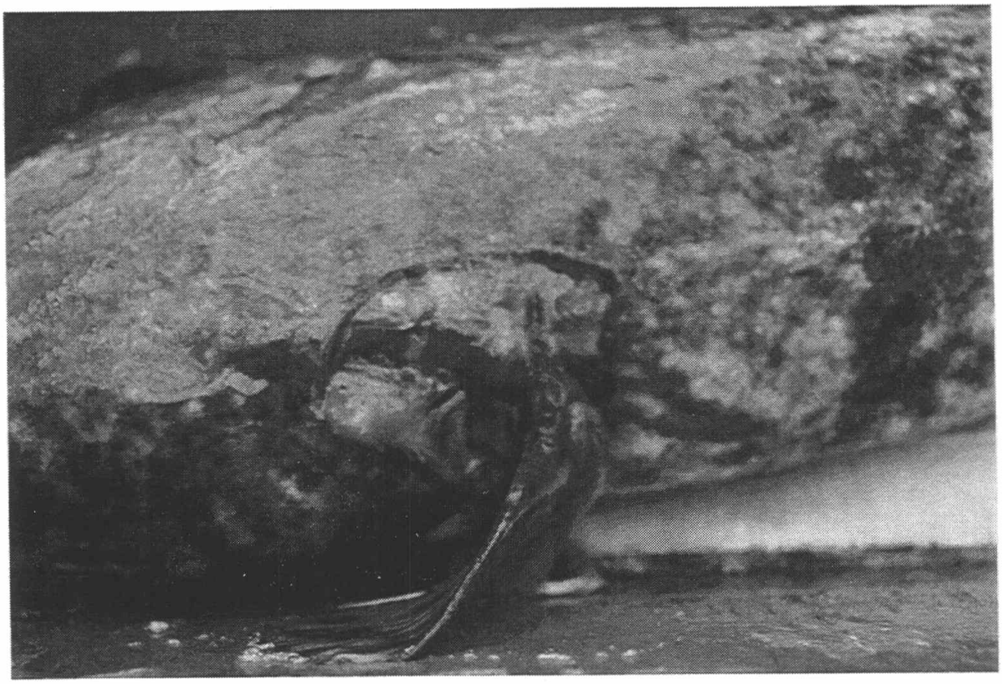


Photo #15 Lesion at left pectoral fin of a burbot; fish captured near Old Entrance (Km 1239).