Techman Engineering Ltd.

March 17, 1981

Director, Western Region
Parks Canada
Room 520, 220 - 4 Avenue S.E.
Calgary, Alberta T2P 3H8

Attention: Mr. J. Kilistoff
Aquatic Resources Manager

Dear Mr. Kilistoff:

Re: Transmittal of Final Report - An Analysis of the Native and Resident Cutthroat Trout (Salmo clarki) in the Bow, Kootenay - Columbia and Waterton River Systems
Our File No. TM 364-01

We are pleased to submit the original and twenty-five (25) copies of the report named above. This project was funded by Parks Canada -Western Region and fulfills the requirements of Contract WR 22-80.

The purpose of this study was to identify sources and characterize populations of native cutthroat trout within the Bow, Kootenay-Columbia and Waterton River systems in Banff, Kootenay and Waterton Lakes National Parks, respectively. Although pure populations of the native subspecies, the westslope cutthroat trout (Salmo clarki lewisi) have been extirpated throughout much of their original range in western Canada, we are pleased to report that most of the fish samples we analysed from study waters represented genetically pure, native populations.

We enjoyed participating in the project, and hope that our findings prove to be useful in future management programs.

Your comments and questions concerning the report are welcomed.

Sincerely,
TECHMAN ENGINEERING LTD.

Dwight R Mudry

D. R. Mudry, Manager,
Environmental and Earth Sciences

DJM/mc
Enclosures

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AN ANALYSIS OF THE NATIVE AND RESIDENT CUTTHROAT TROUT (*Salmo clarki*) IN THE BOW, KOOTENAY-COLUMBIA AND WATERTON RIVER SYSTEMS

FINAL REPORT

by

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TECHMAN ENGINEERING LTD.

for

PARKS CANADA - WESTERN REGION
DEPARTMENT OF ENVIRONMENT

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ABSTRACT

A study was undertaken to identify cutthroat trout strains indigenous to the Bow, Kootenay-Columbia and Waterton River systems in Banff, Kootenay and Waterton Lakes National Parks, respectively, and to identify which park waters within these river systems still contain native cutthroat populations. Cutthroat trout were collected during the spring of 1980 from 10 lakes, 1 stream and 1 lake in Banff, Waterton Lakes and Kootenay National Parks, respectively. A sample from the Connor Lakes, British Columbia, was also analysed for comparative purposes. Morphological analyses were performed on 160 specimens, and tissue extracts from 246 specimens were examined electrophoretically. The westslope cutthroat trout (Salmo clarki lewisi) was judged to be the only cutthroat subspecies native to the study area. Of the 13 samples analysed, 10 were found to be pure S. c. lewisi, including the samples from Block Lake (Upper), Elk Lake, the Fish Lakes (3), Marvel Lake, Mystic Lake, Twin Lake (Lower), Floe Lake and the Connor Lakes. Pure Yellowstone cutthroat trout (Salmo clarki bouvieri) were found in Taylor Lake. Westslope x Yellowstone hybrids were found in Baker Lake and Sofa Creek. There was no evidence of introgression from rainbow trout (Salmo gairdneri) or any other species.

ACKNOWLEDGEMENTS

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Mr. R.A.H. Sparrow, Head of Fish Culture, Fish and Wildlife Branch, British Columbia Department of the Environment, who provided stocking information for the Connor Lakes. Special thanks is extended to Mr. L.M. Belway, Hatchery Supervisor at the Kootenay Hatchery, Wardner, British Columbia, for collecting and storing trout samples from the lakes.

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SUMMARY

It is recognized that the genetic diversity inherent in native stocks is a valuable resource which allows local populations to successfully adapt to unique, local environmental conditions. This study, commissioned by Parks Canada, was designed to identify sources and characterize populations of native cutthroat trout within the Bow, Kootenay-Columbia and Waterton River systems in Banff, Kootenay and Waterton Lakes National Parks, respectively.

We have concluded that the westslope cutthroat trout (Salmo clarki lewisi) is the only cutthroat subspecies native to the Bow, Kootenay-Columbia and Waterton River systems. This trout has been extirpated throughout much of this area by loss of habitat and by replacement by other non-native trouts which have been introduced beyond their ranges and have either out-competed or hybridized with the native form. There are, however, areas within these drainages where essentially pure native cutthroat trout are relatively common, particularly in undisturbed, high elevation areas.

Based on a review of the fish stocking records, together with pertinent Parks Canada file data and information provided by knowledgeable parks personnel, eleven lakes, one stream and one lake in Banff, Waterton Lakes and Kootenay National Parks, respectively, were selected as likely areas where pure native strains might possibly still exist. An additional area, the Connor Lakes, British Columbia, was also studied for comparative purposes.

Most cutthroat trout specimens were collected during June 1980, as they concentrated in tributary streams during the spawning run. In Waterton Lakes National Park (Sofa Creek), fish were collected in May and July. No sample was collected from Hidden Lake, and it is suspected that this lake no longer supports a fish population. A combination of morphological characteristics and a biochemical procedure was selected as the

best means to judge the purity of the samples. Morphological analyses of 160 specimens included: coloration and spotting characteristics, and counts of pyloric caeca, gill rakers, scales in the lateral series, scales above the lateral line and basibranchial teeth. An electrophoretic analysis of skeletal muscle, liver and eye extracts from 246 specimens was also undertaken, and followed the methods described in Allendorf et.al.(1977).

Of the 13 samples analysed, 10 were found to be pure westslope cutthroat trout, including the samples from Block Lake (Upper), Elk Lake, the Fish Lakes (3), Marvel Lake, Mystic Lake, Twin Lake (Lower), Floe Lake and the Connor Lakes. Pure Yellowstone cutthroat trout (Salmo clarki bouvieri), a non-native subspecies, were found in Taylor Lake. Westslope x Yellowstone hybrids were found in Baker Lake and Sofa Creek.

In all samples except one, the results obtained from the morphological and biochemical analyses concurred. In the case of the Baker Lake sample, external morphological criteria were not adequate to detect the hybridization that was apparent in the electrophoretic analysis. In this sample, with 91% westslope isozymes and 9% Yellowstone isozymes, the effect of hybridization was not visually apparent, and the specimens appeared morphologically to be pure westslope cutthroat trout. In the Sofa Creek sample, with 80% westslope isozymes and 20% Yellowstone isozymes, the effect of hybridization was detected in both the morphological and biochemical analyses.

The samples from Fish Lake (First), Fish Lake (Second), Marvel Lake, Mystic Lake and Twin Lake (Lower) were totally monomorphic at all 32 gene loci examined, indicating that these are small and extremely isolated populations. Other samples showing polymorphism support this conclusion, as variation at each of three of the polymorphic loci was restricted to a single sample (Block Lake (Upper), Ldh-4; Elk Lake, Ck-1; Fish lake (Third), Ldh-3). The restricted distribution of these variant alleles combined with their high frequencies in some samples indicate that there is extremely little genetic exchange between these

populations. The large allelic frequency differences between samples also indicates that these populations are probably native and not introduced from a common source.

There was no evidence of introgression from rainbow trout or other species in any of the samples.

1.0 INTRODUCTION

Recent reviews of the historical distribution of trouts of the genus Salmo native to western North America conclude that the only subspecies of cutthroat trout endemic to the Bow, Waterton and Kootenay-Columbia river systems in Canada is the westslope cutthroat trout (Salmo clarki lewisi) (Behnke, 1979; Roscoe, 1974). Another form, the mountain cutthroat trout (Salmo clarki alpestris), has been described from the upper Columbia River drainage near Revelstoke, British Columbia (Dymond, 1931, as cited in Behnke, 1979). However, S.c. alpestris has not been generally accepted as a subspecies and most workers consider this form to be a synonym of S.c. lewisi (Behnke, 1979; Carl et al., 1971; Quadri, 1959).

All of the living forms of the genus Salmo are closely related genetically, and few barriers (other than geographic) exist that would prevent hybridization and the exchange of genetic material. Most inland populations of cutthroat trout have evolved in isolation from other trouts such as the rainbow trout (Salmo gairdneri). As a result, native cutthroat populations have not developed isolating mechanisms which would allow them to coexist with other trouts without hybridization. When species such as S. gairdneri are introduced into waters where cutthroat trout is the only native species, mass hybridization or hybrid "swarms" is often the result, and a lack of some degree of hybridization is rare (Behnke, 1979; Roscoe, 1974). For many years, there has been a steady decline in the range of S.c. lewisi throughout western North America. Habitat degradation has been a contributing factor, but the major causes of population decimation have been associated with the introduction of non-native species. Introduced exotic species such as brown trout (Salmo trutta) and brook trout (Salvelinus fontinalis) have successfully competed for habitat with S.c. lewisi. Salmo gairdneri and non-native cutthroat trouts have been introduced beyond their ranges, and the result of this has been the production of viable hybrids and increased loss of genetic integrity within native populations.

The genetic status of most populations of cutthroat trout in Banff, Kootenay and Waterton Lakes National Parks is not known. It is known that widespread introductions of non-native trouts have occurred in the past. Historical stocking data for parks' waters show that during the early years of fish stocking, little discrimination was exercised in terms of species planted. Ward (1974) reports that many fish were stocked in National Park waters before hatcheries existed.

Parks Canada recognizes that the genetic diversity inherent in native plant and animal life within the national parks is a resource to be protected, maintained and enjoyed, and is charged with the mandate to protect that resource. This study was designed to analyse and identify cutthroat trout strains within selected park waters, and to determine which waters still contain the native strains that were indigenous to the Bow, Kootenay-Columbia and Waterton River systems in Banff, Kootenay and Waterton Lakes National Parks.

1.1 Origin of Stocks

Stocking information for Banff, Kootenay and Waterton Lakes National Parks is provided by Kilistoff et al. (1973), Parks Canada file excerpts (1921-1958, 1926-1958), Rawson (1938, 1939), Sonstegard et al. (undated) and Ward (1974). These sources show that the main species planted in study waters has been the cutthroat trout, with only a few exceptions. Many of the fish planted originated from stocks in the United States, and the distinct possibility exists that some of these stocks were of non-native origin. This assumption is confirmed by Behnke (1979), who states that from 1905-1955, the Yellowstone cutthroat trout (Salmo clarki bouvieri) was the dominant form of cutthroat propagated by hatcheries in the United States. Large numbers of eggs were easily obtained from Yellowstone Lake, and stocks originating from this area were promoted above native stocks. Behnke (1979) also states that as individual states began developing their own propagation programs, they often established brood stock lakes, most of which contained rainbow x Yellowstone cutthroat hybrids. Two major taxonomic groups of native rainbow trout have been described in western North

America on the basis of biochemical genetic information (Allendorf and Utter, 1979) and morphological characteristics (Schreck and Behnke, 1971; Behnke, 1979): the coastal form, which is native to waters west of the Cascade Mountain Range, and the eastern form, which is native to both the Fraser and Columbia River basins east of this range. The overwhelming majority of present-day hatchery brood stocks have been derived from coastal stocks (Allendorf and Utter, 1979; Behnke and Needham, 1962; MacCrimmon, 1971, as cited in Allendorf et al., 1980). It is reasonable to assume, therefore, that any hybridization manifested by cutthroat trout in study area waters would likely be a result of past introductions of Yellowstone cutthroat trout, rainbow trout (coastal form), or hybrid mixtures of both forms.

1.2 Identification of Strains

Western trouts are closely related genetically and there is much overlap in diagnostic characteristics between species, subspecies and within populations (Behnke, 1979). Salmonid fishes are also notoriously labile in external morphology, and many studies have shown that environmental cues such as temperature changes can induce morphological changes, particularly during early stages of development (Barlow, 1961; Garside, 1966, as cited in Schreck and Behnke, 1971). These generic traits have contributed to some disagreement on the recognition of species and subspecies of western Salmo, and on their interrelationships. There is general agreement, however, that certain meristic characters such as vertebra, gill rakers, pyloric caeca and pelvic fin rays are relatively stable under varying natural conditions, and validly reflect the genotype (Behnke, 1979; Gold et al., 1979; Rourke and Wallace, 1978; Schreck and Behnke, 1971). Meristic characters have been used successfully to detect hybridization within Salmo, such as rainbow trout influence on cutthoat trout (Behnke, 1965; Roscoe, 1974; Wernsman, 1973, as cited in Rourke and Wallace, 1978).

In recent years, the refinement of biochemical-genetic techniques has contributed greatly to our present understanding of the systematics and genetics of Salmo. Patterns and amounts of genetic variation or hybrid-

ization between individuals and groups can now be quantified, by examining the gene products of many individual loci through the electrophoretic separation of proteins. The protein variants that are selected for genetic analysis reflect genetic differences that are unaffected by environmental cues. Therefore, this genetic basis for analysis of variation has major advantages over the morphological basis, which is usually affected by an unknown environmental component (Utter et al., 1976). Gene duplication is extensive in salmonids, and this has resulted in a large number of electrophoretically detectable loci, making this group ideally suited for genetic analysis by electrophoretic techniques (Allendorf et al., 1977). Starch-gel electrophoresis has been successfully used to distinguish westslope cutthroat trout, rainbow trout and their hybrids (Reinitz, 1977). Reinitz (1977) has stated: "the purity of a population of westslope cutthroat trout could be better judged by the use of both biochemical and morphological characters than by the use of either alone". Both techniques were chosen as a means of characterizing cutthroat trout populations in the study area.

1.3 Study Area

The selection of particular areas where pure native strains might possibly still exist was based on a thorough review of the fish stocking history of Banff, Kootenay and Waterton Lakes National Parks, together with other pertinent file data and information provided by knowledgeable parks personnel. Waters where minimal or no stocking had occurred were selected for analysis of their cutthroat trout populations, and included eleven lakes, one stream and one lake in Banff, Waterton Lakes and Kootenay National Parks, respectively (Figure 1).

Lakes studied in Banff National Park include Baker, Block (Upper), Elk, Fish (3), Hidden, Marvel, Mystic, Taylor and Twin (Lower) lakes (Figure 2). Seven of the lakes are located within the Alpine Zone, with elevations extending to 2260 m above sea level (Hidden Lake). The remaining four (Taylor, Twin, Mystic and Marvel) are found within the Subalpine Forest Subzone at elevations as low as 1770 m above sea level (Marvel Lake). All are located within the Bow River drainage basin.

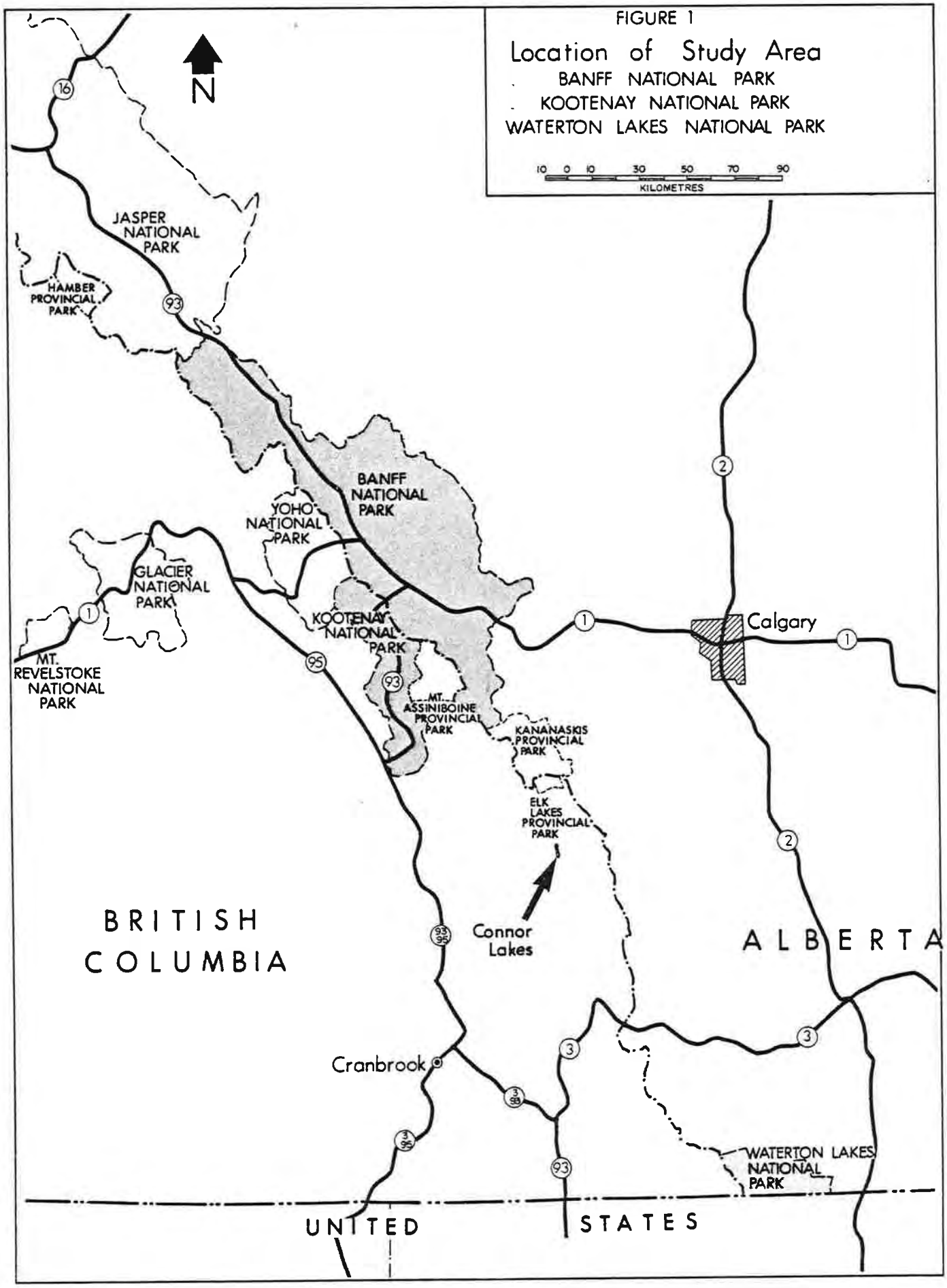
FIGURE 1
Location of Study Area
. BANFF NATIONAL PARK
. KOOTENAY NATIONAL PARK
WATERTON LAKES NATIONAL PARK
10 0 10 30 50 70 90
KILOMETRES
N
JASPER NATIONAL PARK
HAMBER PROVINCIAL PARK
BANFF NATIONAL PARK
YOHO NATIONAL PARK
GLACIER NATIONAL PARK
KOOTENAY NATIONAL PARK
MT. REVELSTOKE NATIONAL PARK
MT. ASSINIBOINE PROVINCIAL PARK
KANANASKIS PROVINCIAL PARK
ELK LAKES PROVINCIAL PARK
Calgary
Connor Lakes
BRITISH COLUMBIA
ALBERTA
Cranbrook
WATERTON LAKES NATIONAL PARK
UNITED STATES

In Kootenay National Park, Floe Lake was selected (Figure 2). This lake is located within the Alpine Zone at an elevation of approximately 2080 m. An additional area, the Connor Lakes, British Columbia, was also chosen for study. Although not located in a national park (Figure 1), the two Connor Lakes were included as they serve as an egg source for the province, and there is only one documented occasion (1950) when eggs derived from an external source were planted here (R.A.H. Sparrow, pers. comm.). Both Flow and the Connor Lakes are located within the Kootenay River drainage basin.

In Waterton Lakes National Park, Sofa Creek was selected for study (Figure 3). This stream originates near the Montana border between Sofa Mountain and Vimy Ridge, and flows in a northerly direction for 12 kilometers before entering Lower Waterton Lake at an elevation of 1280 m. Sofa Creek is located within the Waterton River drainage basin.

FIGURE 2
Location of Study Waters
IN
BANFF NATIONAL PARK
AND
KOOTENAY NATIONAL PARK

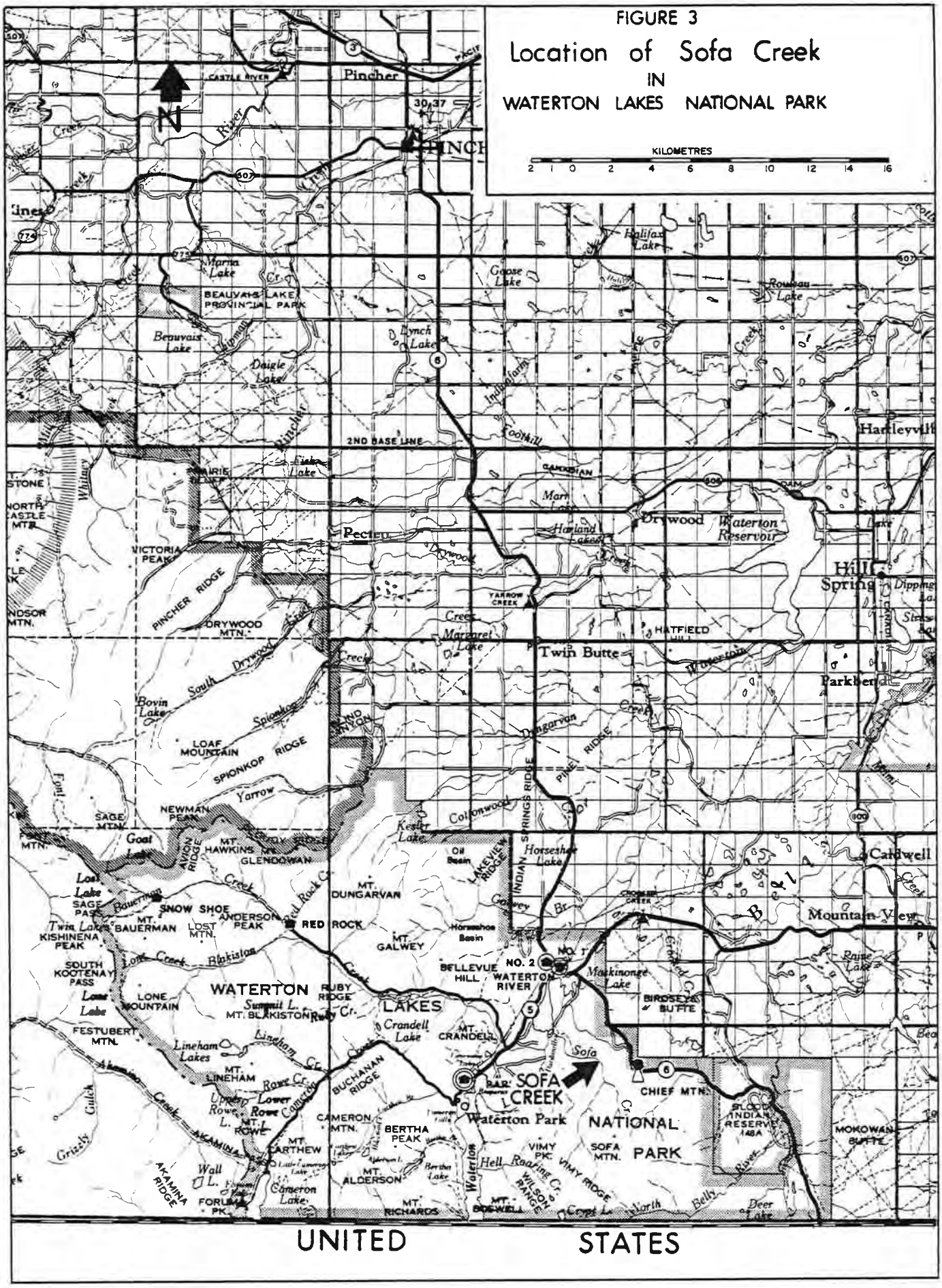
FIGURE 3
Location of Sofa Creek
IN
WATERTON LAKES NATIONAL PARK
KILOMETRES
2 1 0 2 4 6 8 10 12 14 16
N
Pincher
Halifax Lake
Goose Lake
Rowland Lake
BEAUVAIS LAKE PROVINCIAL PARK
Beauvais Lake
Daigle Lake
Lynch Lake
2ND BASE LINE
Drywood Waterton Reservoir
Twin Butte
Parkbeg
Spring
VICTORIA PEAK
PINCHER RIDGE
DRYWOOD MTN.
YARROW CREEK
HATFIELD
Margaret Lake
Bovin Lake
South Drywood Creek
LOAF MOUNTAIN
SPIONKOP RIDGE
Yarrow Creek
NEWMAN PEAK
SAGE MTN.
Goat Lake
MT. HAWKINS
GLENDOWAN
Lost Lake
SAGE PASS
SNOW SHOE
ANDERSON PEAK
RED ROCK
MT. BAUERMAN
LOST MTN.
Twin Lakes
KISHINENA PEAK
SOUTH KOOTENAY PASS
Lone Creek
Blakiston Creek
LONE MOUNTAIN
WATERTON LAKES
Summit L.
MT. BLAKISTON
RUBY RIDGE
Ruby Cr.
FESTUBERT MTN.
Lone Lake
Lineham Lakes
MT. LINEHAM
Lineham Cr.
Rowe Cr.
Upper Rowe L.
Lower Rowe L.
MT. ROWE
Akamina Creek
AKAMINA RIDGE
Grizzly Gulch
Wall L.
FORUM PK.
MT. CARTHEW
Cameron Lake
CAMERON MTN.
BERTHA PEAK
Bertha Lake
MT. ALDERSON
MT. RICHARDS
BUCHANAN RIDGE
Crandell Lake
MT. CRANDELL
Sofa Creek
BAR
SOFA CREEK
Waterton Park
NATIONAL PARK
SOFA MTN.
VIMY PK.
VIMY RIDGE
Hell Roaring Cr.
WILSON RANGE
MT. BOSWELL
Waterton River
CHIEF MTN.
BLOOD INDIAN RESERVE 148A
MOKOWAN BUTTE
Deer Lake
Belly River
Mountain View
Caldwell
Horseshoe Lake
Oil Basin
Horseshoe Basin
MT. GALWEY
MT. DUNGARVAN
LAKEVIEW RIDGE
INDIAN SPRINGS RIDGE
PINE RIDGE
Cottonwood Cr.
Kester Lake
Dungarvan Creek
Gravey Br.
CROWSNEST CREEK
BELLEVUE HILL
NO. 1
NO. 2
Mackinonge Lake
BIRDSEYE BUTTE
Rainy Lake
UNITED STATES

2.0 MATERIALS AND METHODS

Cutthroat trout were collected during June 1980, as they concentrated in tributary streams during the spawning run. The exception was Sofa Creek, where fish were collected on May 13 and July 2, 1980. Fish were electroshocked in most cases, although some specimens were collected by angling or gillnetting. Specimens were frozen and transported to Calgary for morphological examination.

2.1 Morphological Procedures

Coloration and spotting was observed from specimens in the laboratory, and from color photographs taken in the field. Counts of pyloric caeca and scales (above and below the lateral line) followed procedures outlined in Hubbs and Lagler (1974). Scales in the lateral series were counted two rows above the lateral line starting with the first scale touching the pectoral girdle and including the last scale anterior to the distal end of the hypural complex, as determined by flexing the caudal fin. Gill rakers, including rudiments, were counted on both upper and lower limbs. Counts of basibranchial teeth were made using a staining technique suggested by R.J. Behnke (cited in Gold 1977). Tissue paper soaked in an alizarin-potassium hydroxide solution (described by Humason, 1967) was placed on the excised basibranchial plate of each specimen, and left overnight. Basibranchial dentition was then determined under a dissecting microscope, using a fine jet of air to remove excess tissue. The fork length of each specimen was determined by taking a straight line measurement from the most anteriorly projecting part of the head to the mid-line notch of the caudal fin.

Specimens measuring less than 150 mm fork length were not dissected but were kept whole for biochemical analysis. Morphological data, therefore, were not compiled for these individuals.

2.2 Biochemical Procedures

Three separate tissues were excised from all individuals measuring greater than 150 mm fork length: skeletal muscle, liver and eye. These

tissues were frozen immediately, and delivered to the genetics laboratory at the University of Montana for electrophoretic analysis. Electrophoretic procedures followed the methods described in Allendorf et.al.(1977). Extracts were prepared from muscle, liver and eye tissue, by placing equal amounts of tissue and water into 12 x 75 mm glass tubes and blending this mixture into a paste with a glass rod. This process breaks the cell membranes and releases the soluble enzymes contained in that tissue into the water. The samples were then centrifuged for five minutes at 1000 xg, and the supernatant was analysed. Extracts were absorbed by 4 x 6 mm filter paper wicks, which in turn were placed into cuts in starch gels, approximately 3 cm from the cathodal end. These gels were made using 37 grams of hydrolyzed potato starch in 275 ml of the appropriate buffer, and were prepared following the method of Kristjansson (1963). Buffer systems utilized in gel preparation are described by Ridgeway et.al.(1970) and Clayton and Tretiak (1972). Two plastic containers of buffer solution were placed at opposite ends of each gel, and platinum electrodes were placed in the buffer and secured. Disposable, absorbant cloths served to conduct the electric current from the tray buffers to the appropriate ends of the gels. A wick containing a dye marker (diluted red food coloring) was placed at the end of each gel to determine the rate of protein migration. After ten to fifteen minutes of electrophoresis, the wicks were removed and the two sections of each gel were placed firmly together. An ice pack on a glass plate was placed on top of each gel and the appropriate voltage applied until the dye marker had migrated 3 to 8 cm from each cut (origin). In preparation for staining, each gel was sliced horizontally into four or more sections, depending on gel thickness. This was done by sequentially placing pairs of 1.5 mm plastic strips on two opposing sides of each gel, and then drawing monofilament sewing thread through the length of the gel. The slices were placed into individual staining trays with the side of the slice nearest the centre of the gel facing upward. The separated enzymes located on the gels were identified by their specific biochemical reactions, which were manifested by colored products forming visible bands where particular enzymes had been electrophoretically localized. A total of 10 enzymes encoded by 32 gene loci were analysed in all samples (Table 1). An explanation of the biochemical analysis is presented in Appendix D.

Table 1. List of enzymes and number of loci examined.

Enzyme	Abbreviation	EC Number*	Number of loci examined
Aspartate aminotransferase	Aat	2.6.1.1	2
Alchohol dehydrogenase	Adh	1.1.1.1	1
Alpha-glycerophosphate dehydrogenase	Agp	1.1.1.8	1
Creatine kinase	Ck	2.7.3.2	3
Isocitrate dehydrogenase	Idh	1.1.1.42	4
Lactate dehydrogenase	Ldh	1.1.1.27	5
Malate dehydrogenase	Mdh	1.1.1.34	4
Malic Enzyme	Me	1.1.1.40	4
Phosphoglucoisomerase	Pgi	5.3.1.9	3
Phosphoglucomutase	Pgm	2.7.5.1	2
Sorbitol dehydrogenase	Sdh	1.1.1.14	2
Superoxide dismutase	Sod	1.15.1.1	1
			32

* International Enzyme Commission classification number.

3.0 RESULTS

3.1 Analysis of Morphological Characteristics

Yellowstone cutthroat trout, westslope cutthroat trout and rainbow trout are morphologically similar and there is considerable overlap in character values, particularly between the cutthroat forms. The fact that S.clarki is a polytypic species and displays morphological variability throughout its range has presented a problem to taxonomists for many years. Morphological characteristics are influenced by a number of factors, both genetic and environmental. Meristic characters are directly related to the number of body segments, which are mainly genetically controlled. However, the expression of meristic characters can be affected by environmental influences such as water temperature, which affect segmentation rate (Schrech, 1969, as cited in Roscoe, 1974). Certain characters, including gill rakers and pyloric caeca, are quite stable and show little variation due to environmental influence (Wernsman, 1973, as cited in Roscoe, 1974). Average gill raker and pyloric caecal counts are generally higher for S.c. bouvieri than for S.c. lewisi. Other characters, including scales and basibranchial teeth, are quite variable, and are influenced to a greater degree by environmental conditions (Wernsman, 1973, as cited in Roscoe, 1974). Salmo clarki lewisi and S.c. bouvieri cannot generally be distinguished on the basis of scale counts, as these counts are often similar between the subspecies. Average scale counts for S. gairdneri, however, are significantly lower than for cutthroat trouts (Roscoe, 1974). Basibranchial dentition is a diagnostic characteristic that is useful in differentiating rainbow and cutthroat trouts (Behnke, 1979, Roscoe, 1974). Rainbow trout do not have basibranchial teeth, while cutthroat trout do. Behnke (1979) has stated that as a general rule, basibranchial teeth should occur in more than 90% of the specimens in a pure population of cutthroat trout. Salmo clarki bouvieri normally have significantly higher tooth counts than S.c. lewisi (Roscoe, 1974).

Another factor that greatly influences the expression of morphological characteristics in Salmo is hybridization, which is generally manifested by a deviation from normal modes for meristic characters. In Salmo, hybrids do not express character values intermediate between those of the parents, particularly in the F2 generation or later. Investigators have found that chum salmon x pink salmon hybrids have pyloric caecal values higher than those found in either parent (Ivanhov, 1973, as cited in Roscoe, 1974). Often there is effective selection toward one of the parents, possibly due to the suppression of the action of certain genes in one of the parental forms through dominance by multiple genes in the other parent (Nyman, 1970). In cases of rainbow x cutthroat crosses, hybrids can be recognized by higher pyloric caecal and vertebral counts, lower scale counts, a reduction or lack of basibranchial teeth and erratic spotting patterns. In the case of westslope x Yellowstone crosses, hybrids will often have higher scale, gill raker and basibranchial tooth counts, and larger, rounder spots than is typical of S.c. lewisi.

Although meristic characteristics are often similar, spotting and body coloration patterns vary significantly between S.c. lewisi and S.c. bouvieri. Spotting characteristics are consistant throughout the range of each subspecies, and provide the only consistant means whereby the two forms can be distinguished morphologically. Spotting and color characteristics of S.c. lewisi are illustrated in Figure 4 and Photo 8. Spots are small, irregular in outline, and distributed most profusely in the caudal peduncle region. Spots extend forward to the head, most being above the lateral line. Body coloration is generally silvery with rose tints, but can be significantly affected by environmental conditions such as food type. Salmo clarki lewisi does, however, have a genetic basis for developing yellow, orange, red, green or black hues. Spotting and color characteristics for S.c. bouvieri are illustrated in Figure 5 and Photo 12. Body spots are larger, more rounded in outline, more pronounced and fewer in number than those of S.c. lewisi. Spots are concentrated on the caudal peduncle, and are sparsely and evenly distributed forward to the head, often extending below the lateral line. Salmo clarki bouvieri are generally yellowish-brown, silvery or brassy, but can express red and purple hues as well. Spotting characteristics

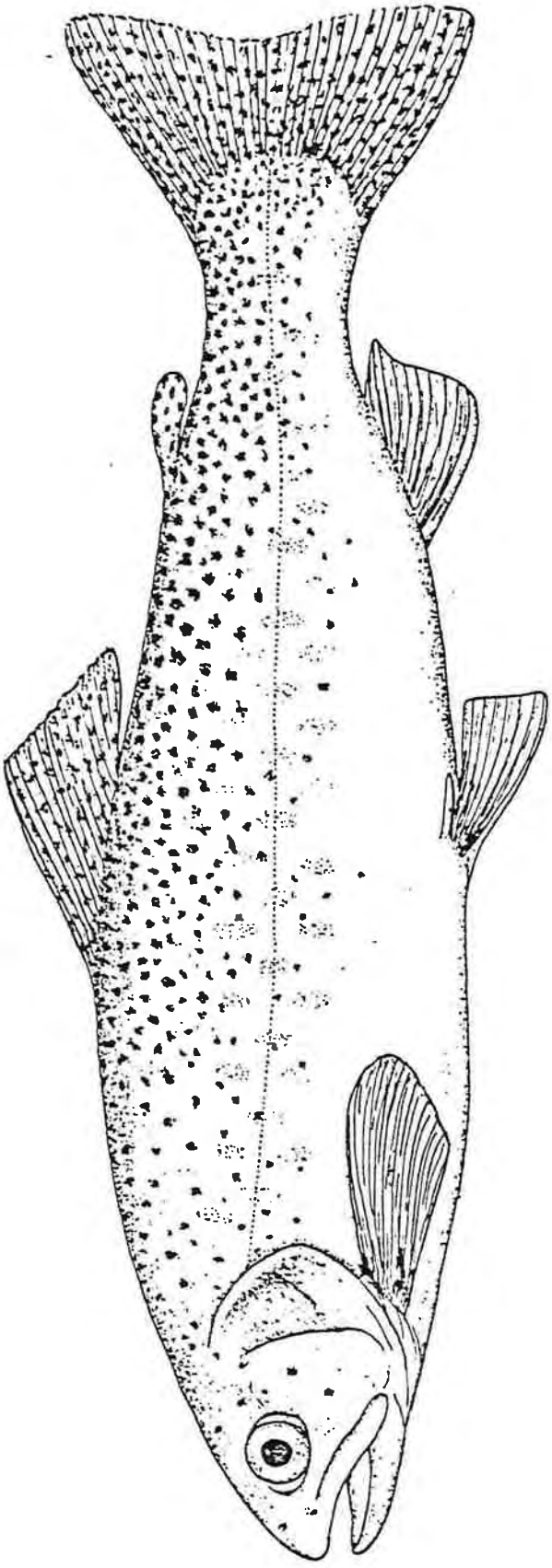

Figure 4. Spotting pattern of westslope cutthroat trout (Salmo clarki lewisi). (Roscoe, 1974).

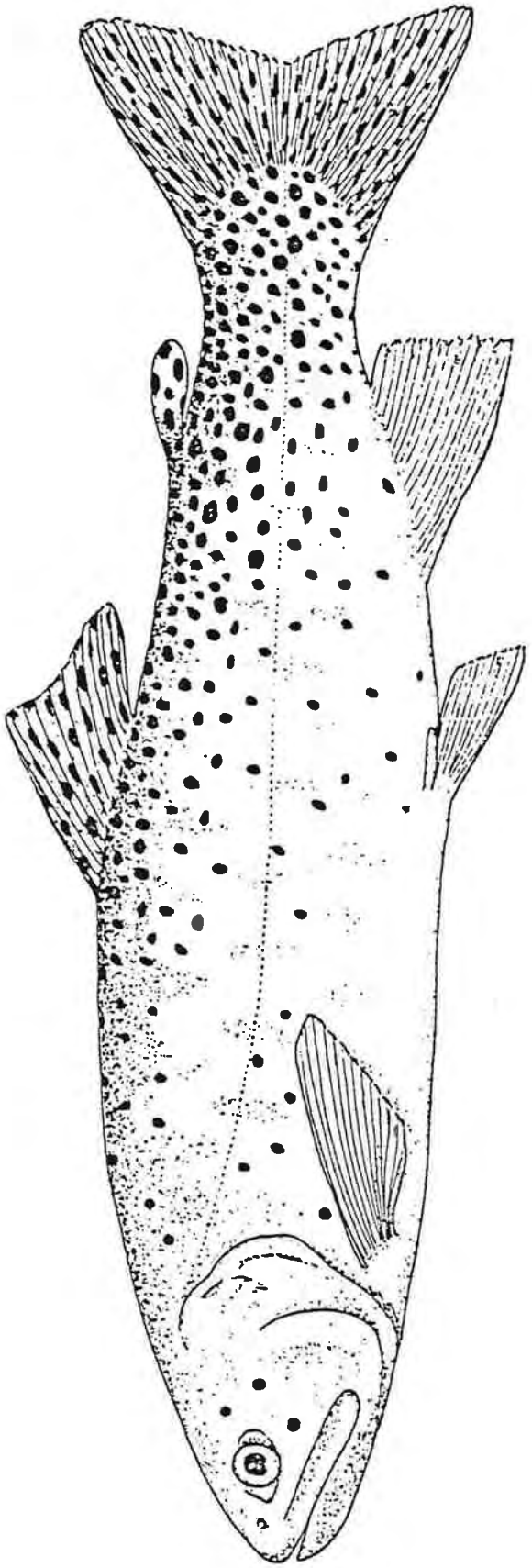

Figure 5. Spotting pattern of Yellowstone cutthroat trout (Salmo clarki bouvieri). (Roscoe, 1974).

of S. gairdneri are shown in Figure 6. Spotting is heavy both above and below the lateral line with small, irregular shaped spots. Salmo gairdneri are often heavily spotted in anterior body regions, in contrast to S.c. lewisi and S.c. bouvieri. Body coloration is generally silvery throughout, with a rose red band along the lateral line at some stage of the life cycle.

A summary of 7 morphological characteristics typical of S.c. lewisi, S.c. bouvieri and S. gairdneri is presented in Table 2. Meristic data compiled for the study samples have been summarized in Tables 3 to 8 and are presented in total in Appendix C.

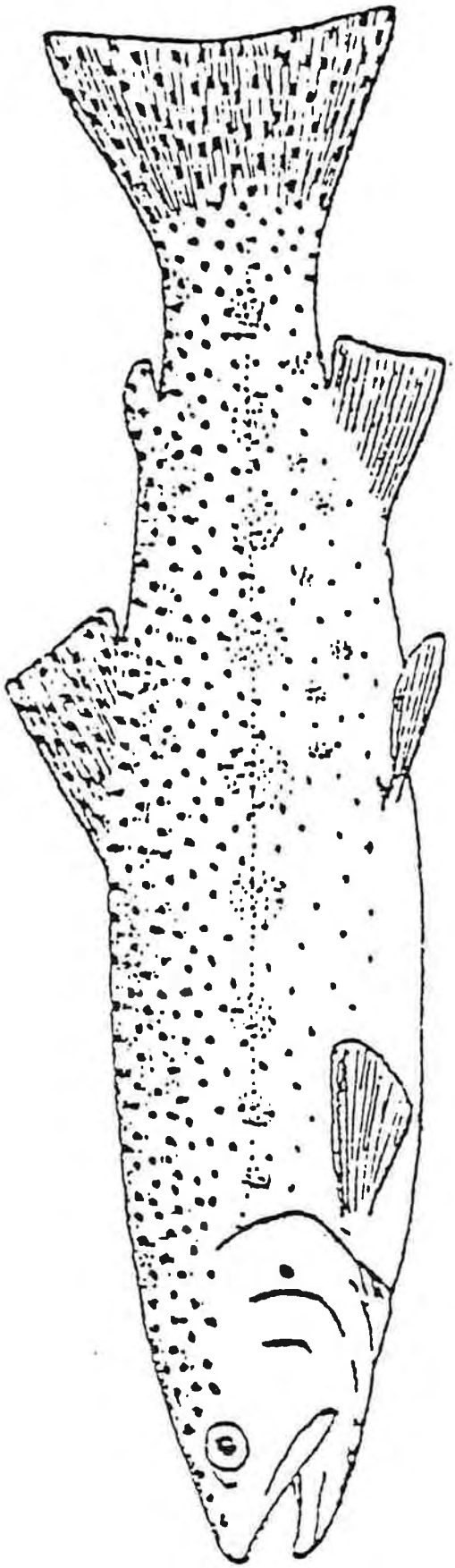

Figure 6. Spotting pattern of rainbow trout (Salmo gairdneri) (Behnke, 1979).

Table 2. Morphological characteristics typical of westslope cutthroat trout, Yellowstone cutthroat trout and rainbow trout*.

Character	*S.c. lewisi* westslope cutthroat trout		*S.c. bouvieri* Yellowstone cutthroat trout		*S. gairdneri*** rainbow trout	
	Typical value	Range	Typical value	Range	Typical value	Range
Pyloric caecal	30-40	24-51	35-45	26-63	50-55	35-75
Gill rakers	18-19	16-24	19-20	17-23	18-20	16-24
Scales in lateral series	165-180	130-205	165-180	128-200	120-140	110-150
Scales above lateral line	-	30-48	-	31-53	28.5	25-32
Basibranchial dentition	-	0-30	-	0-63	absent	
Cutthroat mark	strong		strong		absent	
Lateral band	weak or absent		weak or absent		strong	

* Data presented in this table has been compiled from the following sources: Behnke, 1979; Gold, 1977; Roscoe, 1974; Schreck and Behnke, 1971.

** *Salmo gairdneri* does not include fine-scaled inland forms such as *S.g. kamloops*.

Table 3. Comparison between samples for pyloric caeca

Sample	Sample size	Mean number of pyloric caeca	Range	Standard deviation	Standard error of sample mean
Baker Lake	9	39.7	31-45	4.08	1.33
Block Lake (Upper)	24	37.3	31-47	4.08	0.83
Elk Lake	14	35.7	27-44	5.22	1.40
Fish Lake (First)	14	41.7	32-51	4.68	1.25
Fish Lake (Second)	12	43.75	38-52	4.59	1.33
Fish Lake (Third)	25	40.8	35-52	4.40	0.87
Marvel Lake	4	41.25	37-46	4.03	2.02
Mystic Lake	8	38.6	36-42	2.26	0.80
Taylor Lake	25	38.4	31-47	4.72	0.94
Twin Lake (Lower)	-	-	-	-	-
Floe Lake	4	30.0	23-34	5.23	2.61
Sofa Creek	1	34.0	-	-	-
Connor Lakes	10	33.4	24-41	5.36	1.69

Table 4. Comparison between samples for gill rakers

Sample	Sample size	Mean number of gill rakers	Range	Standard deviation	Standard error of sample mean
Baker Lake	9	18.9	17-23	1.83	0.61
Block Lake (Upper)	24	18.5	16-21	1.22	0.25
Elk Lake	14	18.9	16-21	1.33	0.36
Fish Lake (First)	13	18.85	16-21	1.34	0.37
Fish Lake (Second)	12	18.9	18-21	0.90	0.26
Fish Lake (Third)	25	18.0	16-20	1.04	0.21
Marvel Lake	4	19.5	19-20	0.58	0.29
Mystic Lake	8	17.9	16-19	0.83	0.30
Taylor Lake	24	20.7	19-23	1.08	0.22
Twin Lake (Lower)	5	17.6	17-18	0.55	0.25
Floe Lake	4	16.5	12-18	3.0	1.50
Sofa Creek	1	18.0	-	-	-
Connor Lakes	10	19.1	18-21	0.88	0.28

Table 5. Comparison between samples for scales in the lateral series

Sample	Sample size	Mean number of scales in the lateral series	Range	Standard deviation	Standard error of sample mean
Baker Lake	9	170.7	144-189	14.34	4.78
Block Lake (Upper)	23	171.0	150-187	10.25	2.14
Elk Lake	14	161.4	149-178	8.58	2.29
Fish Lake (First)	14	167.2	153-185	10.59	2.83
Fish Lake (Second)	12	161.75	147-180	11.45	3.31
Fish Lake (Third)	25	161.2	146-186	10.11	2.0
Marvel Lake	4	145.0	132-153	9.76	4.88
Mystic Lake	8	180.5	152-203	18.65	6.59
Taylor Lake	25	167.0	141-184	11.22	2.24
Twin Lake (Lower)	11	173.45	158-196	10.42	3.14
Floe Lake	4	186.0	172-200	12.14	6.07
Sofa Creek	1	141.0	-	-	-
Connor Lakes	10	171.0	157-186	8.03	2.54

Table 6. Comparison between samples for scales above the lateral line

Sample	Sample size	Mean number of scales above the lateral line	Range	Standard deviation	Standard error of sample mean
Baker Lake	9	39.9	35-46	4.08	1.36
Block Lake (Upper)	23	34.2	26-38	2.95	0.60
Elk Lake	14	39.2	36-44	2.08	0.56
Fish Lake (First)	14	39.5	32-46	3.48	0.93
Fish Lake (Second)	12	40.9	36-46	3.12	0.90
Fish Lake (Third)	25	37.7	32-43	2.67	0.53
Marvel Lake	4	41.75	41-43	0.96	0.48
Mystic Lake	8	41.6	39-44	1.92	0.68
Taylor Lake	25	39.3	34-45	3.21	0.64
Twin Lake (Lower)	11	36.8	31-40	2.86	0.86
Floe Lake	4	35.0	31-38	3.56	1.78
Sofa Creek	1	35.0	-	-	-
Connor Lakes	10	36.4	29-43	4.20	1.33

Table 7. Comparison between samples for scales below the lateral line

Sample	Sample size	Mean number of scales below the lateral line	Range	Standard deviation	Standard error of sample mean
Baker Lake	9	32.7	27-38	3.74	1.25
Block Lake (Upper)	24	33.3	28-36	2.37	0.48
Elk Lake	13	31.5	29-35	1.81	0.50
Fish Lake (First)	14	34.7	31-40	2.58	0.69
Fish Lake (Second)	12	33.6	27-37	3.09	0.89
Fish Lake (Third)	25	39.4	29-39	2.52	0.50
Marvel Lake	4	33.5	27-39	5.0	2.50
Mystic Lake	8	34.5	25-38	4.14	1.46
Taylor Lake	25	33.7	28-42	3.30	0.66
Twin Lake (Lower)	11	36.4	33-40	2.58	0.78
Floe Lake	4	33.75	31-38	3.10	1.55
Sofa Creek	1	29.0	-	-	-
Connor Lakes	10	34.5	31-38	2.72	0.86

Table 8. Comparison between samples for basibranchial teeth

Sample	Sample size	Mean number of basibranchial teeth	Range	Standard deviation	Standard error of sample mean
Baker Lake	9	6.7	0-15	4.58	1.53
Block Lake (Upper)	23	8.5	2-39	8.07	1.68
Elk Lake	14	7.9	3-16	3.25	0.87
Fish Lake (First)	13	8.8	0-19	5.43	1.51
Fish Lake (Second)	12	10.6	0-27	8.14	2.35
Fish Lake (Third)	25	3.4	0-13	3.57	0.71
Marvel Lake	4	2.0	1-3	0.82	0.41
Mystic Lake	6	3.2	0-5	2.23	0.91
Taylor Lake	25	13.7	6-27	5.47	1.10
Twin Lake (Lower)	5	7.2	1-20	7.50	2.24
Floe Lake	4	8.5	3-20	7.85	3.93
Sofa Creek	1	18.0	-	-	-
Connor Lakes	10	7.3	1-20	6.27	1.98

3.1.1 Banff National Park

Baker Lake

All specimens exhibited coloration and spotting characteristics typical of S.c. lewisi. Body coloration varied between sexes. Females were generally silvery throughout (Photo 1), while males exhibited copper brown tones which progressed to a deep rose color in ventral regions (Photo 2). Summaries of meristic characteristics of specimens from Baker Lake are presented in Tables 3-8. Meristic counts for all specimens are within the range of values reported for S.c. lewisi, as shown in Table 2. On the basis of the morphological analysis, all specimens should be classified as phenotypically pure S.c. lewisi.

Block Lake (Upper)

All specimens exhibited coloration and spotting characteristics typical S.c. lewisi (Photo 3). Body coloration varied between sexes. Females were generally silvery throughout, while males exhibited copper brown tones which progressed to a deep rose color in ventral regions (Photo 4). Means and ranges of meristic characters analysed are generally within the range of values reported for S.c. lewisi, although exceptions were noted. A distinctive meristic characteristic of some specimens was a low number of scales above the lateral line. Two specimens had less scales above the lateral line (26 and 29) than has been reported for S.c. lewisi. The sample mean for this characteristic (34.2) was the lowest recorded in the study. In addition, one individual had 39 basibranchial teeth, which is higher than reported values for the subspecies. On the basis of the morphological analysis, all specimens should be classified as phenotypically pure S.c. lewisi.

Elk Lake

All specimens exhibited coloration and spotting characteristics typical of S.c. lewisi. Body coloration was similar for both sexes. Specimens were generally silvery throughout, with light rose or golden shades in lateral and ventral regions (Photo 5). Means and ranges of meristic characters analysed are within the range of values reported for S.c. lewisi. On the basis of the morphological analysis, all specimens should be classified as phenotypically pure S.c. lewisi.

Photo 1 - Female westslope x Yellowstone cutthroat trout hybrid from Baker Lake, Banff National Park, Alberta. With 91% westslope isozymes and 9% Yellowstone isozymes, the effect of hybridization is not yet apparent morphologically, and this speciman appears visually to be pure S.c. lewisi.

Photo 2 - Male westslope x Yellowstone cutthroat trout hybrid from Baker Lake, Banff National park, Alberta. With 91% westslope isozymes and 9% Yellowstone isozymes, the effect of hybridization is not yet visually apparent, and this specimen appears morphologically to be pure S.c. lewisi.

Photo 3 - Westslope cutthroat trout from Block Lake (Upper), Banff National Park, Alberta.

Photo 4 - Male westslope cutthroat trout from Block Lake (Upper).

Fish Lake (First)

All specimens exhibited coloration and spotting characteristics typical of S.c. lewisi. Body coloration varied between sexes. Females were generally silvery throughout (Photo 6), while males exhibited copper brown and silver tones which progressed to rose hues in ventral regions (Photo 7). Meristic counts are within the range of values reported for S.c. lewisi. On the basis of the morphological analysis, all specimens should be classified as phenotypically pure S.c. lewisi.

Fish Lake (Second)

All specimens exhibited coloration and spotting characteristics typical of S.c. lewisi. Body coloration varied between sexes. Females were generally silvery throughout (Photo 8), while males exhibited copper brown and silver tones which progressed to rose hues in ventral regions. These specimens exhibited the highest mean number of pyloric caeca of all fish sampled in the study (43.75), which is higher than typical mean values reported for the subspecies. Only one individual, however, had more pyloric caeca (52) than has been reported for S.c. lewisi. Means and ranges of other meristic characters are within the typical range of values. On the basis of morphological analysis, all specimens should be classified as phenotypically pure S.c. lewisi.

Fish Lake (Third)

All specimens exhibited coloration and spotting characteristics typical of S.c. lewisi. Body coloration varied between sexes (Photo 9). Females were generally silvery throughout, while males exhibited rose hues in ventral regions. The sample mean for scales below the lateral line (39.4) was the lowest recorded of all samples studied. Meristic counts for most specimens are within the range of values reported for S.c. lewisi, although some exceptions were noted. One individual had more pyloric caeca (52) than has been reported for the subspecies and seven specimens (28% of the sample) had no basibranchial teeth. On the basis of the morphological analysis, all specimens should be classified as phenotypically pure S.c. lewisi.

Photo 5 - Westslope cutthroat trout from Elk Lake, Banff National Park, Alberta.

Photo 6 - Female westslope cutthroat trout from Fish Lake (First), Banff National Park, Alberta.

Photo 7 - Male westslope cutthroat trout from Fish Lake (First).

Photo 8 - Female westslope cutthroat trout from Fish Lake (Second), Banff National Park, Alberta.

Marvel Lake

All specimens exhibited coloration and spotting characteristics typical of S.c. lewisi (Photo 10). Body coloration varied between sexes. Females were generally silvery throughout, while males exhibited light brown tones which progressed to rose hues in ventral regions. Distinctive meristic characteristics of the fish analysed include a low number of scales in the lateral series ($\bar{x}$ = 145.0), a high number of scales above the lateral line ($\bar{x}$ = 41.75) and a low number of basibranchial teeth ($\bar{x}$ = 2.0). These mean values are the extreme for the study, but do represent sample data that are within the range of values reported for S.c. lewisi, as shown in Table 2. On the basis of the morphological analysis, all specimens should be classified as phenotypically pure S.c. lewisi.

Mystic Lake

All specimens exhibited coloration and spotting characteristics typical of S.c. lewisi (Photo 11). Body coloration was similar between sexes. All fish were generally silvery throughout, although males expressed light brown hues in dorsal and lateral regions. Meristic counts are within the range of values reported for S.c. lewisi. On the basis of the morphological analysis, all specimens should be classified as phenotypically pure S.c. lewisi.

Taylor Lake

Specimens collected from Taylor Lake were distinctly different from all other specimens collected (Photo 12). All specimens exhibited coloration and spotting characteristics typical of Yellowstone cutthroat trout (S.c. bouvieri). Body coloration varied between sexes. Females were generally silvery throughout, with light yellow hues in body and head regions. Males were generally copper brown or grey in dorsal and lateral regions. Bellies were white, with distinct yellow hues, and preopercle and opercle regions were distinctly colored in deep purple hues. This color was also evident in the pectoral, pelvic and anal fins of both sexes. Body spots were large, rounded and distinct, and were predominantly concentrated posterior to the dorsal fin. Significant spotting was noted below the lateral line. Distinctive meristic characteristics of these fish included a high number of basibranchical teeth

Photo 9 - Westslope cutthroat trout from Fish Lake (Third), Banff National Park, Alberta.

Photo 10 - Westslope cutthroat trout from Marvel Lake, Banff National Park, Alberta.

Photo 11 - Westslope cutthroat trout from Mystic Lake, Banff National Park, Alberta.

Photo 12 - Yellowstone cutthroat trout from Taylor Lake, Banff National Park, Alberta.

($\bar{x}$ = 13.7) and a high number of gill rakers ($\bar{x}$ = 19.9). Both values are higher than corresponding values of all other populations sampled in the study, and both values are typical of S.c. bouvieri. On the basis of the morphological analysis, all specimens should be classified as phenotypically pure S.c. bouvieri.

Twin Lake (Lower)

All specimens exhibited coloration and spotting characteristics typical of S.c. lewisi. Body coloration was similar for both sexes, being generally a light gold in head and dorso-lateral regions, which progressed to an orange-rose hue in ventral regions (Photo 13). Spotting was distinctive, in that most specimens had very little or no spotting anterior to the dorsal fin. Means and ranges of meristic characters analysed are within the range of values reported for S.c. lewisi. On the basis of the morphological analysis, all specimens should be classified as phenotypically pure S.c. lewisi.

Hidden Lake

Gillnetting operations here were unsuccessful, and no fish were collected. To our knowledge there have been no reports of angling success here within the last few years, and it is possible that Hidden Lake no longer supports a fish population.

3.1.2 Kootenay National Park

Floe Lake

All specimens exhibited coloration and spotting characteristics typical of S.c. lewisi. Body coloration was similar for both sexes, being generally silvery throughout, with rose hues in ventral regions (Photo 14). Distinctive meristic characteristics the sample include a high number of scales in the lateral series ($\bar{x}$ = 186.0), a low number of gill rakers ($\bar{x}$ = 16.5) and a low number of pyloric caeca ($\bar{x}$ = 30.0). These mean values are the extreme for the study, but do represent sample data that are within the range of values reported for S.c. lewisi. One exception is an extremely low gill raker count (12) for one speciman, which is lower than previously recorded values for the subspecies. On the basis of the morphological analysis, all specimens should be classified as phenotypically pure S.c. lewisi.

Photo 13 - Westslope cutthroat trout from Twin Lake (Lower), Banff National Park, Alberta.

Photo 14 - Westslope cutthroat trout from Floe Lake, Kootenay National Park, British Columbia.

3.1.3 Waterton Lakes National Park

Sofa Creek

With the exception of specimen SO-5, all specimens collected measured less than 150 mm fork length, and were not examined morphologically. A description of specimen SO-5 is provided here, and meristic data are shown in tables 3-8. Body coloration was generally silvery in dorsal and anterior regions, which progressed to orange below the lateral line and on the preopercle and opercle. This fish appeared to be a hybrid, exhibiting spotting characteristics typical of S.c. lewisi and S.c. bouvieri (Photo 15). However, typical of S.c. lewisi, few spots were present below the lateral line, particularly in the anterior region of the body.

3.1.4 Connor Lakes

All specimens exhibited coloration and spotting characteristics typical of S.c. lewisi. Body coloration varied between sexes. Females and males were both generally silvery throughout. Males, however, expressed a heavy grey or black coloration in dorsal regions, which progressed to silver and rose in lateral and ventral regions, respectively. Means and ranges of meristic characters examined are within the range of values reported for S.c. lewisi. On the basis of the morphological analysis, all specimens should be classified as phenotypically pure S.c. lewisi.

3.2 Biochemical Analysis

Eight diagnostic loci differentiating S.c. lewisi, S.c. bouvieri and S. gairdneri were examined from muscle, liver and eye tissue samples (Table 9). Selected diagnostic loci are illustrated in Photos 16 - 19. Based on these loci, no evidence of introgression from S. gairdneri was found in any of the samples. However, specimens from Baker Lake, Taylor Lake and Sofa Creek contained isozymes characteristic of S.c. bouvieri (Tables 10-16). Taylor Lake was found to contain pure S.c. bouvieri, while Baker Lake and Sofa Creek contain S.c. lewisi x S.c. bouvieri hybrids. Specimens from the remaining study waters, including Block

Photo 15 - Westslope x Yellowstone cutthroat trout hybrid from Sofa Creek, Waterton Lakes National Park, Alberta. With 80% westslope isozymes and 20% Yellowstone isozymes, the effect of hybridization can now be detected morphologically. The Yellowstone influence in this speciman is manifested in fewer spots that are larger and more rounded than is typical of the westslope subspecies.

Lake (Upper), Elk Lake, the Fish Lakes (3), Marvel Lake, Mystic Lake, Twin Lake (Lower), Floe Lake and the Connor Lakes were found to be genotypically pure S.c. lewisi. Four loci were variable in samples of pure S.c. lewisi (Tables 17-20; Photos 17, 20-22). Results of the biochemical analysis are summarized in Table 21.

Table 9. Diagnostic loci differentiating westslope cutthroat trout, Yellowstone cutthroat trout and rainbow trout.

Loci	Allelic Mobility* Rainbow	Westslope	Yellowstone
Ck-2	100	84	84
Idh-1	100	100	-75
Idh-3,4	100,40 71,114	100,80 40	100,71
Me-1	100,80	88	100
Me-3	100	100	85
Me-4	100	100	110
Pgi-3	100	88	100
Sdh-2	100	44	100

* Numbers represent proportional electrophoretic mobility of alleles commonly found in that group relative to the standard common allele of rainbow trout.

SOURCE: F.W. Allendorf, unpublished data.

Table 10. Genetic variation at the Idh-1 locus showing alleles characteristic of Yellowstone cutthroat trout.

Sample	Phenotypes: observed (expected) 100	100/-75	-75	Freq (100)	F
Baker Lake	8 (8.0)	1 (1.0)	0 (0.0)	0.944	0.000
Taylor Lake	0	0	25	0.000	-
Sofa Creek	6 (6.0)	1 (1.0)	0 (0.0)	0.929	0.000

Table 11. Genetic variation at the Idh-3 locus showing alleles characteristic of Yellowstone cutthroat trout.

Sample	Phenotypes: observed (expected) 86	86/71	71	Freq (86)	F
Baker Lake	8 (7.1)	0 (1.8)	1 (0.1)	0.889	1.000
Taylor Lake	0	0	25	0.000	-
Sofa Creek	4 (4.0)	1 (1.0)	0 (0.0)	0.900	0.000

Table 12. Genetic variation at the Me-1 locus showing alleles characteristic of Yellowstone cutthroat trout.

Sample	Phenotypes: observed (expected)			Freq (88)	F
	88	88/100	100		
Baker Lake	8 (8.0)	0 (1.0)	1 (0.0)	0.944	0.000
Taylor Lake	0	0	25	0.000	-
Sofa Creek	7	0	0	1.000	-

Table 13. Genetic variation at the Me-3 locus showing alleles characteristic of Yellowstone cutthroat trout.

Sample	Phenotypes: observed (expected) 100	100/85	85	Freq (100)	F
Baker Lake	8 (8.0)	1 (1.0)	0 (0.0)	0.944	0.000
Taylor Lake	0	0	25	0.000	-
Sofa Creek	6 (5.1)	0 (1.8)	1 (0.1)	1.857	1.000

Table 14. Genetic variation at the Me-4 locus showing alleles characteristic of Yellowstone cutthroat trout.

Sample	Phenotypes: observed (expected) 100	100/110	110	Freq (100)	F
Baker Lake	7 (7.1)	2 (1.8)	0 (0.1)	0.889	-0.063
Taylor Lake	0	0	25	0.000	-
Sofa Creek	2 (2.8)	5 (3.5)	0 (0.8)	0.643	-0.444

Table 15. Genetic variation at the Pgi-3 locus showing alleles characteristic of Yellowstone cutthroat trout.

Sample	Phenotypes: observed (expected) 88	88/100	100	Freq (88)	F
Baker Lake	7 (7.1)	2 (1.8)	0 (0.1)	0.889	-0.063
Taylor Lake	0	0	25	0.000	-
Sofa Creek	2 (1.2)	2 (3.7)	3 (2.1)	0.429	0.458

Table 16. Genetic variation at the Sdh locus showing alleles characteristic of Yellowstone cutthroat trout.

Sample	Phenotypes: observed (expected) 40	40/100	100	Freq (40)	F
Baker Lake	6 (6.1)	2 (1.9)	0 (0.1)	0.875	-0.071
Taylor Lake	0	0	25	0.000	-
Sofa Creek	5 (5.1)	2 (1.8)	0 (0.1)	0.857	-0.083

Table 17. Intraspecific genetic variation at the Ck-1 locus in westslope cutthroat trout.

Sample	Phenotypes: observed (expected) 100	100/115	115	Freq (100)	F
Block Lake (Upper)	25	0	0	1.000	-
Elk Lake	1 (1.2)	11 (10.6)	23 (23.2)	0.186	-0.024
Fish Lake-1	14	0	0	1.000	-
Fish Lake-2	28	0	0	1.000	-
Fish Lake-3	25	0	0	1.000	-
Marvel Lake	25	0	0	1.000	-
Mystic Lake	25	0	0	1.000	-
Twin Lake (Lower)	14	0	0	1.000	-
Floe Lake	4	0	0	1.000	-
Connor Lakes	10	0	0	1.000	-

Table 18. Intraspecific genetic variation at the Ldh-3 locus in westslope cutthroat trout.

Sample	Phenotypes: observed (expected) 100	100/33	33	Freq (100)	F
Block Lake (Upper)	9	0	0	1.000	-
Elk Lake	35	0	0	1.000	-
Fish Lake-1	14	0	0	1.000	-
Fish Lake-2	28	0	0	1.000	-
Fish Lake-3	12 (13.6)	13 (9.8)	0 (1.6)	0.735	-0.334
Marvel Lake	25	0	0	1.000	-
Mystic Lake	25	0	0	1.000	-
Twin Lake (Lower)	14	0	0	1.000	-
Floe Lake	4	0	0	1.000	-
Connor Lakes	10	0	0	1.000	-

Table 19. Intraspecific allelic variation at the Ldh-4 locus in westslope cutthroat trout.

Sample	Phenotypes: observed (expected) 100	100/35	35	Freq (100)	F
Block Lake (Upper)	24 (24.0)	1 (1.0)	0 (0.0)	0.980	0.000
Elk Lake	35	0	0	1.000	-
Fish Lake-1	14	0	0	1.000	-
Fish Lake-2	28	0	0	1.000	-
Fish Lake-3	25	0	0	1.000	-
Marvel Lake	25	0	0	1.000	-
Mystic Lake	25	0	0	1.000	-
Twin Lake (Lower)	14	0	0	1.000	-
Floe Lake	4	0	0	1.000	-
Connor Lakes	10	0	0	1.000	-

Table 20. Intraspecific allelic variation at the Pgm-2 locus in westslope cutthroat trout.

Sample	Phenotypes: observed (expected) 100	100/85	85	Freq (100)	F
Block Lake (Upper)	11 (8.9)	8 (12.2)	6 (3.9)	0.600	0.347
Elk Lake	35	0	0	1.000	-
Fish Lake-1	14	0	0	1.000	-
Fish Lake-2	28	0	0	1.000	-
Fish Lake-3	25	0	0	1.000	-
Marvel Lake	25	0	0	1.000	-
Mystic Lake	25	0	0	1.000	-
Twin Lake (Lower)	14	0	0	1.000	-
Floe Lake	1 (1.4)	3 (2.1)	0 (0.4)	0.625	-0.400
Connor Lakes	4 (3.5)	4 (5.0)	2 (1.5)	0.600	0.208

Table 21. Summary of the source of samples in the study area.

Sample	N	Source of isozymes
Baker Lake	9	Westslope (91%) and Yellowstone (9%)
Block Lake (Upper)	25	Westslope
Elk Lake	35	Westslope
Fish Lake-1	14	Westslope
Fish Lake-2	28	Westslope
Fish Lake-3	25	Westslope
Marvel Lake	25	Westslope
Mystic Lake	25	Westslope
Taylor Lake	25	Yellowstone
Twin Lake (Lower)	14	Westslope
Sofa Creek	7	Westslope (80%) and Yellowstone (20%)
Floe Lake	4	Westslope
Connor Lakes	10	Westslope

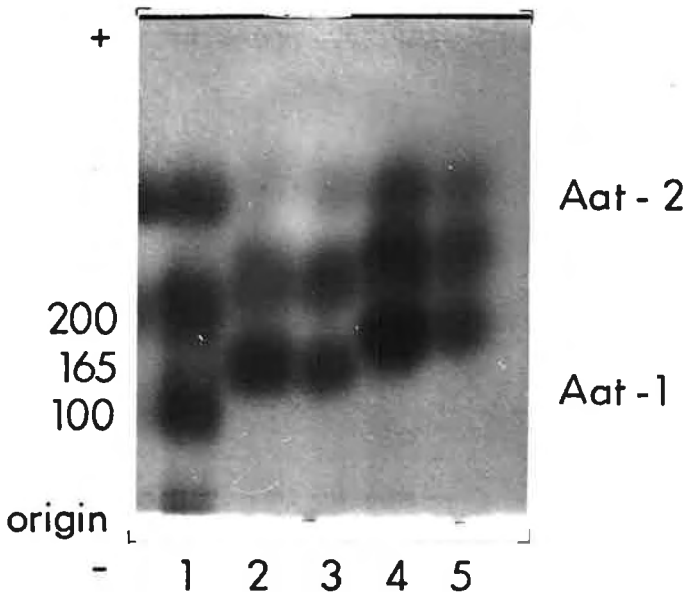

Photo 16 - Interspecific differences at the diagnostic Aat-1 locus. Each taxon has different electrophoretic alleles at this locus:

a. Rainbow trout, Aat-1(100)-sample 1.
b. Yellowstone cutthroat trout, Aat-1(165)-samples 2 and 3.
c. Westslope cutthroat trout, Aat-1(200)-samples 4 and 5.

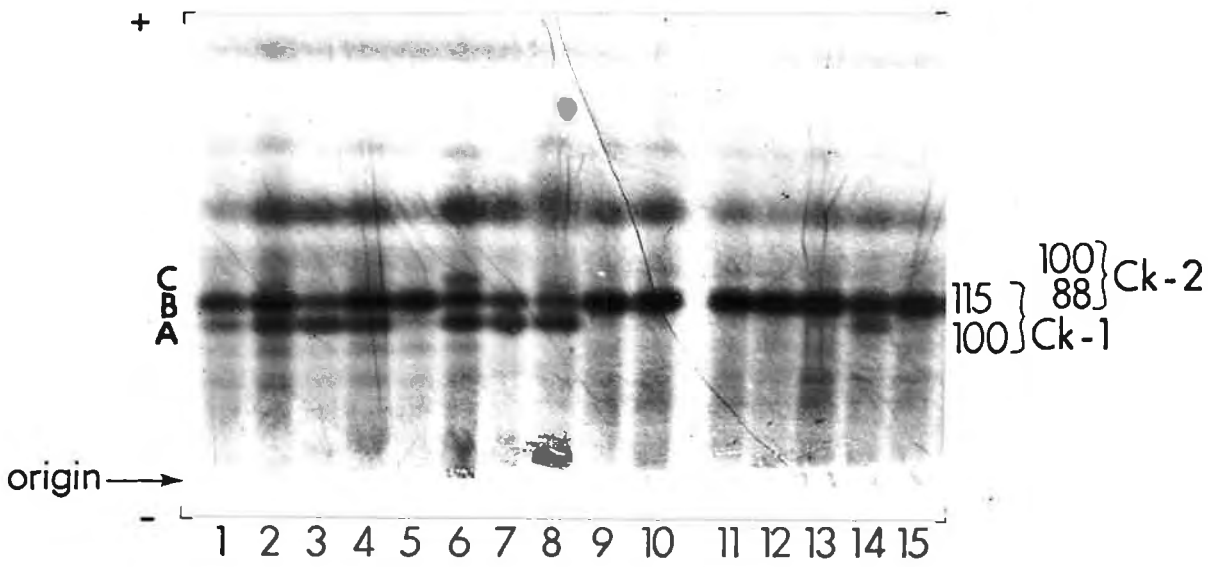

Photo 17 - Phenotypic variation at muscle loci Ck-1 and Ck-2. Samples 6,7 and 8 show interspecific variation at Ck-2 that distinguishes rainbow trout. Both westslope (sample 7) and Yellowstone (sample 8) cutthroat trout have only two Ck isozymes (A and B), while the rainbow trout (sample 6) has three isozymes (A, B, and C). Samples 1-5 and 9-15 show fish from Elk Lake with an allelic variant at the Ck-1 locus having the following genotypes:

a. Ck-1(100/100)-sample 3.
b. Ck-1(100/115)-samples 1, 2, 4 and 14.
c. Ck-1(115/115)-samples 5, 9-13 and 15.

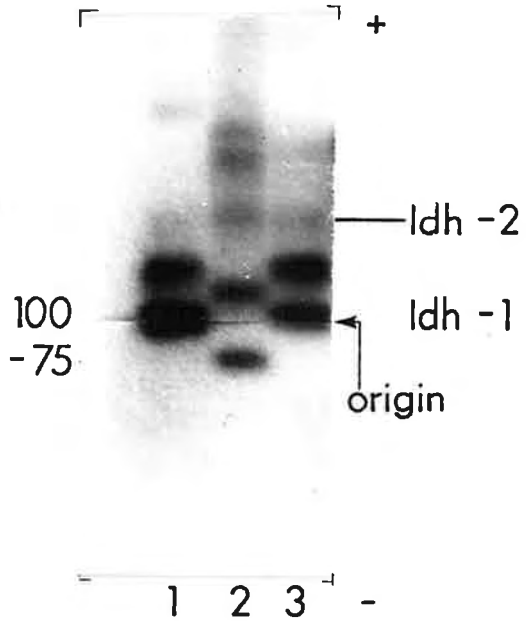

Photo 18 - Interspecific differences at the diagnostic Idh-1 locus that distinguish Yellowstone cutthroat trout:
a. Rainbow trout, Idh-1(100)-sample 1.
b. Yellowstone cutthroat trout, Idh-1(-75)-sample 2.
c. Westslope cutthroat trout, Idh-1(100)-sample 3.

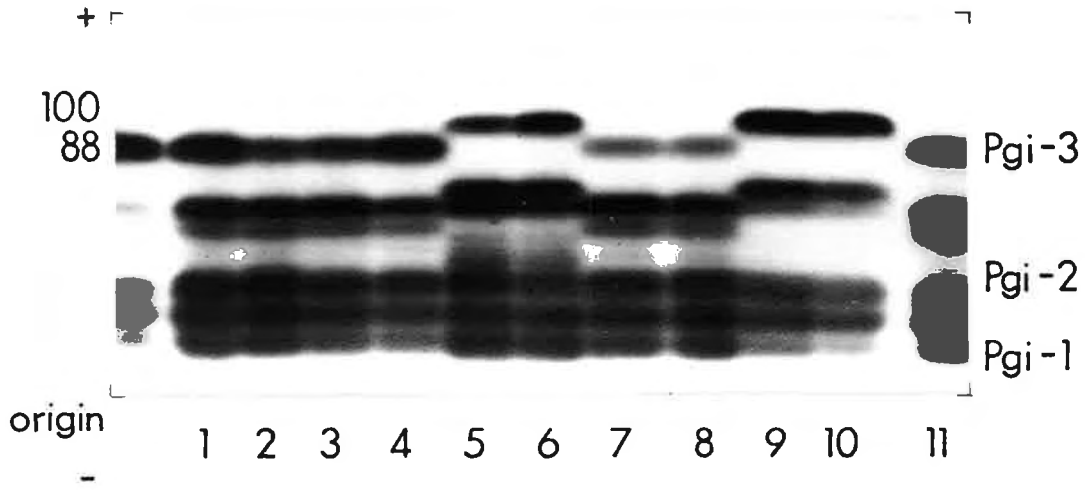

Photo 19 - Interspecific differences at the diagnostic Pgi-3 locus that distinguish westslope cutthroat trout:
a. Rainbow trout, Pgi-3(100)-samples 5 and 6.
b. Yellowstone cutthroat trout, Pgi-3(100)-samples 9 and 10.
c. Westslope cutthroat trout, Pgi-3(88)-samples 1-4, 7, 8 and 11.

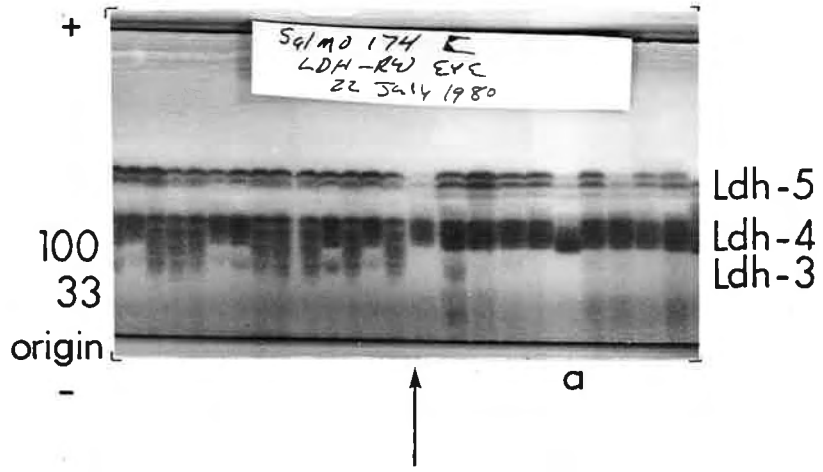

Photo 20 - Intraspecific genetic variation in west-slope cutthroat trout at the Ldh-3 locus. The 14 samples left of the arrow are from the third Fish Lake; those gel profiles right of the arrow show the isozyme pattern at this locus seen in samples from the other Fish Lakes (First and Second). The sample denoted by the letter a is a rainbow trout having a variant allele at the Ldh-4 locus.

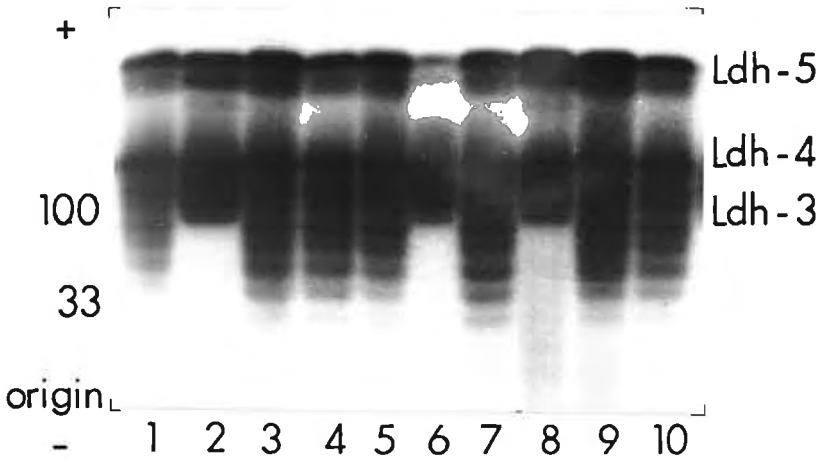

Photo 21 - Enlargement of the Ldh-3 variation in the third Fish Lake. Some individuals and their genotypes are as follows:

a. Ldh-3(100/100)-samples 2, 6 and 8.
b. Ldh-3(100/33)-samples 1, 3-5, 7, 9 and 10.

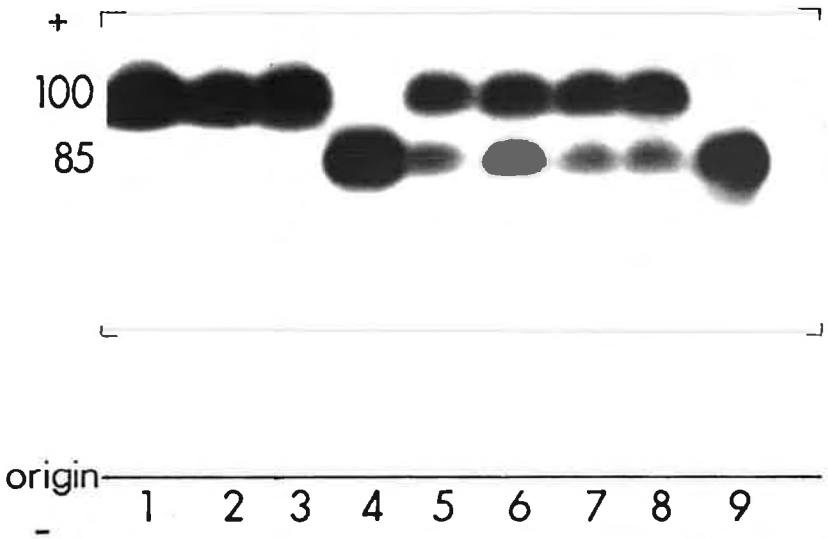

Photo 22 - Intraspecific variation at the Pgm-2 locus in westslope cutthroat trout from Block (Upper), Flow and the Connor Lakes. The three genotypes found are illustrated as follows:
a. Pgm-2(100/100)-samples 1, 2 and 3.
b. Pgm-2(100/85)-samples 5, 6, 7 and 8.
c. Pgm-2(85/85)-samples 4 and 9.

4.0 DISCUSSION

Of the 13 samples analysed, 10 were found to be pure S.c. lewisi. The populations from two sites - Baker Lake and Sofa Creek - are apparently random mating S.c. lewisi x S.c. bouvieri hybrid swarms. The relative contribution of each taxon was estimated using the eight diagnostic loci listed in Table 9. It was found that 91% of the alleles at these loci were characteristic of S.c. lewisi in the Baker Lake sample, while 80% of the alleles in the Sofa Creek sample were of S.c. lewisi origin. Both populations are predominantly derived from S.c. lewisi stocks that were influenced by hybridization with S.c. bouvieri several generations ago, as no F1 specimens were found. Only Taylor Lake contains pure S.c. bouvieri.

The allelic variation found in the pure S.c. lewisi populations is especially significant. Five samples, including those from Fish Lake (First), Fish Lake (Second), Marvel Lake, Mystic Lake and Twin Lake (Lower) were totally monomorphic at all 32 loci (Table 1), indicating that these are small and extremely isolated populations. Those samples showing polymorphism support this conclusion, as variation at each of three of the polymorphic loci - Ck-1, Ldh-3 and Ldh-4 - was restricted to a single sample - Elk Lake, Fish Lake (Third) and Block Lake (Upper), respectively (Tables 17-19). The restricted distribution of these variant alleles combined with their high frequencies in some samples indicates that there is extremely little genetic exchange between these populations. Considering the close proximity of each of the three Fish Lakes, the genetic distinctiveness found between the lakes is especially interesting. The large allelic frequency differences between samples also indicates that these populations are probably native and have not been introduced from a common source. Possible exceptions are Block (Upper), Floe and the Connor Lakes. Samples from these lakes share a Pgm-2 polymorphism at almost identical frequencies (Table 20). This could be due to chance alone, or the result of a common source for all three populations. As was mentioned previously, there was no evidence of introgression from rainbow trout or other species in any of the samples.

In all but one sample, the morphological analysis and the biochemical analysis concurred. In the case of the Baker Lake sample, external morphological criteria were not adequate to detect the hybridization that was apparent in the electrophoretic analysis, and specimens appeared morphologically to be pure S.c. lewisi. In the Sofa Creek sample, which was hybridized to a greater degree, hybridization was detected in both the morphological and biochemical analyses.

The external morphological characteristics analysed did not allow determination of the extent of hybridization in the cutthroat trout samples from Baker Lake and Sofa Creek. The results also indicate that morphological criteria alone are not adequate to detect or quantify relatively small amounts of introgression from other species in populations of westslope cutthroat trout (Example: Baker Lake). The electrophoretic data, however, enabled us to accurately quantify the purity of each sample and to genetically characterize each sample on the basis of gene loci information.

5.0 MANAGEMENT IMPLICATIONS AND RECOMMENDATIONS

The following observations and recommendations for the management of native cutthroat trout stocks in the national parks are based on the data collected and a review of pertinent literature.

1. Genetic diversity accumulated over time has resulted in diverse and uniquely adapted local populations of native westslope cutthroat trout, particularly in Banff National Park. The preservation of the genetic diversity that is inherent in these local native populations should be the highest priority of management plans.

2. Potential sources of native cutthroat trout for stocking purposes include Block Lake (Upper) and Marvel Lake. Large numbers of spawning individuals were observed in these lake outlets during the 1980 spawning run. None of the other lakes studied appear to contain populations that would support a sustained egg collection operation. Should such operations commence at one of these lakes, it is important that the donor population be monitored to avoid a possible depletion of the stock.

3. Areas within the national parks that do not contain native fish (Example: Taylor Lake) provide an opportunity to improve angling through the mechanism of intraspecific diversity. Trojnar and Behnke (1974) found that two subspecies of cutthroat trout, when introduced in a lake, avoided direct competition by partitioning the food supply. The result was a more efficient use of the food resources of the lake and a greater production of fish biomass. Preliminary observations in lakes stocked with S.c. lewisi and S.c. bouvieri indicate that when stocked together, these subspecies will produce more fish biomass than either subspecies could produce alone, and provide a more consistent mountain fishery (Behnke, 1979). In lakes such as Taylor lake that contain non-native or hybrid populations, this management alternative should be considered.

4. Cutthroat trout, more than other trouts, are highly vulnerable to over-exploitation by angling. MacPhee (1966) reported that in an Idaho stream, 50% of all catchable-sized cutthroat trout were taken by only 32 man-hours of angling effort. This vulnerability should result in special regulations regarding bag limits, fish size, gear restrictions, etc. in areas of heavy angling pressure. Special regulations have been used with considerable success in the Yellowstone River and streams in northern Idaho, and have maximized catch per unit effort of more and larger native fish. As a rule-of-thumb, if angling pressure exceeds 50 hours/acre/year on a body of water inhabited by native westslope cutthroat trout, the population likely suffers from over-exploitation, and would benefit from protective regulations (Behnke, 1979). Angler usage of pertinent lakes in the parks should be documented, and appropriate protective regulations should be instituted where necessary. With proper planning and appropriate regulations, a high quality fishery for native cutthroat trout can be sustained indefinitely.

5. Biochemical-genetic data appear to be more useful than morphological data in determining the purity of a potential brood stock. Our data indicate that the electrophoretic phenotype is a direct reflection of the genotype, so that even individual specimens can be unambiguously classified as being pure or hybrid. Morphological traits are controlled by many gene loci and are influenced to an unknown extent by environmental components. As a result, much larger sample sizes are necessary in order to utilize this means of classification.

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APPENDICES

APPENDIX A

Waters selected for analysis of cutthroat trout populations

Appendix A. Waters selected for analysis of cutthroat trout populations

Banff National Park	Location	Elevation in Meters
Baker Lake	51°29'N 116°02'W W5M	2200
Block Lake (Upper)	51°22'N 115°50'W W5M	2230
Elk Lake	51°17'N 115°39'W W5M	2110
Fish Lake (First)	51°38'N 115°10'W W5M	2170
Fish Lake (Second)	51°39'N 115°11'W W5M	2200
Fish Lake (Third)	51°39'N 115°12'W W5M	2200
Hidden Lake	51°28'N 116°06'W W5M	2260
Marvel Lake	50°52'N 115°33'W W5M	1770
Mystic Lake	51°16'N 115°44'W W5M	1990
Taylor Lake	51°17'N 116°05'W W5M	2050
Twin Lake (Lower)	51°12'N 115°58'W W5M	2050
Kootenay National Park		
Floe Lake	51°03'N 116°08'W W5M	2080
Waterton Lakes National Park		
Sofa Creek	41°05'N 113°50'W W4M	2040 - 1280
British Columbia		
Connor Lakes	50°18'N 115°05'W W5M	1800

APPENDIX B

Glossary

Appendix B. Glossary

allele	- one possible form of a gene.
anal fin	- the fin on the ventral median line of the body behind the anus.
basibranchial	- the three median bones on the floor of the gill chamber behind the tongue.
biochemistry	- the study of the chemistry of living things.
buffer	- a solution whose acidity is practically unchanged by dilution.
caudal fin	- the tail fin.
diagnostic locus	- a locus at which two taxonomic groups are genetically distinct, i.e., they do not have any alleles in common.
electrophoresis	- the separation of proteins in an electric field.
enzyme	- a protein that catalyses a specific biochemical reaction.
gene	- the hereditary unit that occupies a fixed chromosomal locus, which through transcription has a specific effect upon the phenotype and can mutate to various allelic forms.
genotype	- the genetic constitution of an organism as distinguished from its physical appearance.
gill rakers	- a series of bony projections or spine-like structures along the anterior edge of the gill arch, located under the opercular flap.
hybrid	- an individual possessing genes originating in more than one species.
hypural complex	- the expanded haemal spines of the posterior vertebrae which support the caudal fin rays.
interspecific	- between different species.
intraspecific	- within a single species.
introgression	- the movement of genes from the gene poole of one species into another.
isozyme	- different genetic form of a single enzyme.
lateral line	- a series of pores (to the sensory canal) along the sides of a fish.

locus	- the positin that a gene occupies in a chromosome.
meristic	- any body part occurring in serial repitition; for example scales and fin rays.
monomorphic	- non-variable.
morphology	- the study of form and structure of animals and plants.
opercle	- the large, flat, thin bones on each side of the head that comprise the gill cover.
pectoral fin	- the paired fin attached to the pectoral girdle.
pectoral girdle	- pectoral arch or shoulder girdle; the complex of bones usually connected with the skull, to which the pectoral fins are attached.
pelvic fin	- ventral, paired fin attached to the pelvic girdle, lying below the pectoral fin.
phenotype	- the observable properties of an organism, produced by the genotype in conjunction with the environment.
polymorphic	- variable.
preopercle	- the bone of the cheek, the most anterior of the opercular series.
protein	- a polypeptide composed of many amino acids.
pyloric caeca	- finger-like processes attached to the pylorus, where the intestine leaves the stomach.
scale	- small flattened rigid dermal or epidermal plate forming an external body covering in fishes.
species	- a group of organisms sharing a common gene pool.
starch gel	- a semi-solid, jelly-like suspension made from potato starch and an appropriate buffer.
subspecies	- a race; a group of organisms within a species that are relatively genetically similar to each other and are distinct from all other members of the species.

APPENDIX C

Meristic data for cutthroat trout from Banff, Kootenay and Waterton Lakes National Parks

Table C-1. Meristic data for 9 cutthroat trout from Baker Lake, Alberta

Character / Specimen No.	Fork length (mm)	Scales: Lateral series	Scales: Above lateral line	Scales: Below lateral line	Pyloric caeca	Gill rakers: Upper limb	Gill rakers: Lower limb	Basibranchial teeth
BA-1	189	159	35	27	40	6	11	5
BA-2	342	144	37	31	43	8	11	6
BA-3	378	170	40	32	42	8	12	9
BA-4	397	164	37	29	31	8	11	8
BA-5	503	178	44	30	40	10	13	15
BA-6	483	189	46	38	39	6	11	0
BA-7	448	175	35	35	37	7	11	1
BA-8	475	168	43	36	40	7	11	6
BA-9	475	189	42	36	45	8	11	10

Table C-2. Meristic data for 24 cutthroat trout from Block Lake (Upper), Alberta

Character / Specimen No.	Fork length (mm)	Scales: Lateral series	Scales: Above lateral line	Scales: Below lateral line	Pyloric caeca	Gill rakers: Upper limb	Gill rakers: Lower limb	Basibranchial teeth
BL-1	363	160	36	36	40	7	12	39
BL-2	280	180	35	35	33	7	11	3
BL-3	280	170	32	33	38	7	12	4
BL-4	304	156	26	29	33	6	11	8
BL-5	286	170	35	34	41	8	12	22
BL-6	325	181	37	32	39	7	12	8
BL-7	255	168	34	34	38	8	12	5
BL-8	290	187	37	35	35	7	11	5
BL-9	356	176	38	31	33	7	12	16
BL-10	298	177	33	35	37	7	11	10
BL-11	292	171	31	33	42	8	10	3
BL-12	330	155	38	36	38	6	11	6
BL-13	261	184	37	35	47	6	10	3
BL-14	228	167	35	36	34	7	11	5
BL-15	331	-	-	34	34	7	12	10
BL-16	298	164	29	28	31	6	10	8
BL-17	243	179	34	31	35	8	12	2
BL-18	320	170	34	31	35	8	11	2
BL-19	293	150	35	34	37	7	11	9
BL-20	301	180	31	31	38	8	11	8
BL-21	249	183	33	32	41	8	13	5
BL-22	245	179	34	34	37	8	11	9
BL-23	203	158	37	33	46	7	11	-
BL-24	210	168	36	38	33	7	12	6

Table C-3. Meristic data for 14 cutthroat trout from Elk Lake, Alberta

Character / Specimen No.	Fork length (mm)	Scales			Pyloric caeca	Gill rakers		Basibranchial teeth
		Lateral series	Above lateral line	Below lateral line		Upper limb	Lower limb	
EL-1	201	154	39	-	38	6	11	9
EL-2	265	170	36	31	32	7	9	10
EL-3	227	163	38	33	38	7	12	16
EL-4	257	172	42	32	44	7	11	10
EL-5	268	178	39	29	41	8	12	10
EL-6	207	155	40	32	42	7	12	9
EL-7	178	157	37	29	27	8	13	8
EL-8	180	151	37	31	37	8	12	7
EL-9	190	166	44	33	31	7	12	5
EL-10	185	149	40	35	42	8	12	4
EL-11	175	169	38	33	32	7	13	8
EL-12	161	160	40	31	32	7	12	3
EL-13	160	159	40	32	32	7	12	6
EL-14	166	156	39	29	32	7	11	6

Table C-4. Meristic data for 14 cutthroat trout from Fish Lake (First), Alberta

Character / Specimen No.	Fork length (mm)	Scales: Lateral series	Scales: Above lateral line	Scales: Below lateral line	Pyloric caeca	Gill rakers: Upper limb	Gill rakers: Lower limb	Basibranchial teeth
FI #1-1	327	153	41	35	39	7	13	5
FI #1-2	344	173	43	37	45	-	-	-
FI #1-3	337	184	46	40	45	7	12	13
FI #1-4	342	156	39	33	40	6	10	10
FI #1-5	375	167	41	32	38	7	13	7
FI #1-6	383	164	32	31	51	7	12	19
FI #1-7	341	158	38	33	41	7	11	5
FI #1-8	341	154	40	38	40	6	11	5
FI #1-9	329	185	40	37	42	7	12	17
FI #1-10	300	163	38	32	39	6	12	13
FI #1-11	300	163	40	36	44	7	12	5
FI #1-12	295	167	43	34	48	7	13	9
FI #1-13	303	178	36	34	32	8	13	6
FI #1-14	305	176	36	34	40	7	12	0

Table C-5. Meristic data for 12 cutthroat trout from Fish Lake (Second), Alberta

Character / Specimen No.	Fork length (mm)	Scales: Lateral series	Scales: Above lateral line	Scales: Below lateral line	Pyloric caeca	Gill rakers: Upper limb	Gill rakers: Lower limb	Basibranchial teeth
FI #2-1	392	149	37	29	40	7	11	0
FI #2-2	337	169	38	33	42	7	12	11
FI #2-3	333	150	46	31	41	8	11	7
FI #2-4	297	163	41	36	42	7	12	4
FI #2-5	330	147	41	37	38	7	11	7
FI #2-6	302	175	44	34	46	8	13	13
FI #2-7	295	172	44	35	50	7	11	0
FI #2-8	342	158	41	35	48	7	11	16
FI #2-9	320	180	44	36	46	8	11	18
FI #2-10	249	169	39	36	42	7	12	18
FI #2-11	250	161	40	34	52	8	12	27
FI #2-12	150	148	36	27	38	7	12	6

Table C-6. Meristic data for 25 cutthroat trout from Fish Lake (Third), Alberta

Character / Specimen No.	Fork length (mm)	Scales			Pyloric caeca	Gill rakers		Basibranchial teeth
		Lateral series	Above lateral line	Below lateral line		Upper limb	Lower limb	
FI #3-1	284	186	35	36	45	7	11	3
FI #3-2	225	162	36	34	37	8	12	13
FI #3-3	203	187	40	34	40	7	10	0
FI #3-4	187	159	43	34	52	6	11	0
FI #3-5	182	147	42	37	40	6	12	4
FI #3-6	193	160	37	35	36	6	11	5
FI #3-7	197	154	38	29	42	7	11	6
FI #3-8	191	161	40	34	37	7	9	0
FI #3-9	192	161	37	34	38	8	12	3
FI #3-10	176	160	38	36	44	7	11	1
FI #3-11	195	173	34	32	41	7	11	12
FI #3-12	172	156	37	38	39	7	11	0
FI #3-13	192	150	38	34	45	7	11	3
FI #3-14	196	156	38	35	35	7	11	3
FI #3-15	174	175	42	38	47	7	12	1
FI #3-16	194	162	36	35	39	7	12	4
FI #3-17	169	157	34	30	47	6	11	0
FI #3-18	155	150	38	39	39	7	11	4
FI #3-19	171	164	39	37	37	6	11	0
FI #3-20	195	161	37	36	41	6	10	4
FI #3-21	149	158	35	38	37	7	11	4
FI #3-22	157	163	40	35	47	8	11	9
FI #3-23	132	146	37	33	41	7	11	5
FI #3-24	165	163	32	32	36	8	11	0
FI #3-25	167	160	40	38	37	8	11	2

Table C-7. Meristic data for 4 cutthroat trout from Marvel Lake, Alberta

Character / Specimen No.	Fork length (mm)	Scales: Lateral series	Scales: Above lateral line	Scales: Below lateral line	Pyloric caeca	Gill rakers: Upper limb	Gill rakers: Lower limb	Basibranchial teeth
MA-1	487	152	41	33	46	8	11	1
MA-3	405	132	43	35	39	7	12	3
MA-5	384	143	42	27	43	8	12	2
MA-6	561	153	41	39	37	7	13	2

Table C-8. Meristic data for 8 cutthroat trout from Mystic Lake, Alberta

Character / Specimen No.	Fork length (mm)	Scales: Lateral series	Scales: Above lateral line	Scales: Below lateral line	Pyloric caeca	Gill rakers: Upper limb	Gill rakers: Lower limb	Basibranchial teeth
MY-1	330	188	42	25	42	7	11	0
MY-2	305	160	41	36	37	7	11	1
MY-3	335	203	39	38	38	7	12	5
MY-4	280	205	44	35	37	7	11	5
MY-5	260	176	44	34	42	7	11	3
MY-6	195	183	42	38	39	7	11	-
MY-7	90	177	42	34	36	7	11	5
MY-8	156	152	39	36	38	6	10	-

Table C-9. Meristic data for 25 cutthroat trout from Taylor Lake, Alberta

Character / Specimen No.	Fork length (mm)	Scales			Pyloric caeca	Gill rakers		Basibranchial teeth
		Lateral series	Above lateral line	Below lateral line		Upper limb	Lower limb	
TA-1	331	180	36	36	33	8	12	19
TA-2	321	167	39	34	42	7	12	7
TA-3	315	169	39	42	45	9	13	12
TA-4	319	169	40	29	45	7	13	8
TA-5	311	157	44	37	43	9	13	17
TA-6	302	168	39	35	34	8	12	17
TA-7	327	163	34	36	36	-	-	10
TA-8	302	141	35	34	35	8	12	15
TA-9	270	178	39	37	47	8	13	27
TA-10	271	173	38	37	39	8	11	14
TA-11	248	165	39	31	40	8	14	24
TA-12	267	154	40	37	39	7	13	13
TA-13	260	150	37	34	41	7	12	11
TA-14	234	170	40	28	40	8	13	13
TA-15	200	150	39	31	45	8	13	15
TA-16	200	164	41	29	32	9	14	20
TA-17	195	163	34	31	40	8	14	9
TA-18	362	182	41	34	34	8	13	16
TA-19	377	184	35	31	32	8	13	20
TA-20	343	172	44	37	41	8	14	6
TA-21	326	178	39	32	38	8	13	7
TA-22	310	170	37	31	33	7	13	9
TA-23	267	183	45	33	40	7	13	14
TA-24	257	171	43	35	34	7	13	13
TA-25	248	154	45	31	31	8	13	7

Table C-10. Meristic data for 11 cutthroat trout from Twin Lake (Lower), Alberta

Character / Specimen No.	Fork length (mm)	Scales: Lateral series	Scales: Above lateral line	Scales: Below lateral line	Pyloric caeca	Gill rakers: Upper limb	Gill rakers: Lower limb	Basibranchial teeth
TW-1	236	178	40	35	-	-	-	-
TW-2	186	158	40	40	-	-	-	-
TW-3	202	173	38	37	-	-	-	-
TW-4	249	168	35	33	-	-	-	-
TW-5	227	181	31	40	-	-	-	-
TW-6	236	171	39	37	-	-	-	-
TW-7	214	170	34	37	-	7	11	1
TW-8	197	196	38	34	-	7	11	20
TW-9	201	174	36	35	-	6	11	3
TW-10	185	179	35	33	-	8	10	7
TW-11	190	160	39	39	-	7	10	5

Table C-11. Meristic data for 4 cutthroat trout from Floe Lake, British Columbia

Character / Specimen No.	Fork length (mm)	Scales			Pyloric caeca	Gill rakers		Basibranchial teeth
		Lateral series	Above lateral line	Below lateral line		Upper limb	Lower limb	
FL-1	322	172	31	31	23	7	11	20
FL-2	336	181	33	32	34	6	12	4
FL-3	376	200	38	38	29	6	6	7
FL-4	372	191	38	34	34	7	11	3

Table C-12. Meristic data for 1 cutthroat trout from Sofa Creek, Alberta

Character / Specimen No.	Fork length (mm)	Scales: Lateral series	Scales: Above lateral line	Scales: Below lateral line	Pyloric caeca	Gill rakers: Upper limb	Gill rakers: Lower limb	Basibranchial teeth
SO-5	175	141	35	29	34	7	11	18

Table C-13. Meristic data for 10 cutthroat trout from the Connor Lakes, British Columbia

Character / Specimen No.	Fork length (mm)	Scales			Pyloric caeca	Gill rakers		Basibranchial teeth
		Lateral series	Above lateral line	Below lateral line		Upper limb	Lower limb	
CO-1	255	167	43	36	24	7	12	1
CO-2	291	170	41	36	37	7	11	4
CO-3	302	175	29	34	34	8	13	20
CO-4	262	186	36	37	33	7	12	9
CO-5	296	166	36	37	25	7	12	4
CO-6	309	178	35	31	41	8	12	1
CO-7	285	175	31	31	36	6	12	1
CO-8	271	171	37	34	38	7	12	13
CO-9	203	165	37	38	33	8	11	11
CO-10	236	157	39	31	33	7	12	9

APPENDIX D

Analysis of the biochemical data

APPENDIX D. Analysis of the biochemical data

Electrophoretic data are collected in the form of phenotypes on a starch gel that directly reflect genetic differences between individual fish. The presence of genetically different forms (i.e. alleles) of the enzyme can be detected directly by differences in mobility of the isozymes on the gel. For example, the diagram below shows phenotypic variation detected at the Pgm-2 locus (see Photo 22 and Table 20):

Specimen no.	1	2	3	4	5	6	7	8	9	10
Phenotype	100	100/85	100/85	100	85	100/85	100	100	100	100/85

Three phenotypes can be seen at this locus: 100, 100/85, and 85. The 100 phenotype is produced by a genotype homozygous for the 100 allele: Pgm-2(100/100); similarly, the 85 phenotype is produced by the homozygous Pgm-2(85/85) genotype; the 100/85 phenotype is produced by the heterozygous genotype Pgm-2(100/85), which contains both alleles.

We first estimate the frequency of the common allele, Pgm-2(100), using the observed phenotypic frequencies.

$$\text{Freq (100)} = \frac{2(\text{no. of 100 phenotypes}) + (\text{no. of 100/85 phenotypes})}{2(\text{total no. of phenotypes})} = P$$

The number of 100 phenotypes must be multiplied by two because each of these individuals has two copies of the 100 allele in the homozygous state, Pgm-2(100/100). Likewise, to estimate the allele frequency we must divide by two times the total number of phenotypes because each individual has two alleles at this locus. Therefore, the frequency of the 100 allele in our diagram is

$$\text{freq (100)} = \frac{2(5) + 4}{2(10)} = 0.70 = P$$

The next step in the analysis is to estimate the expected proportion of each phenotype. If the population from which the sample was taken is random mating, then we expect the two alleles to be distributed independently in individuals (i.e., Hardy-Weinberg proportions). Therefore, the expected proportion of Pgm-2(100/100) genotypes is simply the frequency of the 100 allele squared (P^2). The expected proportion of heterozygotes is 2 P(1-P) and the expected proportion of Pgm-2(85/85) homozygotes is $(1-P)^2$. Thus, the observed and expected frequencies of the three phenotypes are

	100	100/85	85	Freq (100) = P
Observed	5	4	1	0.70
Expected	(4.9)	(4.2)	(0.9)	

The last step in the analysis is to estimate the fixation index, F. This value is an estimate of the proportional excess or deficit of heterozygotes in the population:

$$F = 1 - \frac{\text{observed proportion of heterozygotes}}{\text{expected proportion of heterozygotes}} = 0.05$$

Non-random mating will produce an excess of homozygotes and, therefore, positive values for F. For example, there is a tendency in the hybrid populations of Baker Lake and Sofa Creek to show an excess of homozygotes (F>0). This may be the result of a tendency for westslope 'types' or Yellowstone 'types' to mate among themselves. None of the departures from expected proportions, however, are statistically significant. Larger sample sizes are necessary to detect the presence of significant departures from the expected phenotypic proportions.

APPENDIX E

Terms of reference

PARKS CANADA
* APRIL 1, 1980
TERMS OF REFERENCE
for

A contract to provide the identification of the strains of cutthroat trout-Salmo Clarki Richardson that were indigenous to the Bow, Waterton and Kootenay/Columbia river systems in Banff, Waterton Lakes and Kootenay National Parks respectively, and an analysis of the resident cutthroat trout populations from selected lakes in the above noted Parks to determine if these lakes still contain pure stocks that were indigenous to the respective river systems.

1: Purpose

1.1 Problem

Prior to the days of fish culture and fish stocking by National Parks and other related agencies it is believed, that only one particular strain of cutthroat trout was indigenous to the waters of each of the above noted Parks. Since that time, it is known that non-indigenous strains of this fish species have been introduced (stocked) into some waters of these Parks, but, it is not known which strains or which lakes have been stocked with the non-indigenous strains as the information was not recorded. This information is vital to Parks Canada mandate to protect the ecosystems and to maintain viable populations of the native fish species. Secondly, it is imperative the status of the cutthroat trout strains be established if some of these populations are to be used as back-up sources for re-establishing the native strains in waters in which they were endemic.

1.2 Objectives

1.2.1 To determine/establish the phenotypes (morphometric, meristic and biochemical) that are peculiar to the strains of cutthroat trout known to be indigenous to the Bow, Waterton and Kootenay River systems.

1.2.2 To identify the strains of the resident cutthroat trout populations of Baker, Upper Block, Elk, Marvel, Mystic, Hidden, Taylor, Twin (1) and the three Fish Lakes in Banff National Park;

* An asterisk denotes changes from the March 1980 Terms of Reference.

Stoney Creek in Waterton Lakes National Park; and Floe Lake in Kootenay National Park from the information established. (1.2.1)

2: Project Area

2.1 While this study is of significance to most of the Parks in the Western Region where fish have been or are being stocked, the specific study areas will be restricted to:

2.1.1 Baker, Upper Block, Elk, Marvel, Mystic, Hidden, Taylor, Twin (1) and the three Fish Lakes in Banff National Park.

2.1.2 Stoney Creek in Waterton Lakes National Park.

2.1.3 Floe Lake in Kootenay National Park.

2.1.4 Other lakes may be substituted or added to the study as required provided there is prior discussion and agreement.

2.2 Sampling of resident fish populations will be carried out in the open water season (early May to October).

3: Project Requirements

3.1 More specifically, but without limiting the generality of the foregoing, the project requirements include:

3.1.1 The contractor shall review all the pertinent literature and records relating to the cutthroat trout species strains of the areas defined in 1.1, 1.2.1 and 1.2.2 and will assemble and compile the information into a concise statement of relevant facts.

3.1.2 The contractor will undertake an investigation to determine/

establish via literature review and defensible laboratory research the phenotypes (morphometric, meristic and biochemical) peculiar to the cutthroat trout known to be indigenous to the Bow, Waterton and Kootenay river systems.

3.1.3 The contractor will endeavour to identify the strains of cutthroat trout resident in:

3.1.3.1 Baker, Upper Block, Elk, Marvel, Mystic, Hidden, Taylor, Twin (1) and the three Fish Lakes in Banff National Park.

3.1.3.2 Stoney Creek in Waterton Lakes National Park.

3.1.3.3 Floe Lake in Kootenay National Park.

3.1.4 The contractor will maintain close liaison with the project field coordinator, specifically with Mr. J. Kilistoff of this office. (134 - 11th Avenue, S.E., Calgary, Alberta T2G 0X5, telephone #231-4509).

4: Responsibility for Project Requirements

4.1 The contractor agrees not to transfer the responsibility to a third party without the consent of Parks Canada; Dept. of the Environment.

4.2 The contractor shall:

4.2.1 Provide all the equipment, material, labour necessary to collect a minimum of 25 cutthroat trout specimens from each body of water listed in 3.1.3 (except 3.1.3.2 where total number may have to be less).

4.2.2 Be responsible for the transfer of fish specimens from source to laboratory.

4.2.3 Examine the samples from the sources indicated (sections (3.1.3.1 to 3.1.3.3) and identify the strain or strains of the resident cutthroat trout populations of these lakes.

* 4.2.3 a Recommend for approval, the lakes where more than 25 fish should be analyzed in order to positively identify native strains.

* 4.2.4 Prepare and submit progress (interim) and final reports as detailed in Section 6 Completion Schedule.

4.3 Collection of specimens will be strictly limited to those specified by the contract or to those which are made necessary by the terms of the contract. The contractor and his designated assistants shall comply with the following requirements when collecting specimens under the contract agreement.

4.3.1 Obtain a collection permit from Parks Canada for collecting fish specimens which are made necessary by the terms of the contract.

4.3.2 Obtain any permits that may be required by other agencies relating to collecting of certain fish species or types and numbers of specimens.

4.3.3 Carry the above noted collecting permits (4.3.1 and 4.3.2) at all times when engaged in collecting activities or when in possession of specimens and present same upon request by Parks Canada staff or R.C.M.P. officer.

4.3.4 Limit the collection of specimens to species and number required under terms of contract.

4.3.5 Comply with all the relevant conditions on the collecting permit.

4.3.6 Provide the Parks Superintendent with a list of specimens collected and, at his request, present the specimens for inspection prior to removing them from the Park.

4.4 Specimens

In addition to those fish specimens required for the completion of this contract, the contractor shall provide to each of the Parks (Banff, Waterton Lakes and Kootenay) 1 set (or portion thereof) of properly identified, labelled and preserved specimens collected during the field work for the individual Parks Natural History collection and a second complete set shall be provided for the National Museum of Canada.

5: Progress (interim) and final report requirements.

5.1 Progress reports (original and 1 copy) shall be prepared and presented as separate volumes and not form part of the final report.

5.1.1 The 1st progress report shall present the literature review and plans for the field work.

5.1.2 The 2nd progress report shall present the results of the field work and subsequent laboratory analysis and outline research still to be completed.

5.2 Final Report

The contractor shall provide the original and 25 copies of this report in English only (26 in total) the latter to be properly assembled and bound. This report will describe in detail the phenotypic traits used to distinguish strains and will identify the Cutthroat trout strains in each of the lakes studied. This report shall include the following as well as any other information considered relevant to the study by the contractor:

5.2.1 An abstract presenting the most important results.
5.2.2 A Table of Contents
5.2.3 A List of Figures
5.2.4 A List of Tables
5.2.5 A List of Appendices i.e. glossary, bibliography, etc.
5.2.6 A Summary briefly outlining the study area, objectives,

procedures and results.

5.2.7 A description of methodology and standards, reviewing both field and laboratory techniques followed.

5.2.8 Presentation and an interpretation of all data in tabular, graphic, illustrative, map and text format.

5.2.9 The results of all collection and analysis as specified in Sections 3 and 4 of these Terms of Reference.

5.2.10 A summary of the most significant factors resulting from this project.

5.2.11 As much as possible, photographs will be used to illustrate or accentuate the information presented in the final report. All negatives or slides of such photographs will be submitted with the final report.

5.2.12 An appendix to the report which should include but not be limited to the following.

5.2.12.1 A glossary of terms used in the final report and/or reference to existing glossaries.

5.2.12.2 An annotated bibliography of reports, papers, articles and books related to and used in the determination of the final results of this study.

5.2.12.3 Tables listing the specimens collected and related information such as age classes, lengths, weights, sex and phenotypes.

5.2.12.4 A copy of these Terms of Reference.

6: Completion Schedule

6.1 The contractor will endeavour to submit the progress and final reports on schedule as these will form the basis on which contract payments will be made.

6.1.1 On or before June 1, 1980, submit the 1st progress report presenting the literature review and plans for the field season.

6.1.2 On or before October 30, 1980, submit the 2nd progress report discussing the results of the field work and subsequent laboratory analysis and outlining research still to be completed.

6.1.3 At least 2 oral progress reports are to be made at convenient times between October 30 and December 31, 1980 to the Project Coordinator to discuss the selection of phenotypic traits that will be used to define the different cutthroat strains.

6.1.4 On or before February 27, 1981, the final report describing in detail the phenotypic traits used to distinguish strains and the strains occurring in each lake studied. Specimens referred to in section 4.4 will be submitted at this time.

7: Payment Schedule

The contractor agrees to commence work immediately on signing of this
* contract and that the fixed price shall be $24,027.00 , payments to be made as follows:

7.1 On submission of satisfactory progress report (#1) on or before
* June 1, 1980, $3,000.00.

7.2 On submission of satisfactory progress report (#2) on or before October 30, 1980, $14,000.00.
*

7.3 On or before December 31, 1980 upon satisfactorily concluding (via oral progress reports) the validity of the phenotypic traits to be used for the purpose of determining the strains of the resident cutthroat populations in the lakes being investigated, no payment.

7.4 On submission of satisfactory final report and completion of all contract requirements on or before February 27, 1981 the remaining portion, i.e. $7027.00 plus payment for additional fish analyses at $2,200.00 for the first 100 extra and $1,800 for the second extra 100.

8. Special Conditions

8.1 The contractor shall be: Techman Ltd.
P.O. Box 2840
Calgary, Alberta T2P 2M7

8.2 The principal researcher shall be:
Dr. Dwight Mudry

8.3 The project coordinator will be Mr. J. Kilistoff, Aquatic Resources Manager, Western Region. The field supervisor in each of the Parks shall be the Park Superintendent or his designate in that Park.

8.4 The fixed contract price includes all expenses which may be incurred by the contractor in connection with the work.

8.5 All reports and queries regarding this contract shall be addressed to:

Director, Western Region
Parks Canada
134 - 11 Avenue, S.E
Calgary, Alberta
T2G 0X5

Attention: J. Kilistoff
Aquatic Resources Manager

8.6 The final report will be professionally adequate in content, presentation and terminology and of a quality such that it could, at the discretion of the Director, Parks Canada, be published. The reports paid for under this contract are the property of the Government of Canada.

8.7 The contractor may, subject to the approval of the Director, Western Region Office, Parks Canada publish the report in whole or in part under his own name as a thesis, scientific or professional paper, or other form of publication which is acceptable to the Director. The foregoing in no way limits the rights of the Government of Canada to publish the report.

8.7.1 In this section,

(a) "copyright work" means any work in which a copyright may be subsist, produced in or as a result of performing the contract.

(b) "publication" or "publish" do not include disclosure to an academic supervisor or appraiser for the sole purpose of academic evaluation.

8.7.2 Copyright in any copyright work vests in Her Majesty but in any publication of such work by or on behalf of Her Majesty the contribution of the contractor and of the author shall be acknowledged.

8.7.3 The contractor and the author each shall have a royalty-free non-exclusive license to publish or have published any copyright work in the course of the normal dissemination of knowledge in the subject field, but they shall not publish or have published any copyright work during the performance of the contract or for a period of three months thereafter without the prior written consent of the Minister.

8.7.4 Any copyright work published by or on behalf of the contractor or the author shall acknowledge that the work was performed under contract with Her Majesty unless the Minister gives notice to the contrary.

8.7.5 The copyright and all proprietory rights of ownership or use of any and all slides, photographs-positives and/or negative, sketches or other illustrations made or taken by the contractor in any way related to the work to be performed under this contract shall belong to Her Majesty the Queen in the right of Canada.

8.8 The contractor shall be allowed access to reports in the Research and Resource Inventory collection which pertain to the project, and where necessary, may be provided pertinent information from Branch or Park files.

8.9 The contractor shall ensure that the Superintendents of Banff, Waterton Lakes and Kootenay National Parks are kept informed of the initiation, progress and termination of the field research program.

8.10 Upon completion of the final report, the contractor shall be prepared to give a seminar on his research to provide all the Park personnel with a broad understanding of the purpose, results and methodology of this study.

8.11 If requested, the contractor shall incorporate into this field party at least one Park Warden, designated by the Field Supervisor, and shall instruct the Park Warden in any techniques or methodologies which might be required to supplement or update the data. Due to manpower limitations it is anticipated that Warden input will be of an occasional nature.