



Abilities of trout to swim through highway culverts
by David Andrew Belford

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Fish and Wildlife Management
Montana State University
© Copyright by David Andrew Belford (1986)

Abstract:

Seven culverts in Montana were studied from 1984 -1986 to determine conditions that allowed and prohibited the passage of rainbow trout, brown trout, cutthroat trout and brook trout. A curve was fitted to the most stringent combinations of distances and average bottom water velocities between rest sites in culverts trout swam through. This curve indicated that for distances between rest sites of 0 - 20 m, average bottom velocities of near or below 1.67 - 0.83 m/s, respectively, permitted passage. For distances of 20 - 100 m, average bottom velocities of near or below 0.83 - 0.64 m/s, respectively, permitted passage. Trout 185 - 470 mm in total length passed through culverts with these maximum conditions. No differences in swimming ability were noted among the four trout species studied in the field. Laboratory swimming stamina tests indicated that brown trout, rainbow trout and cutthroat trout had similar staminas. All three types of culvert modifications studied created conditions that permitted trout passage.

ABILITIES OF TROUT TO SWIM THROUGH
HIGHWAY CULVERTS

by

David Andrew Belford

A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Fish and Wildlife Management

MONTANA STATE UNIVERSITY
Bozeman, Montana

July 1986

N378
B412
cop. 2

APPROVAL

of a thesis submitted by

David Andrew Belford

This thesis has been read by each of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

July 17, 1986
Date

William R. Gould
Chairperson, Graduate Committee

Approved for the Major Department

July 17, 1986
Date

Peter F. Brunson
Head, Major Department

Approved for the College of Graduate Studies

July 26, 1986
Date

Henry L. Parsons
Graduate Dean

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a master's degree at Montana State University, I agree that the library shall make it available to borrowers under rules of the Library. Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgement of source is made.

Permission for extensive quotation from or reproduction of this thesis may be granted by my major professor, or in his absence, by the Director of Libraries when, in the opinion of either, the proposed use of the material is for scholarly purposes. Any copying or use of the material in this thesis for financial gain shall not be allowed without my written permission.

Signature

David A. Belford

Date

July 26, 1966

ACKNOWLEDGEMENT

I sincerely thank the following people for help throughout this study. Dr. William Gould directed the study and assisted with the field work and preparation of the manuscript. Drs. Ray White, Lynn Irby, John Priscu and Tad Weaver critically reviewed the manuscript. Charlie Smith, Pat Dwyer and Arthur Viola at the Fish Cultural Development Center provided space and assistance at the Center. Ralph Boland and Chris Clancey, Montana Department of Fish, Wildlife and Parks, critically reviewed the study proposal and provided field assistance, respectively. Dan Gustafson provided statistical and computer assistance. Mike Hensler and other fellow students assisted me in the field. My sincere appreciation also goes to my wife, Susan, and family for encouragement throughout this study.

This study was funded by a Federal Highway Administration grant to the Montana Department of Highways (Project 8093). Special thanks are given to Les Reichelt, Paul Garrett, Donald Harriott, Stephen Kologi and Robert Garber of the above agencies for their interest and support of this study.

TABLE OF CONTENTS

	Page
APPROVAL.	ii
STATEMENT OF PERMISSION TO USE	iii
VITA	iv
ACKNOWLEDGEMENT	v
TABLE OF CONTENTS.	vi
LIST OF TABLES.	viii
LIST OF FIGURES	x
ABSTRACT.	xiii
INTRODUCTION	1
DESCRIPTION OF STUDY AREAS.	4
METHODS	10
Determination of Trout Movements	10
Cedar Creek	10
Sourdough Creek	11
Depuy's Spring Creek	12
Cottonwood Creek.	12
Twelvemile Creek.	13
Measurement of Physical Parameters	13
Experimental Field Work	15
Experimental Laboratory Study	16

Table of Contents (continued)

	Page
RESULTS	20
Cedar Creek	20
Sourdough Creek	30
Depuy's Spring Creek - North Channel	41
Cottonwood Creek	45
Twelvemile Creek	50
Laboratory Study	53
DISCUSSION	56
Distance - Velocity Relationship	56
Other Factors Affecting Passage	61
Evaluation of Culvert Modifications	62
REFERENCES CITED	65

LIST OF TABLES

Table		Page
1.	Physical characteristics of the study culverts.	6
2.	Locations of rocks in the west culvert of Sourdough Creek from March 21 - April 21, 1986. All rocks were removed on April 21.	16
3.	The structure of the swimming stamina test. Each fish began the test under conditions of interval one and was subjected to the states of successive intervals until fatigued	19
4.	Characteristics of cutthroat trout that did and did not pass through the improved culvert of Cedar Creek from July 5 - 23, 1984	20
5.	Characteristics of cutthroat trout that did and did not pass through the improved culvert of Cedar Creek from June 12 - 27, 1985	21
6.	Characteristics of cutthroat trout that did and did not pass through the unimproved culvert of Cedar Creek from June 12 - 27, 1985.	22
7.	Characteristics of trout that passed through the east culvert of Sourdough Creek from April 28 - May 22, 1985	31
8.	Characteristics of trout that passed through the west culvert of Sourdough Creek from March 22 - April 23, 1986	32
9.	Characteristics of rainbow trout that passed through the culvert of Depuy's Spring Creek from March 20 - April 19, 1985	41

LIST OF TABLES (continued)

Table		Page
10.	The lengths and weights of brown trout displaced below the culvert of Depuy's Spring Creek that did and did not return upstream from October 18 - December 5, 1985	42
11.	The lengths and weights of brown trout displaced below the culvert of Cottonwood Creek that did and did not return upstream from October 17 - November 21, 1984. . . .	46
12.	Characteristics of trout displaced below the culvert of Twelvemile Creek that did and did not return upstream from October 17 - November 2, 1984	51
13.	Results of the comparative swimming stamina test	53
14.	Maximum velocities and distances between rest sites for passage indicated in this study and those recommended previously. . .	59

LIST OF FIGURES

Figure		Page
1.	Locations of the study areas. 1 - Cedar Creek, 2 - Sourdough Creek, 3 - Depuy's Spring Creek - North Channel, 4 - Cottonwood Creek, and 5 - Twelvemile Creek.	5
2.	Diagram of the swimming stamina test apparatus showing 1 - testing section, 2 - intake pipes, 3 - outlet pipes, and 4 - control valve. Arrows indicate the direction of water flow.	17
3.	Water velocities at every third passage site over the rungs (open squares) and rest site (open triangles) in the improved culvert of Cedar Creek on July 13, 1984. Closed squares indicate highest summer velocities recorded (July 8, 1984)	23
4.	Water velocity profile in the improved culvert of Cedar Creek on October 11, 1984	25
5.	Water velocity profile in the unimproved culvert of Cedar Creek on July 12, 1984 (open squares), June 20, 1985 (open circles), and on June 21, 1985 (closed circles) after the placement of two rocks. Closed squares indicate highest summer velocities recorded (July 5, 1984)	26
6.	Stage level and daily maximum and minimum temperatures of Cedar Creek during June and July, 1984.	28
7.	Stage level and daily maximum and minimum temperatures of Cedar Creek during June, 1985	29

LIST OF FIGURES (continued)

Figure		Page
8.	Water velocity profile in the east culvert of Sourdough Creek on May 1, 1985 (closed circles), and May 22, 1985 (open circles). Closed squares indicate velocities recorded during highest spring discharge (May 4, 1985).	33
9.	Water velocity profile in the west culvert of Sourdough Creek on June 5, 1985 (closed circles), and May 22, 1985 (open circles). Closed squares indicate velocities recorded during highest spring discharge (May 4, 1985).	35
10.	Water velocity profile in the west culvert of Sourdough Creek with the placements of four rocks on March 23 (closed circles), three rocks on March 21 (open circles) and April 6 (closed squares), two rocks on April 16 (open squares), one rock on April 21 (open triangles), and no rocks on April 23 (closed triangles)	36
11.	Stage level and daily maximum and minimum temperatures of Sourdough Creek during April and May, 1985	38
12.	Stage level and daily maximum and minimum temperatures of Sourdough Creek during October and November, 1985.	39
13.	Stage level and daily maximum and minimum temperatures of Sourdough Creek during March and April, 1986	40
14.	Water velocity profile in the culvert of Depuy's Spring Creek on April 10, 1985 (closed circles), and December 16, 1985 (open circles). Closed squares indicate highest spring velocities recorded (March 18, 1985)	43

LIST OF FIGURES (continued)

Figure		Page
15.	Stage level and daily maximum and minimum temperatures of Depuy's Spring Creek during March and April, 1985	44
16.	Water velocity profile in the culvert of Cottonwood Creek on July 10, 1984 (closed circles), and November 15, 1984 (open circles). Closed square indicates the highest summer velocity recorded (July 9, 1984).	47
17.	Stage level and daily maximum and minimum temperatures of Cottonwood Creek during June and July, 1984	48
18.	Stage level and daily maximum and minimum temperatures of Cottonwood Creek during October and November, 1984.	49
19.	Water velocity profile in the culvert of Twelvemile Creek on November 17, 1984	52
20.	Stage level and daily maximum and minimum temperatures of Twelvemile Creek during October and November, 1984.	54
21.	The measurements of mean bottom velocity (V) and distance between rest sites (D) in the study culverts that were the most stringent tests of the trouts' swimming abilities. The line was fitted to the points of passage.	57

ABSTRACT

Seven culverts in Montana were studied from 1984 - 1986 to determine conditions that allowed and prohibited the passage of rainbow trout, brown trout, cutthroat trout and brook trout. A curve was fitted to the most stringent combinations of distances and average bottom water velocities between rest sites in culverts trout swam through. This curve indicated that for distances between rest sites of 0 - 20 m, average bottom velocities of near or below 1.67 - 0.83 m/s, respectively, permitted passage. For distances of 20 - 100 m, average bottom velocities of near or below 0.83 - 0.64 m/s, respectively, permitted passage. Trout 185 - 470 mm in total length passed through culverts with these maximum conditions. No differences in swimming ability were noted among the four trout species studied in the field. Laboratory swimming stamina tests indicated that brown trout, rainbow trout and cutthroat trout had similar staminas. All three types of culvert modifications studied created conditions that permitted trout passage.

INTRODUCTION

In many instances, conditions permit highway management agencies to design either culverts or bridges when crossing streams. In these situations, the highway management agencies often prefer to install culverts rather than bridges because of reduced costs. In contrast, conservation agencies often prefer that bridges be used because the literature contains documentation of culverts impeding or preventing fish movements.

Culvert installations often cause high water velocities which impede or block fish movements. High velocities in culverts have been found to prevent the passage of Arctic grayling (Thymallus arcticus), longnose suckers (Catostomus catostomus), northern pike (Esox lucius) (Derksen 1980), steelhead (Salmo gairdneri), coho salmon (Onocorhynchus kisutch), chinook salmon (O. tshawytscha) (Kay and Lewis 1970) and cutthroat trout (S. clarki) (Huston 1964). Higher velocities can develop in culverts than in natural streams because culverts have lower roughness coefficients or steeper slopes. Agencies have tried to mitigate this passage problem by installing velocity reducing structures in some culverts. Fish passage may also be prohibited because of high velocities

in adjacent stream sections caused by culvert hydraulics which can prevent fish from either entering or leaving the culverts (Evans and Johnston 1977).

Oversized culverts or culverts with steep gradients have produced shallow water conditions which can block fish passage (Bryant 1981). Shallow water can block fish movements because it reduces the fish's swimming ability. (Webb 1975). Evans and Johnston (1977) have recommended that minimum water depths for passage in culverts be 15 and 30 centimeters (cm) for resident trout and anadromous salmonids, respectively.

Elevated culvert outlets also can prevent fish passage. Evans and Johnston (1977) recommended that single jumps not exceed 30 cm in height for resident trout and 61-91 cm for anadromous salmonids. A jumping pool depth of 1.25 times the jump height is also recommended for these situations (Gebhards and Fisher 1972).

Light levels within culverts were once thought to influence fish passage (Metsker 1970). However, it is now generally regarded as an insignificant factor (Bell 1973; Lauman 1976).

The study of fish passage through culverts or steep pass fishways has largely focused on the abilities of anadromous salmonids (Gauley 1960, 1967; Kay and Lewis 1970; Slatick 1971). It has been assumed that anadromous salmonids have greater passage abilities than

nonanadromous salmonids, but the actual capabilities of the latter have largely been unmeasured.

The goal of this study was to relate the physical conditions in and around selected highway culverts in Montana to salmonid passage. The specific objectives were to measure the velocities, distances between rest sites and water depths in culverts and determine if the brown trout (S. trutta), rainbow trout (S. gairdneri), brook trout (Salvelinus fontinalis) and/or cutthroat trout present could pass through them. In addition, evaluations of the effectiveness of the fish passage structures present in three culverts and the relative swimming abilities of brown trout, rainbow trout and cutthroat trout were made. The findings of this study can be used to help determine if planned and existing highway culverts will prevent or allow nonanadromous salmonid passage.

DISCRIPTION OF STUDY AREAS

Culverts at five sites in Montana were chosen for study (Figure 1). The characteristics of the seven culverts at these sites have been given in Table 1. Cedar Creek, tributary to the Yellowstone River, was located in Park County approximately 44 air kilometers (km) south of Livingston. It flowed under U.S. Highway 89 through two culverts lying side by side.

Discharges in Cedar Creek were estimated to have been 0.02 - 1.22 cubic meters per second (m^3/s) during the study periods. The creek has resident brown trout, cutthroat trout and brook trout. It was also a spawning site for migrating cutthroat trout from the Yellowstone River.

The north culvert was fitted with a ladder - like structure on the bottom. The ladder rungs were spaced at mean (range) distances of 1.22 m (1.13 - 1.45 m) apart and held bedload which provided rest sites for trout. The structure was approximately 1.1 m wide and extended the full length of the culvert. The south culvert contained no structures. Prior to the installation of the ladder both culverts blocked migratory cutthroat trout movement (Berg 1975).

