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ELECTROFISHING INDUCED MORTALITY AND INJURY TO RAINBOW TROUT, ARCTIC GRAYLING, HUMPBACK WHITEFISH, LEAST CISCO, AND NORTHERN PIKE[1]

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ABSTRACT

Studies were conducted to determine the effects of pulsed direct current electrofishing on all species of fish for which electrofishing was being used as a method of sampling by the Alaska Department of Fish and Game. Species studied were rainbow trout *Oncorhynchus mykiss*, Arctic grayling *Thymallus arcticus*, northern pike *Esox lucius*, humpback whitefish *Coregonus pidschian*, and least cisco *Coregonus sardinella*. Rainbow trout sustained high rates of mortality (13.9 percent) and injury (40.9 percent) and electrofishing has been discontinued as a method of sampling for this species. Northern pike sustained a moderate rate of injury (12.5 percent) which was significantly higher than that sustained by a control sample. Additional research is being conducted to determine the effects of these injuries. Several experiments were conducted with Arctic grayling and injury rates varied from 0 percent to 18.3 percent. Although variable, virtually all of these injuries were minor and it was concluded that electrofishing does not have a substantial detrimental effect on grayling populations. Neither species of whitefish sustained injury due to electrofishing. Because of the problems of objectively assessing the degree and impact of injury, it was recommended that the most useful method of assessing the effects of electrofishing is at the population level, by testing for differential survival and growth over time between test and control groups of fish.

KEY WORDS: electrofishing, pulsed direct current, rainbow trout, *Oncorhynchus mykiss*, Arctic grayling, *Thymallus arcticus*, northern pike, *Esox lucius*, humpback whitefish, *Coregonus pidschian*, least cisco, *Coregonus sardinella*, injury, mortality.

INTRODUCTION

The Alaska Department of Fish and Game (ADFG) has employed pulsed direct current electrofishing gear (hereafter referred to as electrofishing gear) as a primary tool for the capture of rainbow trout *Oncorhynchus mykiss*, Arctic grayling *Thymallus arcticus*, northern pike *Esox lucius*, humpback whitefish *Coregonus pidschian*, and least cisco *Coregonus sardinella*. Sharber and Carothers (1988) determined that a large portion (44% to 67%) of large rainbow trout received spinal injuries (determined through X-ray and autopsy) as a result of exposure to pulsed DC current and that such injury rates could bias estimates of age, growth, and abundance based on mark-recapture techniques; and potentially pose a threat to the population if sampled intensively.

Publication of the work of Sharber and Carothers (1988) provided the impetus for initiation of this research. Since their work spoke directly to large rainbow trout, our initial research was limited solely to the only Alaskan situation where rainbow trout were being captured with electrofishing gear: the Kenai River. Experimentation with Kenai River rainbow trout was designed only to provide a quick answer as to whether the results of Sharber and Carothers (1988) were applicable to Kenai River electrofishing conditions for rainbow trout. As a result, the study contained no controls and only provided estimates of mortality and injury for fish exposed to electrofishing (Table 1). In addition, the electronic configuration and settings at use at the time (see Boat Descriptions) were rigorously tested to estimate threshold power necessary to stun rainbow trout for capture. Upon learning that large Kenai River rainbow trout also sustained high rates of injury due to capture with electrofishing gear and that these rates were similar to those reported by Sharber and Carothers (1988), additional research was designed to investigate the possibility of severe injury and/or mortality for other species of fish in Alaska that were commonly sampled with electrofishing gear (Figure 1). A more complete approach was taken with these studies and they provided for comparisons of mortality and injury with other gear types, and, in some instances, provided comparisons of long term mortality (Table 1). Additional threshold power experimentation was not attempted during these studies since the Kenai River experiment demonstrated that the standard electrofishing gear at use at the time was correctly set for threshold power.

The objective was to determine if detrimental effects of electrofishing (mortality rates, injury rates, or growth rate changes) were of such severity as to cause ADFG to discontinue the use of electrofishing gear. Specific study objectives were to:

1. estimate the rate of immediate and short term mortality;

2. estimate the rate of electrofishing-caused injury;

3. estimate the rates of long term survival and growth of the species in question captured with electrofishing and control gears; and,

4. determine the threshold power needed to sufficiently stun rainbow trout for capture.

Table 1. Summary of parameters measured for: (a) treatment groups (fish captured with electrofishing gear); and (b) control groups (fish captured with other gear types), 1988-1989.

Species	Location	Parameter Measured	Control	Duration of Experiment
Rainbow Trout	Kenai River	Immediate Mortality	None	During Sampling
		Short Term Mortality	None	4 Days
		Threshold Power to Capture	None	During Sampling
Arctic Grayling	Chatanika River	Immediate Mortality	Seine and Hook & Line	During Sampling
		Short Term Mortality		7 Days
		Electrofishing-caused Injury		7 Days
		Cumulative Effect		7 Days
	Gulkana River	Immediate Mortality	Hook & Line	During Sampling
		Short Term Mortality	Hook & Line	7 Days
		Electrofishing-caused Injury	Hook & Line	7 Days
		Cumulative Effect		7 Days
		Long Term Survival		1 Year
	Delta River	Immediate Mortality	Seine and Hook & Line	During Sampling
		Electrofishing-caused Injury		2 Days
		Long Term Survival		1 Year
		Long Term Growth		1 Year
	Fielding Lake	Long Term Survival	Trap	1 Year
		Long Term Growth		1 Year
Humpback Whitefish	Chatanika River	Immediate Mortality	Seine	During Sampling
		Short Term Mortality	Seine	7 Days
		Electrofishing-caused Injury	Seine	7 Days
		Cumulative Effect		
Least Cisco	Chatanika River	Immediate Mortality	Seine	During Sampling
		Short Term Mortality	Seine	7 Days
		Electrofishing-caused Injury	Seine	7 Days
		Cumulative Effect		
Northern Pike	Minto Flats	Immediate Mortality	Trap, Gill-net, Hook & Line	During Sampling
		Electrofishing-caused Injury		During Sampling
		Long Term Survival		1 Year
		Long Term Growth		1 Year

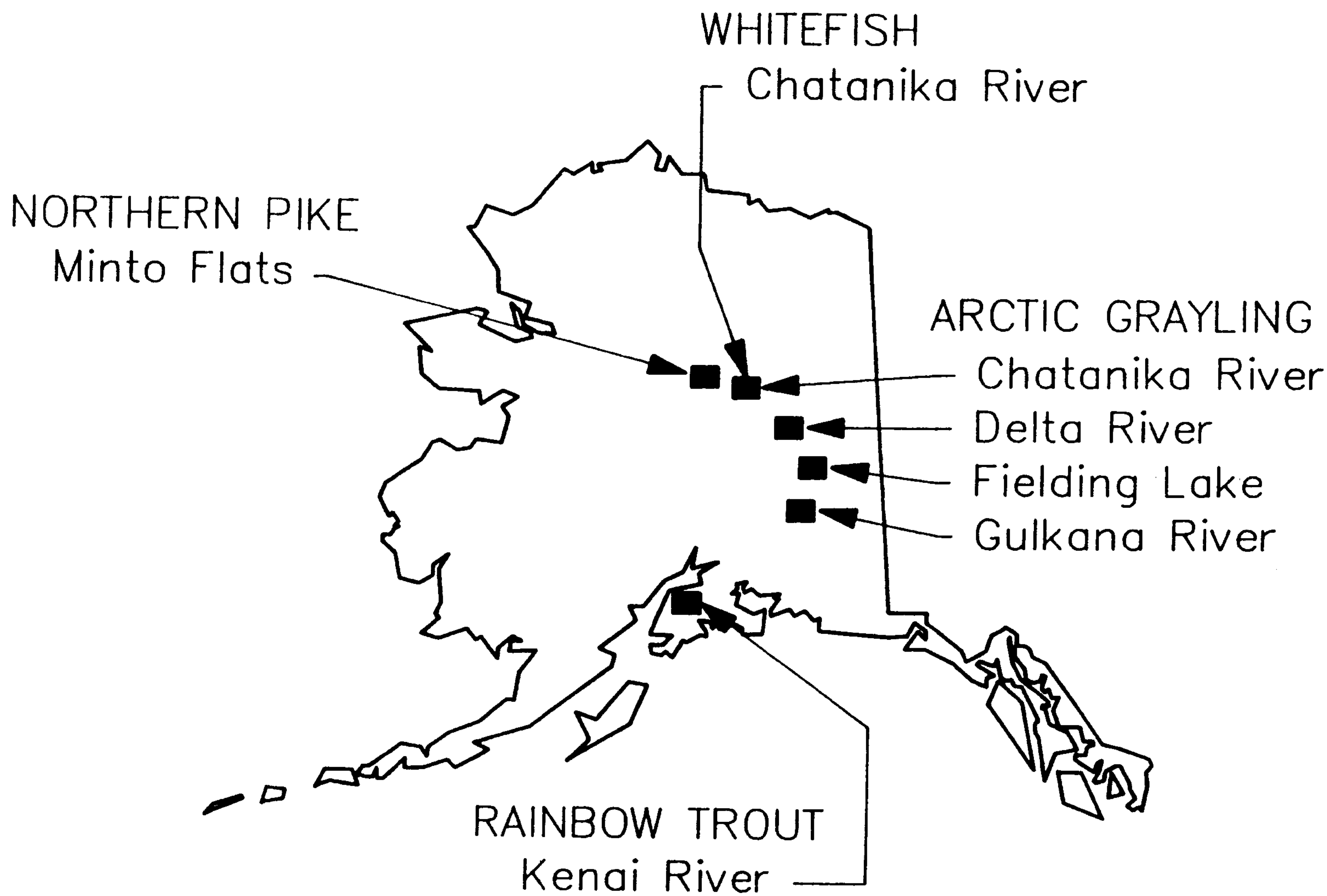


Figure 1. Sampling sites for electrofishing research, 1987-1989.

This report is organized with a general discussion of methods followed by chapters devoted to individual studies. Each chapter contains a specific summary of methods, and a results and discussion section. A conclusions section at the end of the report provides a summary of findings from all studies.

GENERAL METHODS

For the evaluation of injuries, immediate mortality, and short term mortality, the following general sampling sequence was followed:

1. a sample of fish to serve as a control was collected using a gear other than electrofishing (beach seine, trap net, gill net, or hook and line as required);

2. another sample of fish (hereafter referred to as the test group) was collected using electrofishing gear (a boat-mounted, pulsed-DC electrofishing unit using the minimum voltage required for efficient capture);

3. initial capture mortality by gear was recorded, and all fish killed during sampling were measured and retained for autopsy and X-ray;

4. all live sampled fish were measured to the nearest millimeter of fork length (FL), given an adipose finclip, tagged with FD-67 Floy anchor type tags, and placed in a holding pen(s);

5. dead fish were counted daily and placed in a freezer for later autopsy and X-ray;

6. after 7 days, samples of test fish and control fish were killed by placing them in a cooler containing a large concentration of MS-222 (in several experiments, all captured fish were used, while in other experiments, subsamples of fish were randomly selected, X-rayed, and autopsied to evaluate hemorrhaging associated with the spine, spinal dislocation, or spinal compression fractures (all mortalities were sampled in a similar manner); and,

7. data were analyzed using contingency table analysis with correction for continuity (Steel and Torrie 1980) to test the hypothesis that there were no significant differences in immediate mortality, short term mortality, and injury rate between test and control groups. Differences in mortality, injury, survival, and growth rates were considered significant if a test resulted in a probability level of 0.05 or less.

Boat Descriptions

Three separate boats were used for various portions of the electrofishing study. All boats were similar in design. Each was a 6.1 m long flat bottom river boat with a jet powered outboard motor. Power to the electrofishing system was supplied by a 2.5 to 3.5 kw gasoline powered generator. A Coffelt VVP-15 was used to control voltage and pulse rate for sampling performed on the Kenai and Gulkana rivers (Boat A) and the Delta River and Minto Flats (Boat B). An old (22 years) Coffelt VVP (no model number) was used to control voltage and pulse rate for sampling performed on the Chatanika River (Boat C). This VVP accepted 115 volt input and was capable of 300 volt maximum output. Pulse rate and voltage output varied by species, water body, and water conditions and are presented for each study. Current was passed into the water through three (Boat A) or four (Boats B & C) anodes located on a boom extending approximately 2 m beyond the bow of the boat. Anodes were 1.5 to 3 m long and were made of 9.5 mm (Boat B & C) or 19.1 mm (Boat A) diameter steel cable. Electrodes on Boat C were modified with a shield composed of 19.1 mm flexible conduit. Electrodes on Boat A were modified with a shield composed of 101.6 mm diameter plastic pipe. Anodes extended into the water approximately 1 to 2 meters. The aluminum hull served as the cathode on all boats. Stunned fish were removed from the water by dip net and placed immediately into a plastic live well.

X-ray Technique

X-rays of fish were taken using a Bowie portable X-ray unit on 14 X 17 in Dupont high speed film. Exposure times were from 0.10 to 0.15 sec. From one to 10 fish fit on each cassette. Both lateral and dorsal/ventral views were taken of each fish sampled from the Chatanika River and Minto Flats. Only a lateral view was taken of fish sampled from the Kenai, Gulkana, and Delta rivers. Vertebral abnormalities were designated as minor compression fractures (minor reduction in the amount of intervertebral space), moderate compression fractures (five or fewer vertebrae with no visible intervertebral space), major compression fractures (more than five vertebrae with no discernable intervertebral space), and dislocations. Vertebral abnormalities were further characterized as naturally occurring (those with more densely fused vertebral sections than seen with electrofishing-induced injuries; Sharber and Carothers 1988), old injuries that had healed (those injuries without associated hemorrhages), and new electrofishing-induced injuries (those injuries with associated hemorrhages). Injury locations were identified by vertebrae number with the atlas designated as vertebrae one.

Autopsy Technique

Autopsies of all sample fish were performed immediately after X-rays were taken. External condition of each fish was noted prior to autopsy. Some fish captured with electrofishing gear exhibited dark bands of discoloration, usually across the back of the fish. These marks were termed "brands." The left side of the fish was filleted to expose the spinal column. The location of any hemorrhage was noted. Each hemorrhage was subjectively rated as minor, moderate, or major. Each autopsied fish was photographed for future evaluation. Locations of hemorrhages were designated (vertebrae number) by comparing photographs with X-rays. During autopsies, the laboratory personnel did not know whether individual fish were from test or control samples.

Measured Parameters

Immediate and short-term mortality were measured from the entire population of captured test and control fish in each study. Injury rates were measured either from: (1) the entire population of test and control fish, or (2) a random sample of test and control fish. In either case, estimates of injury are irrespective of fate (sampling mortality or survivor), except for the Delta River grayling study, in which only survivors were randomly sampled. The cumulative short-term effect of sampling for test and control gears was estimated as total mortality plus electrofishing-caused injury to survivors. Long-term effects of electrofishing were measured from estimates of: (1) survival of tagged fish 1 year later, and (2) growth (millimeter length) of tagged fish 1 year later.

CHAPTER 1 - RAINBOW TROUT

Introduction

In 1986, the Department initiated a study on rainbow trout in the Kenai River. Currently, the sport fishery for rainbow trout in the Kenai River is among the largest in the State for this species and the fishery is known for its large fish. The objective of this study was to determine stock structure, and then to estimate sustainable yield for the appropriate population units. A tagging study was identified as the means by which these objectives were to be accomplished. During the first year of study, various methods of capture were investigated including: hook and line, electrofishing, traps, nets, and weirs. Electrofishing was identified as the most efficient means of sampling these fish in their mainstem habitat. Mark-recapture surveys were conducted in 1987 with the use of a boat-mounted pulsed DC electroshocker and this work was to be continued in 1988. After Sharber and Carothers (1988) demonstrated that electrofishing could cause a high rate of injury to large rainbow trout, sampling was suspended in 1988 until the effects of electrofishing could be evaluated.

Methods

Short term mortality and the incidence of internal injury were measured for the electronic configuration as described in Chapter 4 of this report (Boat A). To summarize: 101.6 mm (4 inch) diameter shields were placed around each of five 19.1 mm (3/8 inch) electrodes, and output voltage was kept at 250 volts which produced a current of approximately 1 to 1.5 amps. At the time of capture, conductivity was 70 μmho/cm at 6.3 °C.

For this study, short term mortality was defined as mortality that occurred within 96 hours and was measured by simply holding fish in a pen. For this study, we elected to only sample the larger fish; defined here as fish greater than 400 mm FL. The rational for this is as follows. Capture of fish with electricity is known to be selective for larger fish (Sullivan 1956). We hypothesized that the greater susceptibility of larger fish to electrified water would also make them more susceptible to injury from the electricity. Therefore, evaluation of mortality and injury to the larger fish provides a "worst-case" answer since smaller fish may be affected to a lesser degree. In addition, rainbow trout greater than 400 mm FL comprised over 50% of all samples captured with electrofishing during 1987 (Lafferty 1989).

A single hypothesis was tested: the cumulative effects of short term mortality and serious internal injury for large fish occur in less than 15% of the sampled fish. A sample of 45 large rainbow trout were to be captured and held in net pens for 96 hours. Rainbow trout less than 400 mm were also held in the pen, but were not to be sacrificed. No control sample was taken.

The desired sample was obtained, but unfortunately, a large number of fish escaped from the pens during the holding period when water levels rose above the top of the holding pen. The pens were covered with a tarpaulin, but were not sealed to prevent escape. Water levels did not rise until at least 48 hours after capture. Confidence in results is compromised due to the escape of a large part of the sample. However, we have attempted to offer an interpretation of how this loss could have affected each conclusion.

Results

Short term mortality was noted and internal injury was examined in test fish remaining in net pens after 96 hours from the time of capture.

Short Term Mortality:

Seventy-two rainbow trout were captured and put into the pens. At the end of 96 hours, a total of 41 rainbow trout were still accounted for, either through mortalities or at large in the pens. Ten fish, or 14% of the total sample of 72 fish, died within 96 hours (Table 2). Mortalities were not related to size ($D = 0.25$, $P = 0.55$; Figure 2) although sample sizes were small and mortalities do not appear to be evenly distributed over all size categories. Mortality declined over time and 70% of the mortality occurred within 48 hours (Figure 3).

Twenty-four percent of the rainbow trout had brands at the time of capture. The incidence of brands was not related to fish size ($D = 0.22$, $P = 0.45$; Figure 4) although again, sample sizes were small. No brands were evident at the end of the 96-hour holding period. Of the fish that remained alive in the pens, a total of three rainbow trout (of the original 17) were recorded as having brands at the time of capture.

All of the fish that remained alive in the pens at the end of the 96-hour holding period appeared lively and in good condition. The holding pens were placed in the river with a slight current and all of the fish were actively holding their position. Fish that escaped over the top of the pens when the water rose can be assumed to be actively swimming.

Internal Injury:

Thirty-two rainbow trout were examined for internal injuries (Table 2). This sample included the 10 mortalities and the 22 fish greater than 400 mm that remained alive in the pens.

Table 2. Mortality and injury rates of rainbow trout captured by electrofishing gear, Kenai River, 1989.

Mortality or Injury	Frequency	(%)
Live	69	(95.8)
Dead	3	(4.2)
Short Term Mortality[a,b]		
Live	62	(86.1)
Dead	10	(13.9)
Spinal Injuries (X-ray)[c]		
No Injury	8	(25.0)
Minor Compression	10	(31.2)
Moderate Compression	4	(12.5)
Major Compression	7	(21.9)
Dislocation	3	(9.4)
No Injury[d]	7	(31.8)
Minor Compression	8	(36.4)
Moderate Compression	3	(13.6)
Major Compression	4	(18.2)
Dislocation	0	
Hemorrhage (Autopsy)[c]		
None	8	(25.0)
Minor	8	(25.0)
Moderate	2	(6.3)
Major	14	(43.7)
None[d]	6	(27.3)
Minor	5	(22.7)
Moderate	2	(9.1)
Major	9	(40.9)

[a] 96 hours.

[b] Includes the three immediate mortalities. A total of 31 fish escaped from the pens leaving only 42 fish available for examination. The 31 escaped fish are presumed to have been alive at the end of 96 hours.

[c] Includes the 10 mortalities and 22 survivors after 96 hours, which were greater than 400 mm.

[d] Includes only the 22 survivors after 96 hours which were greater than 400 mm.

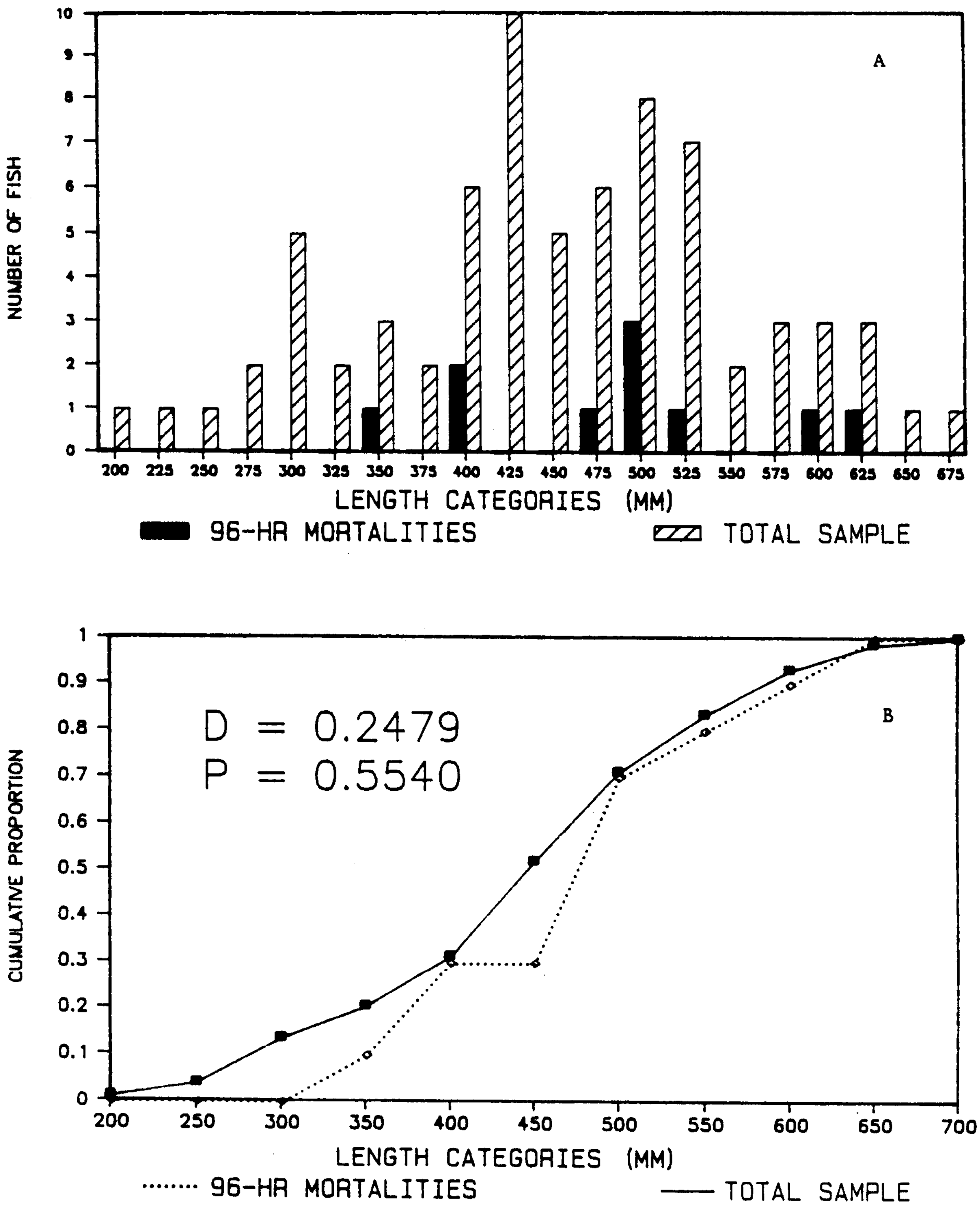


Figure 2. Length distribution of mortalities (A) and cumulative proportion of mortalities by length (B) for: (1) the total sample of rainbow trout captured with electrofishing gear; and, (2) those that subsequently died within 96 hours of capture, Kenai River, 1988.

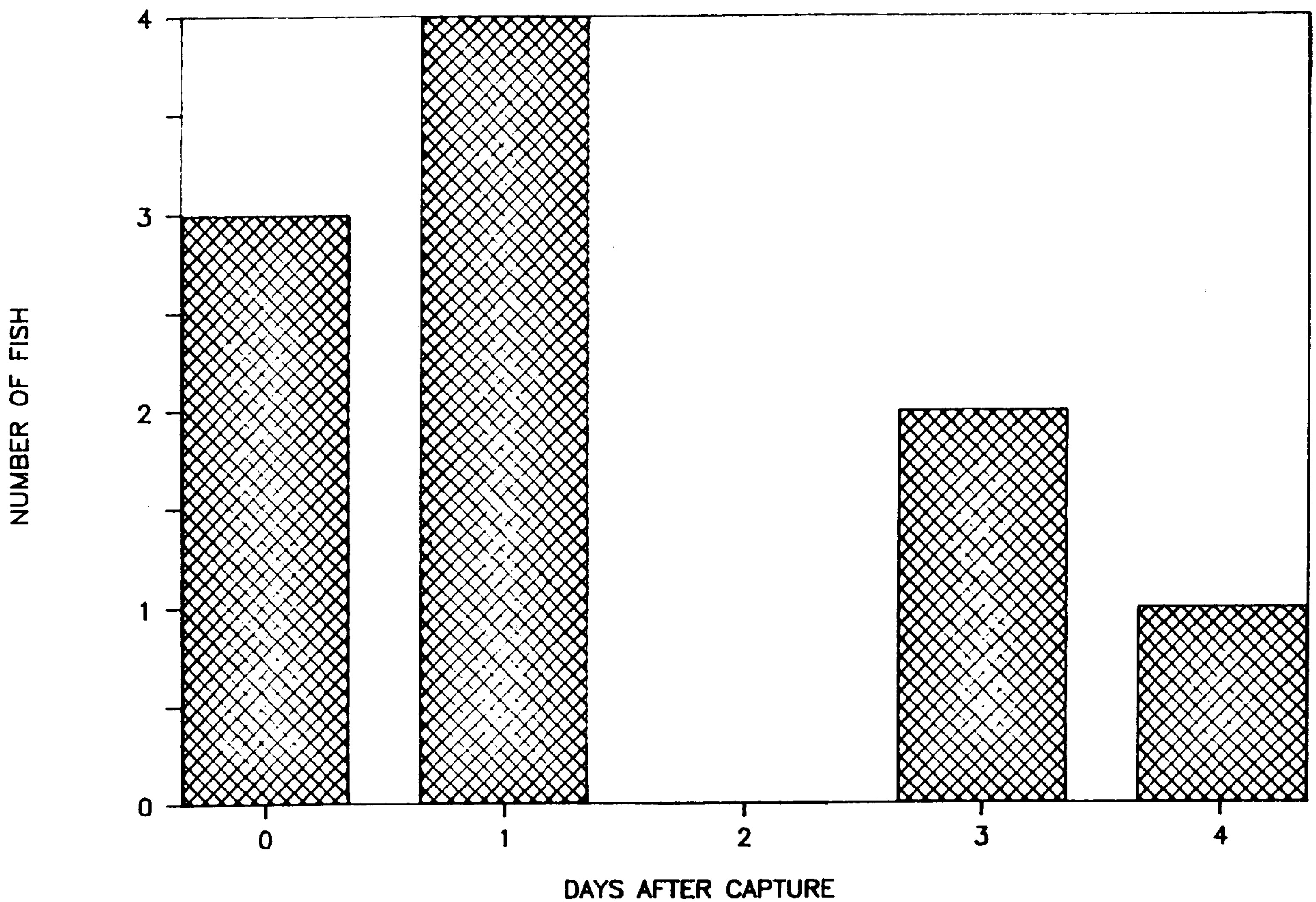


Figure 3. Mortalities over time of rainbow trout captured with electrofishing gear, Kenai River, 1988.

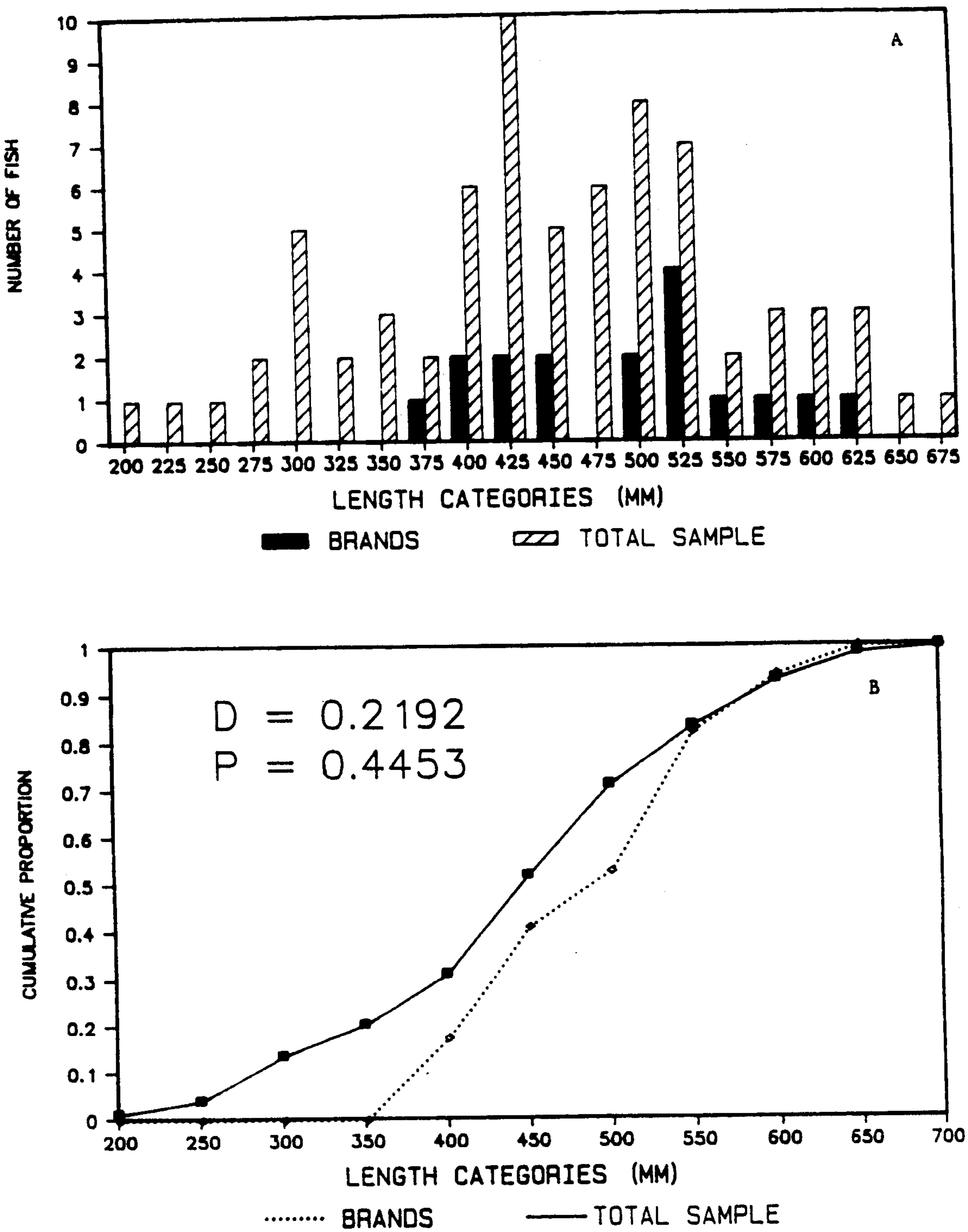


Figure 4. Length distribution of brands (A) and cumulative proportion of brands by length (B) for: (1) the total sample of rainbow trout captured with electrofishing gear; and, (2) those that received brands, Kenai River, 1988.

From X-rays, 15 of the 22 fish that were sacrificed (68%) showed some evidence of spinal abnormality. Of these, 7 (32%) were major or moderate. From the autopsies, 16 of the 22 fish that were sacrificed (73%) showed some evidence of injury. Of these, 11 (50%) were major or moderate.

Injuries described from the X-rays did not always occur in the same areas as those apparent in autopsies. Fifty-nine percent (13 fish) of the fish that did not die (22 fish) sustained some type of major injury (apparent in X-rays or autopsies). Of these 14 fish, four showed no evidence of a spinal hemorrhage. The appearance of these injuries and the lack of spinal hemorrhages associated with the structural defects suggest that these injuries may have been old. Therefore, 41% of the fish that did not die sustained a major injury that involved a hemorrhage. Including the mortalities greater than 400 mm FL (10%), a total of 53% of the sampled fish greater than 400 mm FL either died or received a recent major injury (Figure 5).

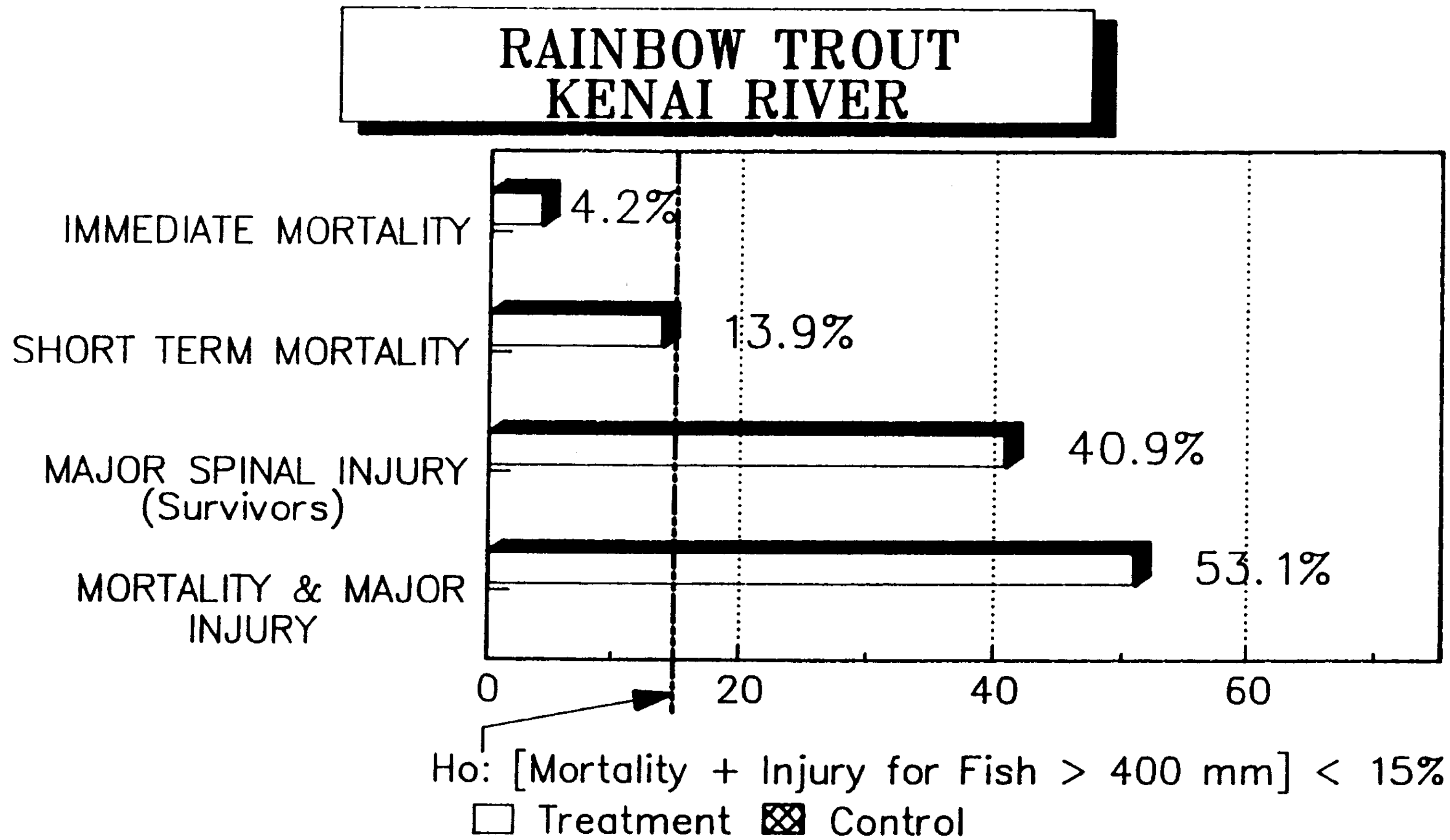
It is possible that the fish that escaped may have been in "better" shape than the fish that remained. However, even if all fish that escaped were free from internal injury, the estimated rate of internal injury that resulted in some level of hemorrhaging would have been 26%; and the rate of major internal injury that involved a hemorrhage would have been 14%. In combination with the short term mortality (14%), the total effect of death or injury would be 28% and we would still reject our hypothesis: that the cumulative effects of short term mortality and serious internal injury for large fish occur in less than 15% of the sampled fish.

Discussion

Since fish did not escape until at least 48 hours into the experiment, and no recent mortalities were found of the fish that remained in the pens, we do not believe that these conclusions are seriously compromised by the loss of fish. Observations indicate that the fish that remained in the pen were lively enough to have escaped and we doubt that the escaped fish were injury-free. Sharber and Carothers (1988) saw no behavioral cues that would indicate spinal damage.

These results are similar to those of Sharber and Carothers (1988). However, several major questions remain unanswered. First, to what extent are spinal aberrations the result of causes other than electrofishing (i.e. natural, hook and line, handling)? The lack of a control group in this experiment does not allow us to answer this question. While we doubt that spinal hemorrhaging is caused to any degree by factors other than electrofishing, it is possible that some of the hard tissue damage is the result of other factors. For instance, Sharber and Carothers (1988) present an example of vertebral compression which they attribute to natural causes. Vertebral compression without associated hemorrhages comprised 20% of the observed injuries of fish that did not suffer short term mortality.

To what extent are these results applicable to other populations of rainbow trout? Since our results primarily pertain to fish greater than 400 mm, we suspect that our results are applicable to populations of rainbow trout that are comprised of a significant proportion of large fish. This conclusion is



CONCLUSION: Reject Null Hypothesis.
Electrofishing has significant, detrimental impact on large rainbow trout.

Figure 5. Summary of effects of electrofishing on large rainbow trout, Kenai River, 1988.

supported by the work of Sharber and Carothers (1988). We are unable to determine if populations of smaller rainbow trout would be similarly affected.

Finally, to what extent do these internal injuries affect long term survival and growth? To fully evaluate this question, it would be necessary to tag and sample a large number of fish by electrofishing and some other capture method in a given year, and then estimate survival and growth of these fish the following year. We were able to obtain a preliminary answer to the question of survival from voluntary returns of sport-caught fish. In 1987, sampling occurred with both electrofishing and hook and line in the same section of river in which the 1988 sampling occurred[1]. A total of 994 fish were caught with electrofishing and 412 fish were caught with hook and line. The distribution of lengths from these two samples were not significantly different ($\alpha = 0.05$, $D = 0.07$). A total of 27 tagged fish from these samplings were voluntarily returned by anglers during 1988 of which 18 were originally caught by electrofishing and 9 were originally caught by hook and line. These rates of return are not significantly different ($\chi^2 = 0.216$; $P > 0.975$). Similarly, we compared the rate of voluntary tag returns by gear type that were recovered during 1989; 2 years after tagging. A total of 15 tagged fish were recovered of which 9 were originally caught by electrofishing and 6 were originally caught by hook and line. Again, these rates of return are not significantly different ($\chi^2 = 0.837$; $P > 0.75$). Since it was not possible to obtain accurate measurements of length from voluntary angler returns, we were unable to assess growth. However, we did compare the length distribution of the fish that were voluntarily returned in 1988, as measured in 1987 at the time of tagging, to the original length distributions by gear type. While small sample sizes preclude a definitive analysis, the length distributions of returns were evenly distributed around the modal lengths for both gear types and it does not appear that survival to the creel for either gear type was a function of length. Despite the alarming conclusions regarding the immediate and short term effects of electrofishing in this experiment, the cumulative effects of mortality and injury on survival, both 1 and 2 years after sampling, were not obviously different between electrofishing and hook and line.

CHAPTER 2 - ARCTIC GRAYLING

Introduction

Arctic grayling (hereafter referred to as grayling) support the largest fisheries on native species in interior Alaska. Electrofishing gear has been used by ADFG as the major sampling tool for grayling since 1968. Electrofishing has proven to be the most effective method by which large numbers of grayling can be captured during the summer months. Electrofishing is employed on an annual basis for population monitoring, abundance estimation, and estimation of various dynamic rates of grayling in several rivers and lakes in central Alaska. Because of the widespread use of electrofishing, the

[1] This section of river is a sampling site established by Lafferty (1989), 16 km in length, and bounded by Jim's Landing and the confluence of the Russian River.

possibility of harmful effects are greater for grayling than for any other species. Thus, studies were designed to evaluate immediate mortality, short term mortality, injury rates, and long term mortality rates.

Methods

Experiments to evaluate the effects of electrofishing on grayling were conducted in four locations: the Chatanika, Gulkana, and Delta rivers and Fielding Lake (Table 1, Figure 1). The Chatanika River flows southwesterly to the Tanana River (Figure 6) and is typical of clear runoff streams in which much of the Department's electrofishing sampling occurs. ADFG has monitored the grayling population of the Chatanika River since 1983. The Gulkana River, currently the largest grayling fishery in Alaska (in terms of harvest), flows south from Summit and Paxson lakes and drains into the Copper River (Figure 7). Tagging studies were initiated in 1986 to evaluate grayling stock status and migration patterns. The Delta River serves as the primary outlet of the Tangle Lakes system. It flows north and drains into the Tanana River (Figure 6). The Delta River was chosen as a study site because prior sampling (Baker 1989) showed that large numbers of grayling could be captured using control gear (hook and line and seine) and because no electrofishing had been conducted on the Delta River since 1974. Fielding Lake is an alpine lake located in the Alaska Range near the Delta River (Figure 8). It supports a grayling sport fishery and ADFG has conducted mark-recapture population experiments there since 1986.

Experiments were conducted to estimate: (1) short term mortality and injury rates, and (2) long term survival and growth. In each experiment, these parameters were estimated for fish caught with electrofishing and tested against a control group.

Short Term Mortality and Injury:

Four hypotheses were tested (Table 1):

1. immediate mortality rate of grayling caught with electrofishing gear equals immediate mortality rate of grayling caught with control gears (either hook and line, seine, or fyke traps);

2. short term mortality rate (0-7 days) is equal between grayling caught with electrofishing and control gears;

3. the rate of electrofishing caused injury (defined as spinal injury combined with spinal hemorrhage at the same location) is equal between grayling caught with electrofishing and control gears; and,

4. cumulative effect (defined as mortality plus electrofishing caused injury) is equal between grayling caught with electrofishing and control gears.

Short term and injury experiments were conducted in three locations: the Chatanika, Gulkana, and Delta rivers. In the Chatanika River, a total of 85 control fish were captured, primarily with beach seine (Table 3). A total of

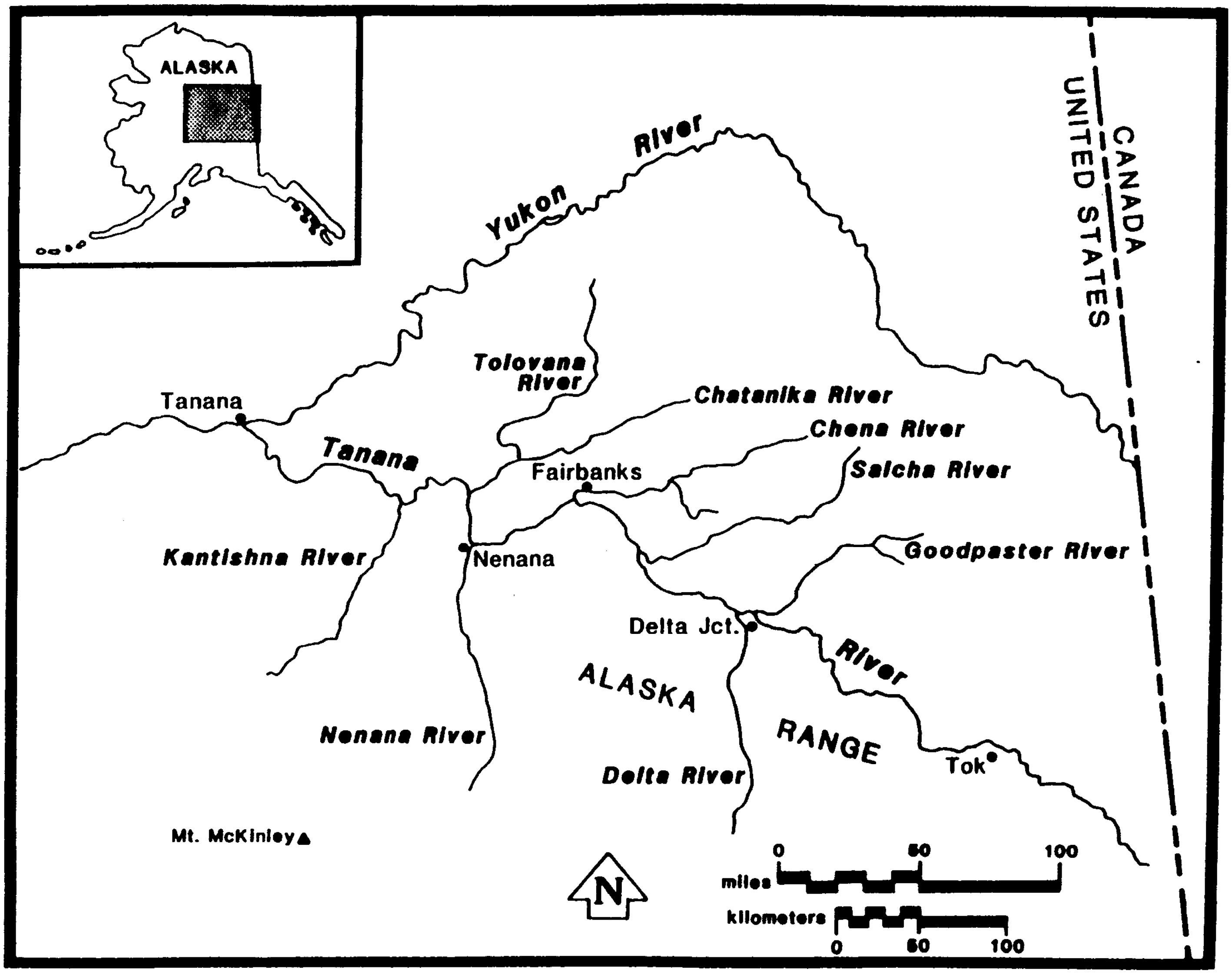


Figure 6. Tanana River drainage.

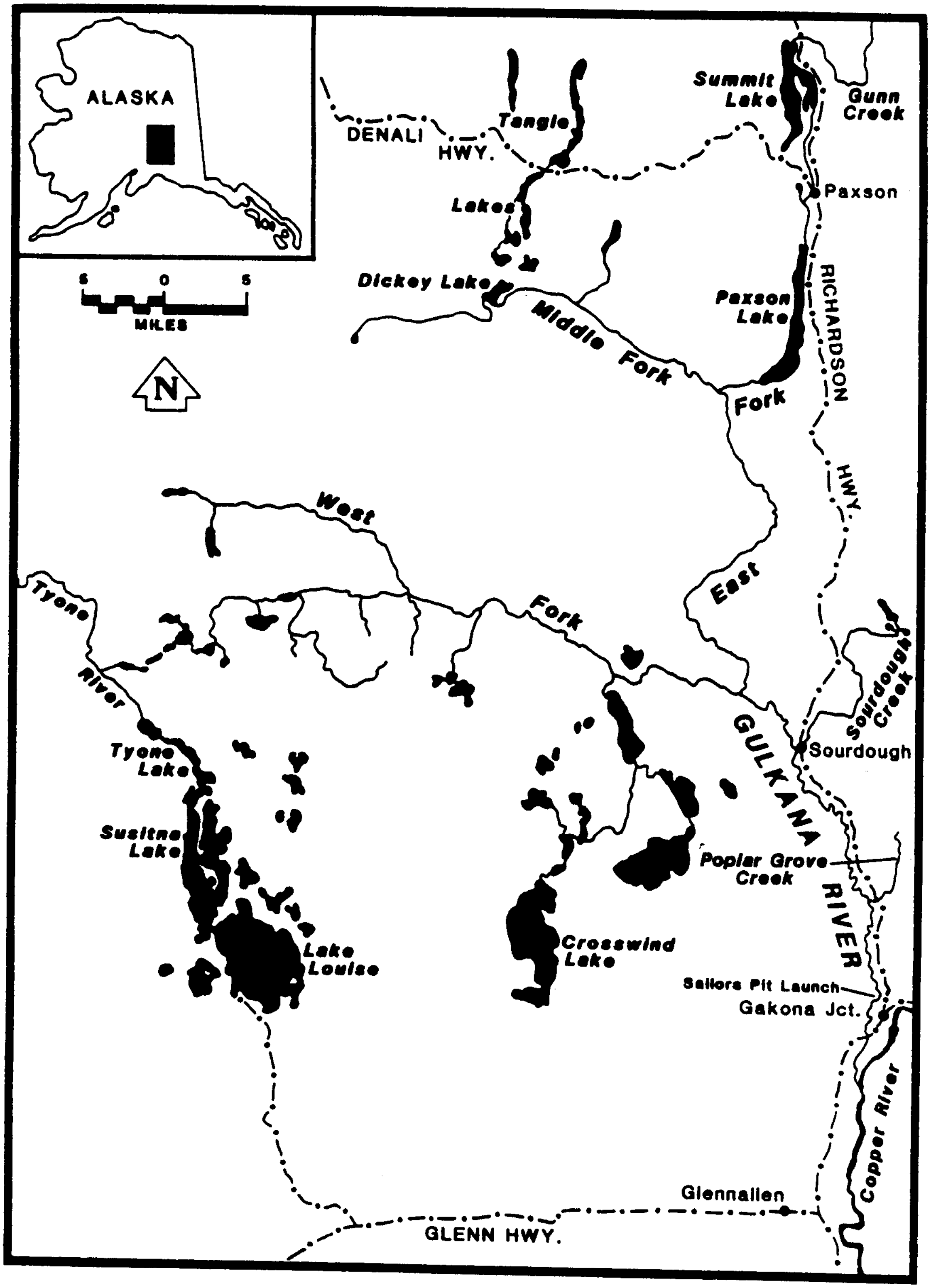


Figure 7. Gulkana River drainage.

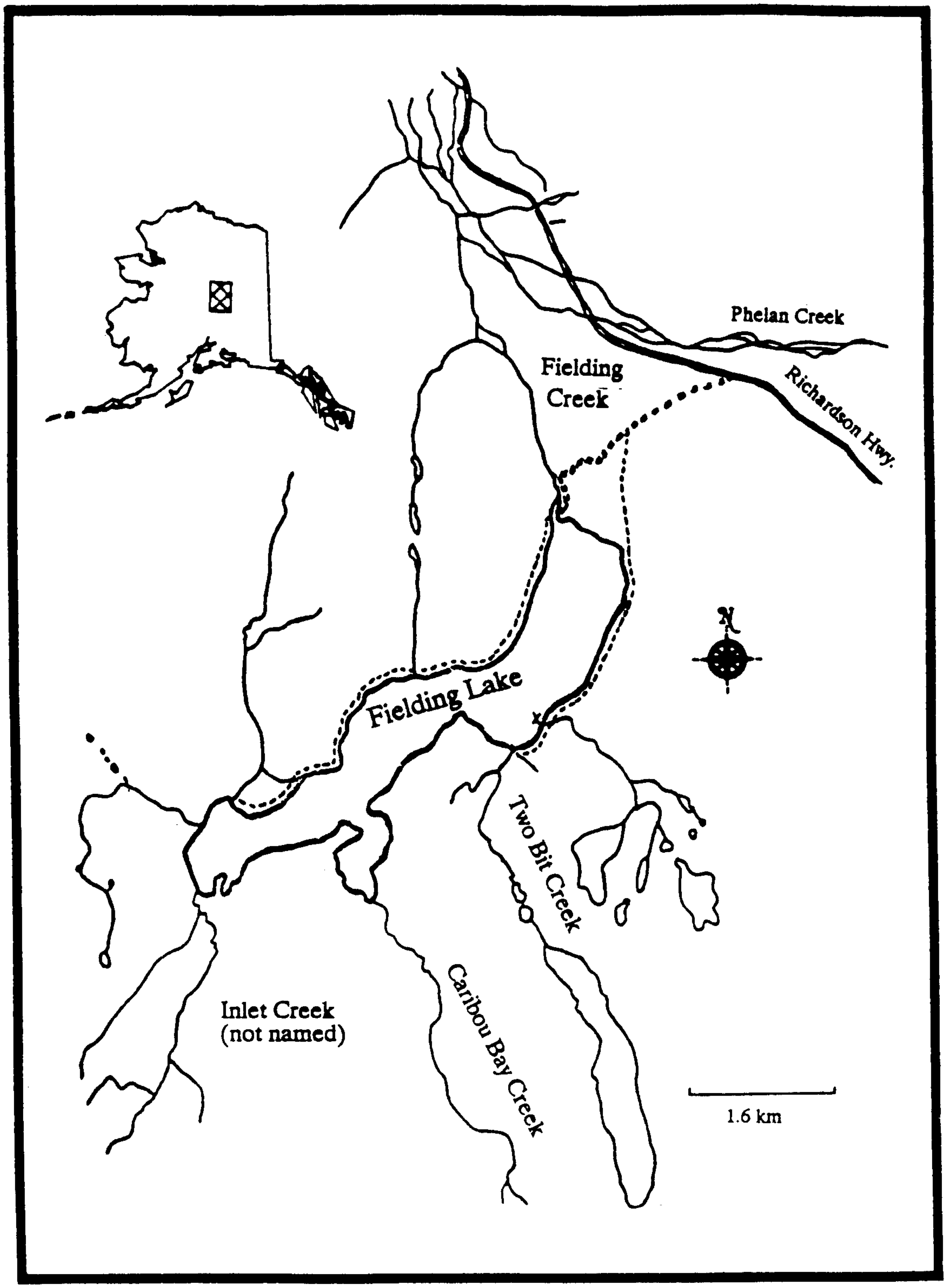


Figure 8. Fielding Lake.

Table 3. Sampling effort for experiments to evaluate the effects of electrofishing on grayling.

Location	Measured Parameter	Date	Gear	Sample Sizes		
				Tagged	Held[a]	Sacrificed[b]
Chatanika River	Immediate Mortality	8/15/88-8/18/88	Beach Seine	8	8	7
	Short Term Mortality	8/15/88-8/18/88	Hook and Line	77	77	56
	Injury of Survivors	8/15/88-8/18/88	(Total Controls)	85	85	63
		8/17/88-8/19/88	Electrofishing	103	103	62
Gulkana River	Immediate Mortality	6/22/88-6/23/88	Hook & Line	11	11	11
	Short Term Mortality		(Total Controls)	11	11	11
	Injury of Survivors	6/22/88-6/23/88	Electrofishing	88	88	88
Delta River	Immediate Mortality	8/24/88-8/24/88	Beach Seine	132	0	13
	Injury of Survivors	8/25/88-8/25/88	Hook and Line	494	0	59
			(Total Controls)	626	0	72
			Electrofishing	616	0	68
Gulkana River	Long Term Survival	7/01/87-8/31/87	Hook and Line	460		
			(Total Controls)			
			Electrofishing	1,557		
Delta River	Long Term Survival	8/01/87-8/31/87	Beach Seine	119		
	Long Term Growth		Hook and Line	435		
			(Total Controls)	554		
			Electrofishing	548		
Fielding Lake	Long Term Survival	6/01/87-6/30/87	Fyke Traps	222		
	Long Term Growth		Electrofishing	221		

[a] These fish were kept in holding pens for 7 days to estimate rates of short term mortality.
[b] These fish were sacrificed for autopsy and x-ray to estimate rates of injury.

103 test fish were captured downstream from the area where sampling for controls was conducted (Tables 3 and 4). Grayling larger than 195 mm FL were placed in a holding pen located in the Chatanika River. Sixty each of test and control group fish were randomly selected within 50 mm length classes to be X-rayed and autopsied. In addition, three control and two test sampling mortalities were also X-rayed and autopsied. X-rays and autopsies were conducted on a daily basis starting on 22 August 1988 (7 days after the first samples were taken) and ending on 31 August 1988.

In the Gulkana River, 88 grayling were captured with electrofishing gear and 11 grayling were captured with hook and line (lures were the terminal tackle) (Tables 3 and 4). Electrofishing was conducted downstream from the area where sampling for controls was conducted. Captured grayling were placed in a holding pen located in Sourdough Creek, approximately 100 m upstream from its confluence with the Gulkana River. All fish were held through 30 June 1988 (7 to 8 days) at which time they were all sacrificed for X-rays and autopsies.

In the Delta River, controls were captured with seine gear (132 fish) and hook and line gear (494 fish; Table 3). A total of 616 fish were captured with electrofishing gear (Tables 3 and 4). All captured fish were placed in a holding pen, then sampled and released at the end of the experiment. On the last day of sampling a random sample of 60 test and 61 control fish was sacrificed for X-rays and autopsies. In addition, 11 control and eight test sampling mortalities were also X-rayed and autopsied. Only the hypotheses concerning immediate sampling mortality (hypothesis 1) and electrofishing caused injury (hypothesis 3) were tested during this experiment. Fish were not held in pens for more than 2 days which did not allow us to test the hypothesis concerning short term mortality (hypothesis 2). Because fish were only randomly sampled from among survivors, the hypothesis concerning cumulative effect (hypothesis 4) could not be tested.

Length distributions for test and control group fish were tested for all three sites and were not significantly different (Figure 9). The length distributions of hook and line and seine captured control fish from the Delta River were significantly different (Figure 9). However, since only 13 seine captured fish were included in the Delta River control group, and since the analyses of test versus control group fish did not differ if these 13 fish were included or excluded, the length frequency differences between control gear types were ignored.

Long Term Survival and Growth:

Two hypotheses were tested:

1. the proportion of tag recoveries after 1 year for grayling captured with electrofishing gear equals that of fish captured with control gears; and,

2. average growth (after 1 year) of fish captured with electrofishing gear equals that of fish caught with control gears.

Table 4. Physical and electrical variables for experiments to evaluate the effects of electrofishing on grayling.[a]

Location	Water: Conductivity (μmho)	Water: Temperature (°C)	Boat Type[b]	Voltage (Volts)	Duty Cycle (Hertz)	Pulse Width (%)	Output Current (amperes)
Chatanika River	80-88	10.0-11.0	C	225-300	80	40	3.0-4.0
Gulkana River	60-88	9.3-14.5	A	175-225	40-120	40	1.7-2.5
Delta River	39-40	9.0-11.0	B	250-280	80	40	< 1.0[c]
Fielding Lake	not measured	8.0	C	200	80	40	2.0

[a] The same boat and variables were in effect for the whitefish experiment.

[b] All boats had similar hulls; VVP boxes and electrode configurations were as follows:

Boat A, Coffelt VVP-15, 220 Volt input, 600 Volt output (max), three 19.1 mm steel electrodes shielded by 101.6 mm perforated plastic pipe.

Boat B, Coffelt VVP-15, 220 Volt input, 600 Volt output (max), four 9.1 mm steel electrodes (unshielded).

Boat C, Coffelt (model unknown, manufactured 1968)), 115 Volt input, 300 Volt output (max), four 9.5 mm steel electrodes shielded by 19.1 mm flexible steel conduit.

[c] No reading was apparent on the Amp meter.

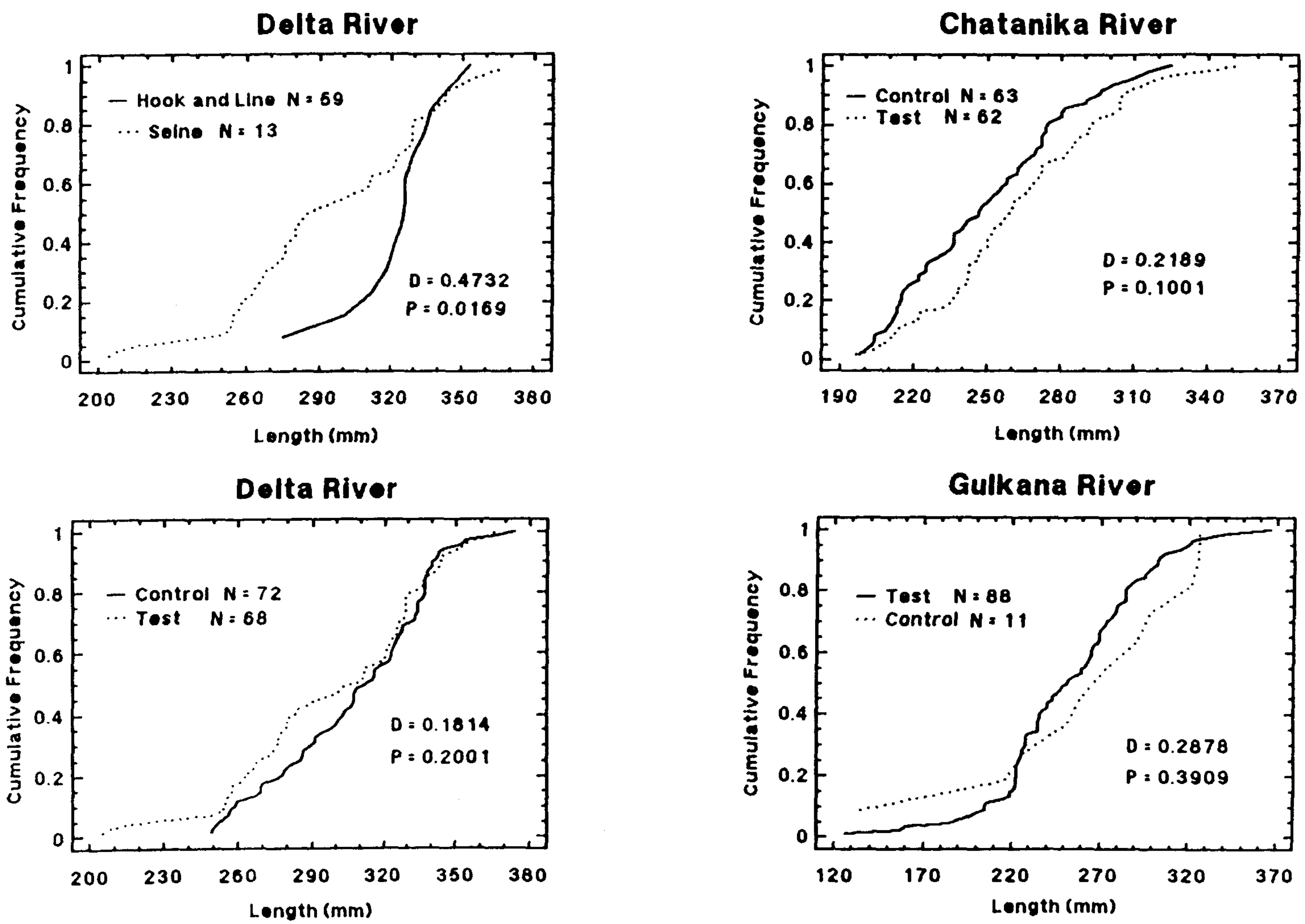


Figure 9. Length frequencies of grayling captured with electrofishing (test) gear and control gears, for short term studies, by river.

Long term survival and growth experiments were conducted in three locations: the Gulkana River, Delta River, and Fielding Lake. During 1987, a total of 1,557 grayling were captured in the Middle Fork reach of the Gulkana River with electrofishing gear (Figure 7). In addition, 460 grayling were captured with hook and line gear from the same reach and time frame (Table 3). All captured fish greater than 200 mm FL were measured, tagged, and released. The length distributions of test and control fish were significantly different (Figure 10); however, sample sizes were large and the differences were minor. Fish were recovered in May 1988 at a weir in Poplar Grove Creek, a tributary to the Gulkana River that supports a run of spawning grayling. We assumed that the contribution of Poplar Grove fish to the test and control groups in 1987 was equal.

In the Delta River, the 554 control and 548 test fish that were tagged, measured, and released in August 1988 were available for recapture 1 year later (Table 3). In August 1989, sampling was conducted in the same area using both hook and line and electrofishing. Length frequency distributions of test and control fish were significantly different (Figure 10); however, sample sizes were large and the differences in length frequencies appear to consist of only a 10 mm shift in average size. Stratifying at various lengths failed to eliminate the significant differences in length-frequency. Because test fish were (on average) larger than control fish, they would be more likely to be affected by electrofishing. Also, any bias in survival or growth due to size differences between test and control fish would favor control fish (since they were smaller, and therefore younger). Therefore, if size bias influenced any conclusions regarding survival and growth differences between gear types, the bias would make the conclusion more conservative, and favor control gear types.

In Fielding Lake during June 1987, a total of 443 grayling were tagged and released into the lake (Table 3). Of these, 222 were captured in fyke traps set off the mouths of spawning creeks and 221 were caught with electrofishing gear (Table 4) operated along the shore of the lake at night. Sampling was conducted for recaptures during June 1988 using the same capture gears. Length distributions of fish marked with control and test gears were significantly different (Kolmogorov-Smirnov Two Sample Test $D = 4.24$, $P = 0.00$). When stratified into two length classes, the length frequencies were no longer significantly different ($D = 0.20$, $P = 0.31$ for grayling greater than 299 mm FL; $D = 0.13$, $P = 0.17$ for grayling less than 300 mm FL, Figure 10). To eliminate the bias due to gear selectivity, all comparisons of recapture rates and growth were made within these two length strata.

<u>Results</u>

Short term mortality, injury and cumulative effect, and long term survival and growth of test and control fish were examined for the study areas.

Mortality:

There was no immediate mortality in either the Chatanika River or Gulkana River experiments (Tables 5 and 6) and only minimal immediate mortality for both test (1.3%) and control (1.8%) groups in the Delta River experiment

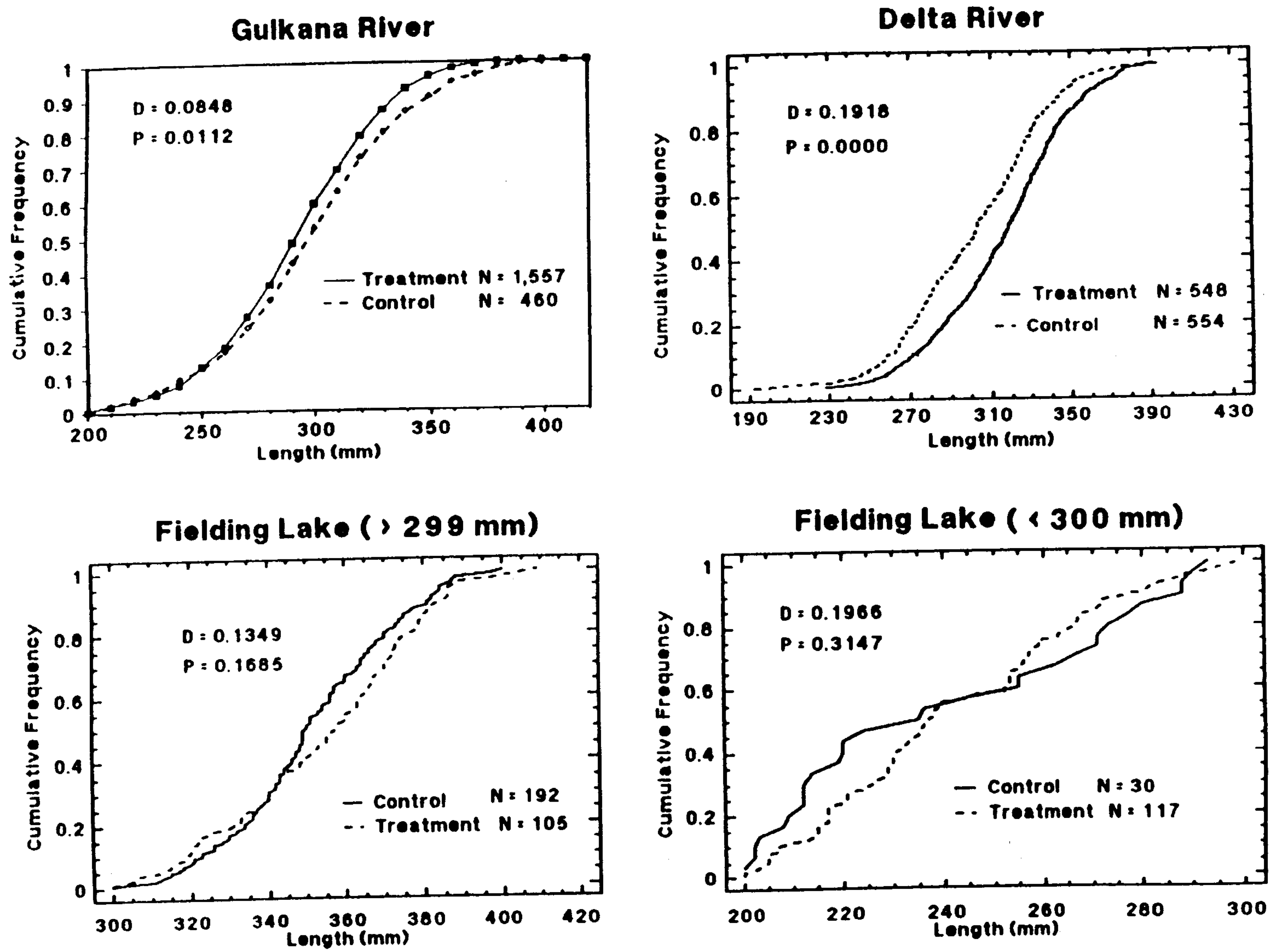


Figure 10. Length frequencies of grayling captured with electrofishing (test) and control gears, for long term survival and growth studies, by river.

Table 5. Mortality and injury rates of Arctic grayling captured by control and electrofishing gears on the Chatanika River, 1988.

Mortality or Injury Comparison	Frequency (%) Control	Electrofishing	Value of X^2	Signif. Level
Immediate Mortality				
Live	85 (100.0)	103 (100.0)		
Dead	0	0	< 0.01[a]	p = 1.00
Short Term Mortality				
Live	72 (84.7)	99 (96.1)		
Dead	13 (15.3)	4 (3.9)	6.19	p = 0.01
Live[b]	68 (94.4)	99 (96.1)		
Dead[b]	4 (5.6)	4 (3.9)	0.02	p = 0.88
Spinal Injury (X-ray)				
No injury[c]	53 (88.4)	58 (96.7)		
Minor compression[c]	0	1 (1.7)		
Moderate compression[c]	1 (1.7)	0	1.92[d]	p = 0.17
Major compression[c]	4 (6.7)	1 (1.7)		
Dislocation[c]	2 (3.3)	0		
No injury[b]	46 (88.5)	58 (96.7)		
Minor compression[b]	0	1 (1.7)		
Moderate compression[b]	1 (1.9)	0	1.73[d]	p = 0.19
Major compression[b]	3 (5.8)	1 (1.7)		
Dislocation[b]	2 (3.8)	0		
Hemorrhage (Autopsy)				
None[c]	54 (90.0)	57 (95.0)		
Minor[c]	5 (8.3)	3 (5.0)	0.48[d]	p = 0.49
Moderate[c]	1 (1.7)	0		
Major[c]	0	0		
None[b]	49 (94.2)	57 (95.0)		
Minor[b]	3 (5.8)	3 (5.0)	< 0.01[d]	p = 1.00
Moderate[b]	0	0		
Major[b]	0	0		
Electrofishing Injury[e]				
Yes	0	0		
No	60 (100)	60 (100)	< 0.01[a]	p = 1.00

-Continued-

Table 5. (Page 2 of 2).

Mortality or Injury Comparison	Frequency (%)		Value of X^2	Signif. Level
	Control	Electrofishing		
<u>Cumulative Effect</u>[f]				
Affected[c]	50 (83.3)	58 (96.7)		
Not Affected[c]	10 (16.7)	2 (3.3)	4.54	p = 0.03
Affected[b]	48 (92.3)	58 (96.7)		
Not Affected[b]	4 (7.7)	2 (3.3)	0.36	p = 0.55

[a] More than one-fifth of cell sizes are less than five.
[b] Control grayling captured on 17 August were excluded from this analysis.
[c] Entire random sample.
[d] This table was collapsed to 2 X 2 to reduce the number of cells with expected values less than five.
[e] Defined as spinal injury (determined from X-rays) combined with spinal hemorrhage (determined from autopsy) at the same location.
[f] Cumulative effect is defined as mortality plus electrofishing injury (see footnote e) to survivors.

Table 6. Mortality and injury rates of Arctic grayling captured by control and electrofishing gears on the Gulkana River, 1988.

Mortality or Injury Comparison	Frequency (%)		Value of X^2	Signif. Level
	Control	Electrofishing		
<u>Immediate Mortality</u>				
Live	11 (100.0)	88 (100.0)		
Dead	0	0	< 0.01	p = 1.00
<u>Short Term Mortality</u>				
Live	11 (100.0)	85 (96.6)		
Dead	0	3 (3.4)	< 0.01	p = 1.00
<u>Spinal Injury (X-ray)</u>[a]				
No injury	9 (81.8)	33 (37.5)		
Minor compression	1 (9.1)	34 (38.6)		
Moderate compression	0	3 (3.4)	6.15[b]	p = 0.01
Major compression	1 (9.1)	18 (20.5)		
Dislocation	0	0		
<u>Hemorrhage (Autopsy)</u>[a]				
None	11 (100.0)	64 (72.7)		
Minor	0	24 (27.3)	2.61[b]	p = 0.11
Moderate	0	0		
Major	0	0		
<u>Electrofishing Injury</u>[c]				
Yes	0	15 (17.0)		
No	11 (100)	73 (83.0)	1.08	p = 0.30
<u>Cumulative Effects</u>[d]				
Affected	0	18 (20.5)		
Not Affected	11 (100.0)	70 (79.5)	1.55	p = 0.21

[a] Entire random sample.
[b] Table was collapsed to 2 X 2 to reduce the number of cells with expected values less than five.
[c] Defined as spinal injury (determined from X-rays) combined with spinal hemorrhage (determined from autopsy) at the same location.
[d] Cumulative effects equal mortality plus electrofishing injury (see footnote c) to survivors.

(Table 7). There was no significant difference in mortality between gear types.

Short term mortality was only measured for the Chatanika and Gulkana experiments (Tables 5 and 6). In the Chatanika River, a total of 13 control and four test fish had died 7 days after capture. The rate of short term mortality for the control group (16.5%) was significantly higher than that of the test group (3.9%; Table 5). However, an inspection of mortalities demonstrated an inordinately high mortality rate for the control fish captured on 17 August (nine of 11 fish died; Appendix A1). This suggests that fish captured on 17 August underwent an additional stress not experienced by other fish in the control group. After capture, these fish were held in a live well for the majority of a day, and it is suspected that the water was not kept properly aerated. This conclusion is further supported by comparison of rates of injury among controls. There was no significant difference in rate of spinal injury or spinal hemorrhages of control fish whether fish caught on 17 August are included or excluded from the analysis (Table 5). However, if the control fish sampled on 17 August are removed from the analyses, the short term mortality rate for the control drops to 5.6% and is no longer significantly higher than the mortality rate of fish caught using electrofishing gear (Table 5).

Further evidence that sampling stress was the primary cause of death for both test and control fish in the Chatanika experiment is found in the temporal pattern of mortalities (Figure 11). Of the 13 control mortalities, 11 died on the last day of the holding experiment. All four test fish mortalities occurred on the last day of the 7-day holding experiment. This most likely occurred because of cumulative stress associated with crowding in the holding pens. Many of the fish developed fungal infections. These infections were more common in the control group (28%) than the test group (11.7%); ($\chi^2 = 4.21$, $p = 0.04$). The extra handling associated with hook and line capture and scraping of fish along the river bottom associated with seining probably explains the higher infection rate for control group fish, and may also explain the somewhat higher mortality rate suffered by the control group. There was no significant difference in incidence of hook caused injuries (defined as any injury associated with the mouth) between control fish (16.6%) and test fish (13.2%; $\chi^2 = 0.27$, DF = 1, $p = 0.06$). Thus, hook injuries were probably not a major factor in the slightly higher rate of mortality suffered by the control group. No fish, from either control or test groups, had external brands.

Short term mortality in the Gulkana River experiment was similar to that of the Chatanika River experiment in that the rate of mortalities was low (3.4% in the test group and 0% in the control group) and was not significantly different ($\chi^2 = 0.00$, $p = 1.00$; Table 6). The three mortalities from the test group were probably due to the test (as opposed to handling and holding in a pen as seen above) since all three fish died within 4 hours of capture.

The cumulative effects of all mortality were low for both test and control groups in all experiments (Figure 12). The rate of mortality for the test group was not significantly different from that of the control group for any of the experiments.

Table 7. Mortality and injury rates of Arctic grayling captured by control and electrofishing gears on the Delta River, 1988.

Mortality or Injury Comparison	Frequency (%) Control		Electrofishing		Value of X^2	Signif. Level
Immediate Mortality						
Live	615	(98.2)	608	(98.7)		
Dead	11	(1.8)	8	(1.3)	0.18	p = 0.67
Spinal Injury (X-ray)[a,b]						
No injury	58	(95.1)	23	(38.3)		
Minor compression	1	(1.6)	36	(60.0)		
Moderate compression	2	(3.3)	0		41.49[c]	p < 0.01
Major compression	0		0			
Dislocation	0		1	(1.7)		
Hemorrhage (Autopsy)[a]						
None	53	(86.9)	45	(75.0)		
Minor	8	(13.1)	10	(16.7)	2.06[c]	p = 0.15
Moderate	0		4	(6.7)		
Major	0		1	(1.7)		
Electrofishing Injury[a,d]						
Yes	0		11	(18.3)		
No	61	(100)	49	(81.7)	10.18	p < 0.01

[a] Fish randomly sampled from survivors only.

[b] X-rays from three control fish were unreadable and were excluded from this analysis.

[c] Table was collapsed to 2 X 2 to reduce the number of cells with expected values less than five.

[d] Defined as spinal injury (determined from X-rays) combined with spinal hemorrhage (determined from autopsy) at the same location.

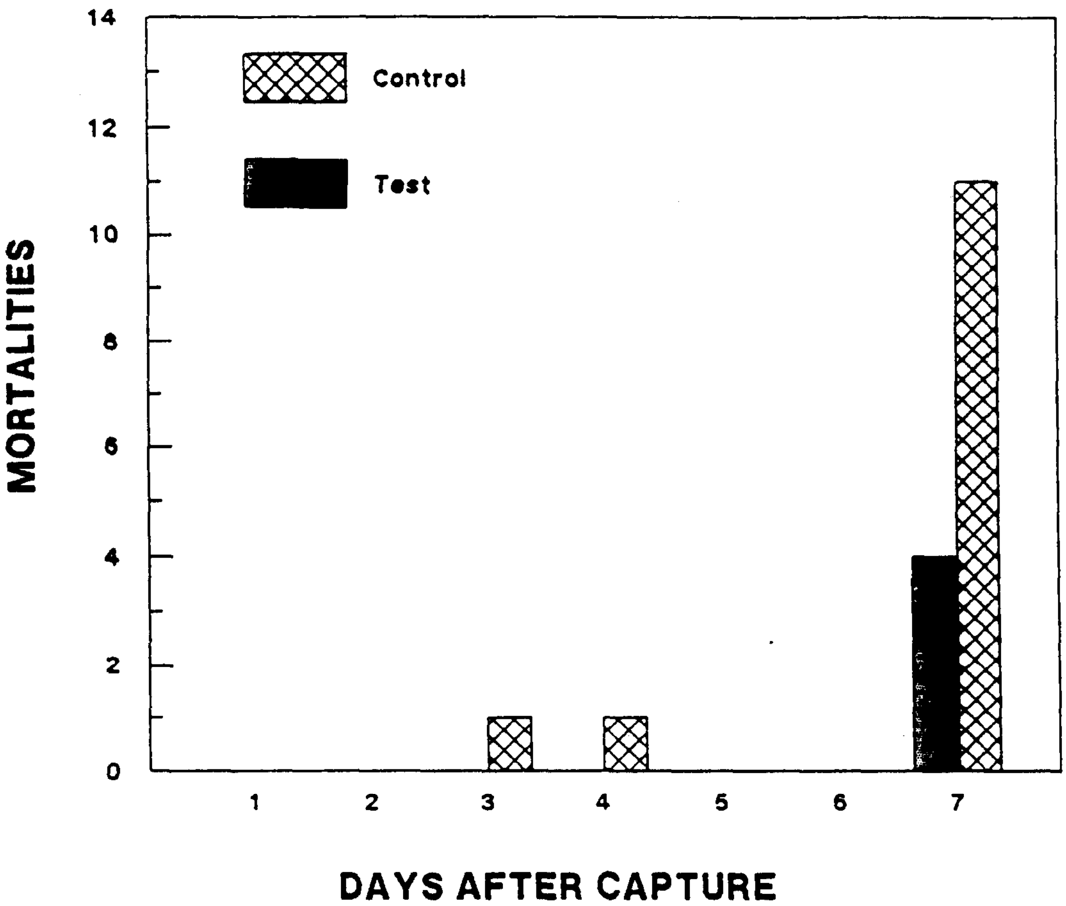


Figure 11. Short term mortality by day after capture for test and control fish, Chatanika River.

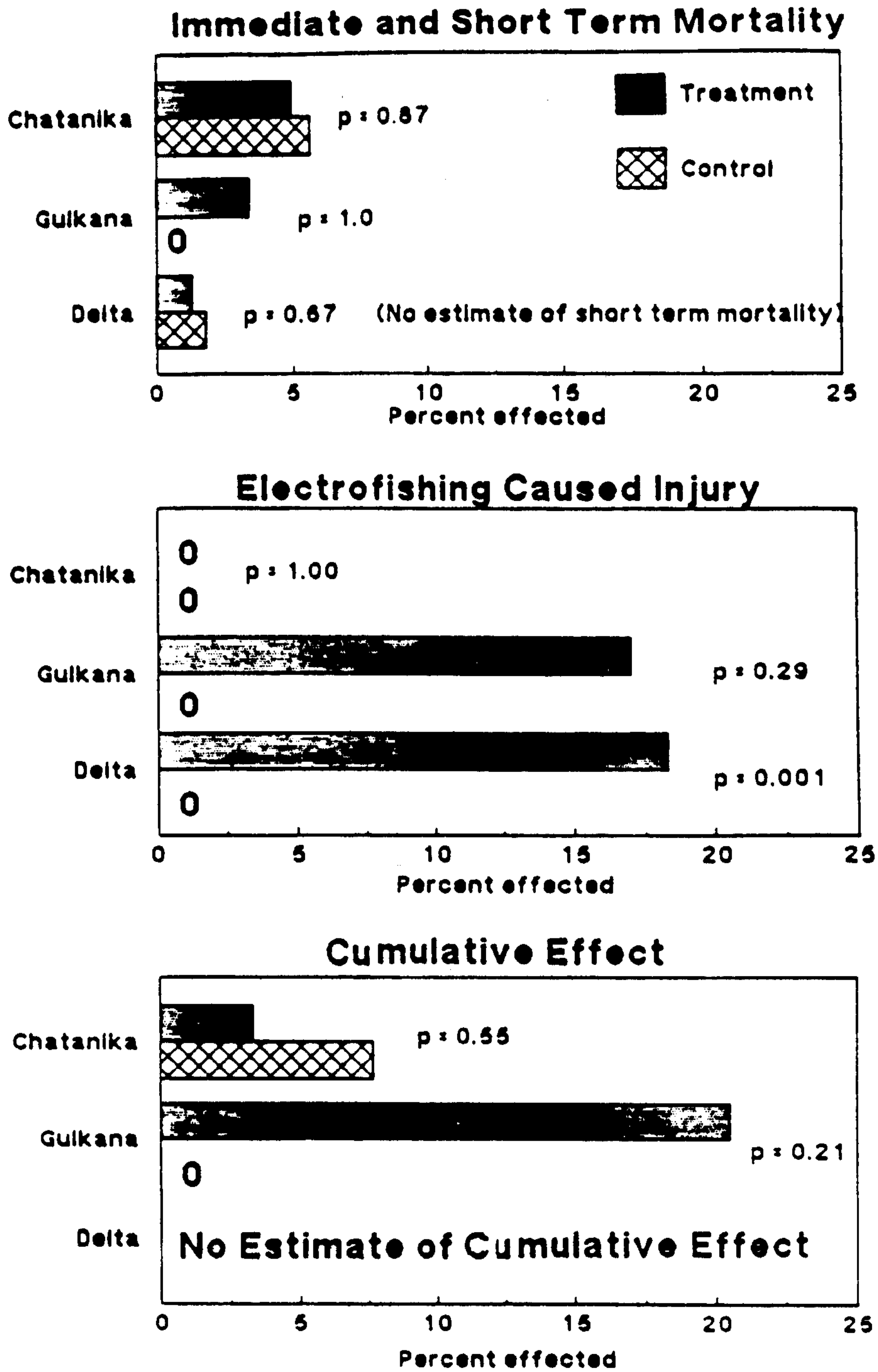


Figure 12. Summary of short term effects of electrofishing in grayling by river.

Injury and Cumulative Effect:

The rate of spinal injury of survivors varied considerably across the three experiments (Appendices A1-A3, Tables 5-7, and Figure 12). In the Chatanika River, seven of 60 control fish (11.6%) had some type of spinal abnormality. The rate of spinal injuries apparent in X-rays of test fish was considerably less (3.4%; Table 5). Hemorrhaging associated with the spine was also more common in control (10%) than test fish (5%); however, these differences were not significant (Table 5). Not all hemorrhages were associated with the spinal column and none occurred in fish that had spinal abnormalities (Table 5; Appendix A1). These injuries could have occurred during any state of the handling, however, they probably are an indication of the stress associated with sampling by each method.

Only two of the control fish with spinal injuries also had spinal hemorrhages (Appendix A1). However, in each case, the hemorrhage was located in a different area of the spine from where the X-ray abnormality occurred. None of the three test fish that had spinal injuries had an associated hemorrhage. The lack of associated hemorrhages in both test and control fish indicates that spinal injuries were either natural deformities or the result of past injuries that had healed. Examination of X-rays indicated that five spinal injuries in the control group were naturally occurring deformities while two spinal injuries of test fish were natural deformities. These injuries were excluded from analysis. Because there were no associated hemorrhages, the other abnormalities were considered old injuries that have healed. The autopsy data on spinal hemorrhages, in combination with an associated spinal deformity, are considered the best measure of injury due to electrofishing (Figure 12).

In the Gulkana River, varying degrees of spinal compression were observed in the X-rays on 55 of the 88 test fish (62.5%), while three of the 12 control fish (18.2%) had spinal injuries. The difference in these injury rates was significant (Table 6), although sample size for the control group was very small. Two of the control fish with spinal injuries had been captured in 1987 using electrofishing gear (tag recoveries) and may have received the injuries at that time. Three other control fish were also recaptures from the 1987 study (captured with electrofishing gear); they had no spinal injuries. The majority of spinal injuries were rated as minor and usually occurred from the area between the posterior attachment of the dorsal fin to the adipose fin.

Test fish also had a significantly higher rate of spinal hemorrhages than did control fish (Table 6). Twenty-four test fish (27.3%) had spinal hemorrhages (all rated as minor), while no hemorrhages were observed in the control fish. Eight additional test fish had hemorrhages associated with the dorsal musculature (Appendix A2). While the spinal hemorrhages were small and localized, two of the musculature hemorrhages extended over a large area. Twenty of the spinal hemorrhages occurred in fish with observable spinal injuries (from X-rays), and 15 of these hemorrhages occurred in the same area of the spine as the spinal injury. The injuries of these 15 fish, 17% of the sample, are assumed to have been caused by electrofishing. These fish averaged 230 mm FL (SE = 9.1). The entire sample of fish caught by electrofishing averaged 251 mm FL (SE = 4.7). These lengths were not significantly different ($t = 1.88$; $P > 0.05$).

Four test fish (4.6%) showed external signs of spinal curvature (scoliosis) while no similar physical changes were observed for the control fish; however, these differences were not significant (χ^2 = 0.57, df = 1, P = 0.50). Scoliosis was observed in the X-rays of 10 (11.5%) test fish while one fish (8.3%) in the control group showed spinal curvature. These differences were not significant (χ^2 = 0.11, df = 1, P = 0.75).

Brands were observed on 14 test fish (16.1%) when placed in the holding pen but all brands had disappeared by the end of the experiment. All 14 fish had associated spinal injuries which is significantly more than would be expected (χ^2 = 6.65, df = 1, P = 0.01).

In the sample from the Delta River, spinal abnormalities apparent in X-rays occurred in three of 61 control fish (4.9%) and in 37 of 61 test fish (61.7%). The rate of injury in test fish was significantly higher than that in control fish (Table 7). All but two of the spinal injuries of test fish were rated as minor (Table 6). Hemorrhages associated with the spine occurred in 13.1% of control fish and 25% of test fish. All eight hemorrhages of control fish were rated as minor whereas four of the 15 hemorrhages of test fish were rated moderate, and one was considered major (Table 7). However, the overall occurrence of hemorrhages associated with the spine was not significantly different for control and test fish (Table 7).

Eleven of the 15 test fish with spinal hemorrhages had associated spinal injuries that were apparent in X-rays (Table 7). Four of the test fish with spinal hemorrhages and all of the hemorrhages of control fish had no associated spinal injury (Table 7). Only one fish (test group tag number 84397) had a major spinal injury (dislocation at vertebrae 21-23). This same fish was also the only one to have a major spinal hemorrhage (vertebrae 20-24). Not all hemorrhages were associated with the spinal column and many did not occur in fish that had spinal abnormalities (Appendix A3). Injuries to the 11 fish with both spinal hemorrhages and spinal abnormalities (18.3% of the sample) were assumed to be caused by electrofishing (Figure 12). The average length of fish with injuries (304 mm FL; SE = 7) did not differ significantly from that of the entire sample (310 mm FL; SE = 4; t = 0.71; P < 0.40).

One hundred sixty-three test fish (26.5%) had a "brand" (no control fish had brands). Eighteen of 47 test fish with spinal injuries had associated brands (38.3%). This is significantly higher than would be expected from the population as a whole (χ^2 = 3.04, df = 1, P = 0.08), again indicating that branding is an external indicator of possible spinal injury due to electrofishing.

Long Term Survival and Growth:

Eleven of the 12 grayling recaptured in Poplar Grove Creek in 1988 were originally captured in the Middle Fork reach in 1987 using electrofishing gear (0.71% recapture rate); one of the recaptures was collected in 1987 using hook and line gear (0.22% recapture rate). The difference in these recapture rates was not significant (χ^2 = 1.44, df = 1, P = 0.23) although sample sizes were small (Figure 13). Too few fish were recaptured to compare growth rates between the two capture techniques.

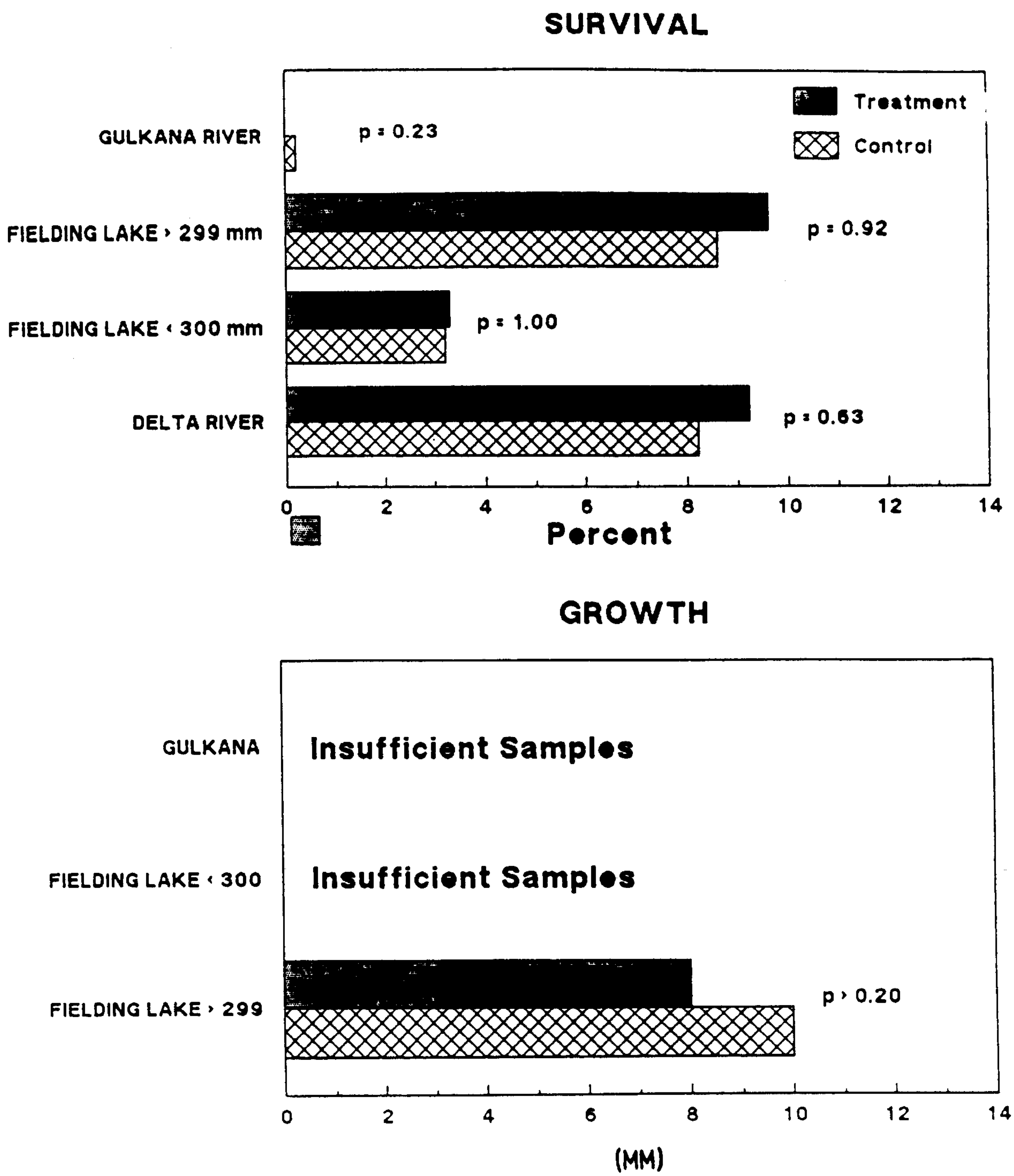


Figure 13. Summary of long term survival and growth of test and control grayling, by area of study.

In Fielding Lake, 11 of 29 grayling (> 299 mm FL) recaptured in 1988 were originally captured in 1987 using electrofishing gear (9.6% of those originally marked with electrofishing gear); 18 were captured in 1987 using fyke nets (or 8.6% of those originally marked with fyke traps). The difference in these recapture rates was not significant ($\chi^2 = 0.01$, df = 1, P = 0.92) which indicates that survival of large fish (> 299 mm FL) over a period of 1 year was not significantly different between fish caught using the two gear types (Figure 13). Because of gear selectivity, only five recaptures were obtained for fish that were less than 300 mm FL when tagged. The rates of return for fish marked with electrofishing gear (3.3%) and those marked with fyke nets (3.2%) are virtually identical.

All fish recaptured using fyke nets were greater than 270 mm FL; fish recaptured using electrofishing gear ranged from 215 to 382 mm FL. To compare the average growth increment of fish captured by the two gear types, similar length frequencies are required. The length structure of fish larger than 300 mm FL caught using the two gear types was not significantly different (Figure 10). Therefore, average growth of only fish larger than 300 mm was compared. Between June 1987 and June 1988, the 16 recaptured fish originally caught using fyke nets grew an average of 10 mm (SE = 2); 10 recaptured fish originally caught using electrofishing gear grew an average of 8 mm (SE = 2). The difference in these average growth rates is not significant (t = 0.98, P > 0.2).

Of the 554 control fish tagged in 1988 on the Delta River, 51 (9.2%) were recaptured in 1989, and of 548 test fish, 45 (8.2%) were recaptured. This rate of return was not significantly different between gear types ($\chi^2 = 0.23$, DF = 1, p = 0.63). The average amount of growth between test and control fish was also not significantly different (t = 0.32, DF = 1, p = 0.75).

Discussion

Results were not entirely consistent across all locations (Table 8) and sampling problems, particularly small sample sizes, compromised some results. Never-the-less, the preponderance of evidence indicated that the effects of electrofishing were not significantly different from control gears. Immediate and short term mortality was negligible, and did not differ among test and control fish. Conflicting and equivocal results were realized for electrofishing-caused injuries. However, long term survival and growth did not differ between treatment and control groups.

Mortality:

Immediate mortality did not occur for either test or control gear types in the Chatanika or Gulkana studies. Immediate mortality was low for both gear types in the Delta River study, and there was no significant difference in the rates of immediate mortality between gear types (Table 7). The first hypothesis regarding immediate mortality was therefore accepted.

Short term mortality was also low in the study areas in which it was measured. In the Gulkana River, there was no significant difference in short term mortality between test and control gears. In the Chatanika River, short term

Table 8. Summary of results[a] for electrofishing experiments on Arctic grayling.

Location	Immediate Mortality	Short term Mortality	Recent Injury due to Electrofishing	Cumulative effects of Mortality & Injury	Long term Survival	Long term Growth
Chatanika	NS	NS	NS	NS	NA	NA
Gulkana	NS	NS	NS	NS	NS	NA
Delta	NS	NA	T>C	NA	NS	NS
Fielding > 299 mm	NA	NA	NA	NA	NS	NS
Fielding < 300 mm	NA	NA	NA	NA	NS	NA

[a] NS - Not Significant
NA - Not Applicable
T - Treatment
C - Control

mortality was significantly higher for control fish (Table 5). No significant difference in short term mortality between gear types was found in the Chatanika study if control fish captured on 17 August were excluded from analysis. Because mortalities among control group fish were probably due to post-capture handling stress, and because no significant differences between gear types were found if the 17 August control fish were excluded, the second hypothesis regarding short term mortality was accepted.

Many previous studies include some indication of mortality to fish due to electrofishing. Several studies (Barrett and Grossman 1988, Hudy 1985, Horak and Klein 1967, Maxfield et al. 1971) report no significant differences in mortality rates between electroshocked and control fish. Hauck (1949) reported that 26% of rainbow trout electroshocked "died as a result of electroshocking or subsequent handling"; however, no control group was used in the study. Comparisons between this study and earlier studies cited must be made with caution, since the methods used and species and size of fish used in all of these studies are different. For Arctic grayling captured with electrofishing gear normally used by the ADFG, immediate and short-term mortality rates were low, and did not differ from other commonly used gear types (hook and line or seine). Immediate mortality data from the Delta River (Table 7, Figure 12) and short-term mortality data from the Chatanika River (Table 5) further suggested that post capture handling stress made a substantial contribution to immediate and short-term mortality, and this was also suggested by Barrett and Grossman (1988).

Injury and Cumulative Effect:

Rates of spinal injury (determined from X-rays) were significantly higher for test versus control gears in both the Delta River and Gulkana River (Tables 6 and 7). The rate of spinal injury (determined from X-rays) on the Chatanika River was not significantly different between gear types (Table 5). Rates of spinal hemorrhage (determined from autopsy) were not significantly different between gear types in any of the study areas.

The rate of electrofishing caused injury (defined as spinal injury determined from X-rays combined with spinal hemorrhages determined from autopsy at the same location on the spine) was zero for both test and control groups from the Chatanika River. The rate of electrofishing caused injury was significantly higher for the test group in the Delta River study (Figure 12). Therefore the third hypothesis regarding electrofishing caused injury was accepted for the Chatanika and Gulkana rivers, but rejected for the Delta River.

The rate of cumulative effect of electrofishing (defined as mortality plus electrofishing caused injury to survivors) was not significantly different from the rate for test group fish from the Chatanika River if control fish captured on 17 August were excluded (Table 5, Figure 12). The rate of cumulative effect was not significantly different among gears on the Gulkana River. Hypothesis (3) regarding cumulative effect was accepted for the Chatanika River and Gulkana River; cumulative effect was not determined for the Delta River.

Previous studies have found highly variable rates of spinal injury from electrofishing. McCrimmon and Bidgood (1965) reported that 7.6% of rainbow trout captured by electrofishing had abnormal vertebrae, but concluded that these abnormalities were natural and not a result of electrofishing. Spencer (1967) found spinal injury (dislocated vertebrae or spinal hemorrhage) in 1.5% of bluegills *Lepomis macrochirus* exposed to direct current electroshocking. Hudy (1985) exposed rainbow trout and brook trout *Salvelinus fontinalis* to high-voltage alternating current. He reported that 21% of sampling mortalities had fractured or dislocated vertebrae and that 77% of fish appearing abnormal (burned or erratic swimming) had such injuries. However, he found that only 1% of normal fish had spinal injuries, and that less than 2.5% of fish exposed had visible abnormality. Sharber and Carothers (1988) reported that between 44% and 67% of rainbow trout captured with direct current electrofishing had damaged vertebrae.

Sharber and Carothers (1988) found that spinal injury caused by electrofishing was always accompanied by spinal hemorrhage. In this study we have defined electrofishing caused injury as spinal injury combined with spinal hemorrhage at the same location on the spine. The rates of electrofishing-caused injury for test fish varied from 0% from the Chatanika River to 18.3% from the Delta River. The high end of this range is substantially lower than reported by Sharber and Carothers (1988), but higher than reported by other previous studies (McCrimmon and Bidgood 1965, Spencer 1967, Hudy 1985). Comparisons must be made with caution, since capture gear and definitions of injury of all cited studies (except Sharber and Carothers 1988) varied substantially from those used in this study.

It is unclear why injury rates differed so much between the Chatanika River and the other two study areas. The only variable that differed a great deal between sites was the type of VVP box used on the Chatanika (Table 4). Sharber and Carothers (1988) found that different wave forms caused significantly different injury rates. It is possible that this VVP unit produces a substantially different wave form than the VVP units used on the Delta and Gulkana rivers. VVP unit wave forms were not examined in a laboratory.

The rates of electrofishing-caused injury from the Delta and Chatanika rivers could be cause for concern, except that most of the spinal injuries and almost all of the spinal hemorrhages found were minor injuries, and both immediate and short-term mortality was very low. Sharber and Carothers (1988) did not report mortality, nor did they describe the severity of the injuries they reported. The spinal injuries among control fish found in this study were probably old electrofishing injuries that have healed. Spencer (1967) reported that many fish had spinal injuries that had appeared to have healed completely. Horak and Klein (1967) reported that 39% of the fish electroshocked had burn marks, but only 5% died after a 35 day period. The best indication of the effect of electrofishing on fish populations is probably long term survival and growth.

Long Term Survival and Growth:

Recapture rates for test and control fish were not significantly different from any of the study areas (Figure 13). The recapture rate was very low for the Gulkana River, despite reasonably large initial sample sizes. Fish captured by different gear types from the Delta River had significantly different length frequency distributions (Figure 10). Because fish captured with control gear type were (on average) smaller, any bias introduced due to size differences would tend to favor control fish. This is because shorter (therefore younger) fish should have lower natural mortality and greater growth than longer fish, and because longer fish are probably affected by electrofishing more than shorter fish (Ellis 1975). Long term survival does not appear to differ between test and control groups, and the first hypothesis regarding long term survival was accepted.

Growth after 1 year also did not differ between test and control fish in the areas where sample sizes permitted testing (Figure 13). Therefore, the second hypothesis regarding long term growth was accepted. Previous studies of the effects of exposure to electroshock on growth of fish have produced varying results. Several studies (Maxfield et al. 1971, Ellis 1974, Kynard and Lonsdale 1975) found no effect on growth from a single exposure to electroshocking. Gatz et al. (1986) reported that rainbow trout exposed to repeated electroshocking had significantly lower growth rates. This suggests that the exposure to electroshocking that fish receive during normal mark-recapture experiments conducted by the ADFG probably does not adversely affect fish growth.

CHAPTER 3 - WHITEFISH

Introduction

The fastest growing sport fishery in interior Alaska is a spear fishery for whitefish, primarily humpback whitefish and least cisco. This fishery takes place during the whitefish spawning run on the Chatanika River during September and October. In 1986, ADFG initiated a population monitoring program that involved mark-recapture experiments for each of these species. Through this program, whitefish were captured using electrofishing gear. Separate experiments to evaluate the effects of electrofishing (injury, immediate mortality, and short term mortality) were conducted on humpback whitefish and least cisco. These experiments were conducted in conjunction with the grayling experiment on the Chatanika River.

Methods

Experiments were conducted to estimate short term mortality and injury rates. Four hypotheses were tested for each species (Table 1):

1. immediate mortality rate of fish caught with electrofishing gear equals immediate mortality rate of fish caught with control gear (beach seine);

2. short term mortality rate (0-7 days) is equal between fish caught using electrofishing gear and those caught using beach seine gear;

3. electrofishing-caused injury (defined as spinal injury with spinal hemorrhage at the same location on the spine) rate is equal between fish caught with electrofishing gear and those caught using a beach seine; and,

4. cumulative effect (defined as mortality plus electrofishing caused injury to survivors) is equal between fish caught using electrofishing gear and those caught using beach seine gear.

Humpback Whitefish:

From 15 to 17 August, 108 humpback whitefish were captured with beach seines, comprising the control group (Table 9). From 17 to 19 August, 278 fish were captured with electrofishing gear, comprising the test group. On the first day of electrofishing (17 August), sampling was performed only after all beach seining was completed. Water conditions and VVP setting were the same as those listed in the chapter on grayling (Table 4). All humpback whitefish captured during sampling on a given day were placed in a holding pen located in the Chatanika River (grayling and least cisco were placed in the same pen). A sample of 60 each of test and control fish was selected to be X-rayed and autopsied. Overall length distributions of control and test fish were significantly different ($\chi^2 = 8.25$, df = 2, $p < 0.03$), with larger fish being more common in the electrofishing sample. Therefore, equal numbers of test and control fish to be autopsied and X-rayed were randomly sampled within 50 mm length classes (Figure 14). X-rays were taken and autopsies conducted on a daily basis starting on 22 August 1988 (7 days after the first samples were taken) and ending on 31 August 1988.

Least Cisco:

From 15 to 17 August 1988, 48 least cisco were captured with beach seines, comprising the control group. From 17 to 19 August 1988, 118 fish were captured with electrofishing gear (Table 9), comprising the test group. Electrofishing on 17 August was conducted only after all beach seining was completed. All least cisco captured during sampling on a given day were placed in a nylon holding pen located in the Chatanika River. No difference in the length distribution of control and test fish was noted ($\chi^2 = 3.45$, df = 3, $p > 0.25$; Figure 15). All 48 control fish and a random sample of 83 test fish were X-rayed and autopsied. X-rays were taken and autopsies conducted on a daily basis starting on 22 August (7 days after the first samples were taken) and ending on 31 August.

<u>Results</u>

Immediate and short term mortality, injury, and cumulative effects in test and control fish were examined.

Mortality:

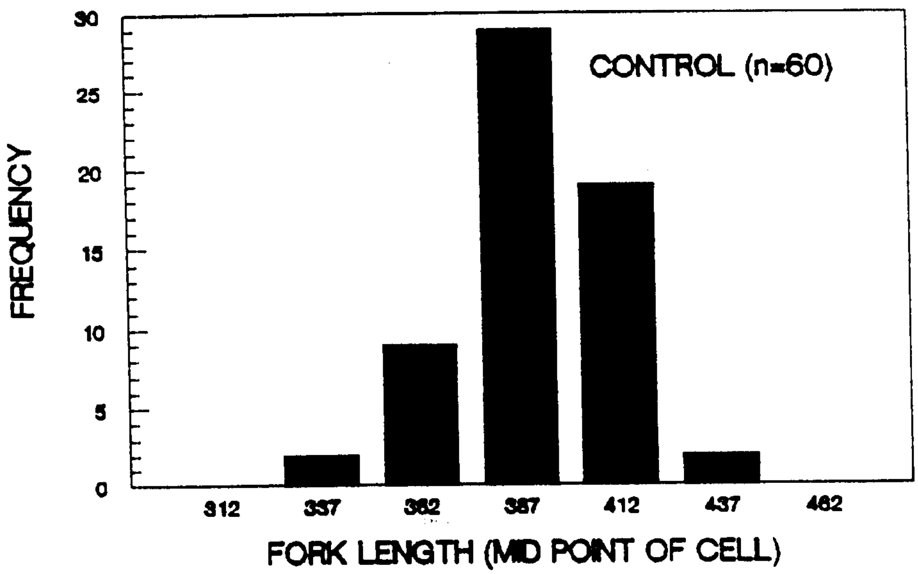
All 108 control group and 278 test humpback whitefish were captured alive. Therefore, there was no difference in immediate mortality between the two groups (Table 10). Seven days after capture, 13 control and 15 test fish had

Table 9. Sample sizes by gear type for electrofishing injury and mortality studies of humpback whitefish and least cisco from the Chatanika River, 1988.

Species	Date	Gear	Sample Sizes		
			Tagged	Held[a]	Sacrificed[b]
Humpback Whitefish	Aug. 1988	Beach Seine	108	108	60
		Electrofishing	278	278	60
Least Cisco	Aug. 1988	Beach Seine	48	48	48
		Electrofishing	118	118	83

[a] These fish were kept in holding pens for 7 days to determine rates of short term mortality.

[b] These fish were sacrificed for autopsy and X-ray to determine injury rates.



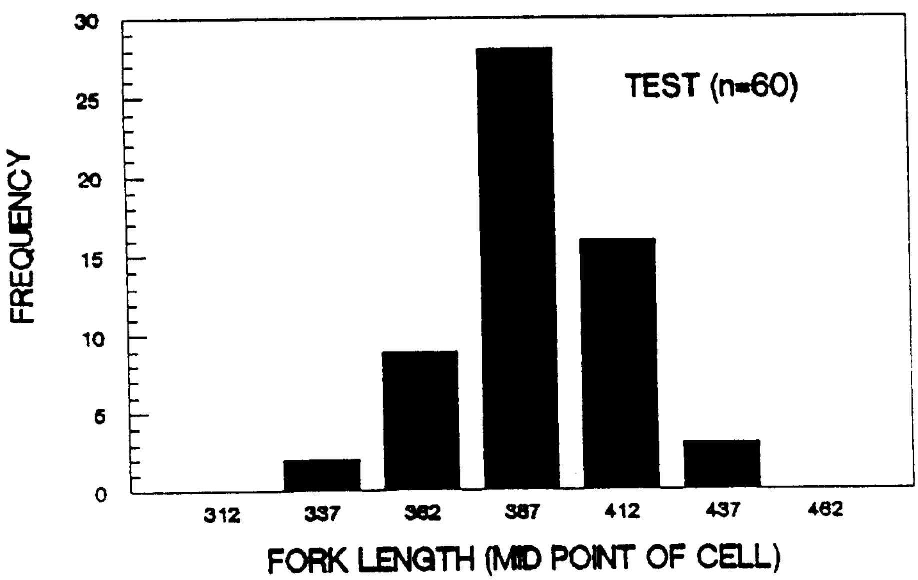
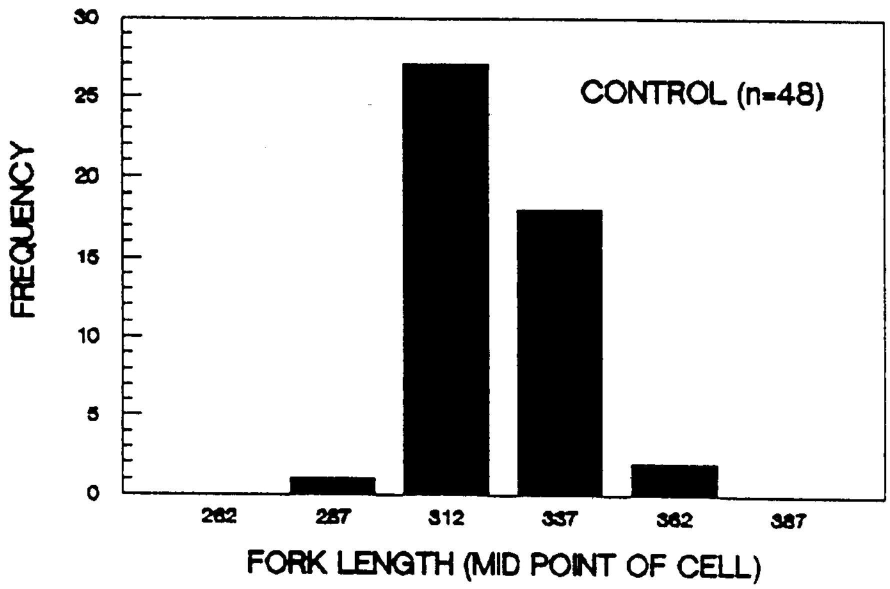


Figure 14. Length distributions of control and test humpback whitefish, Chatanika River, 1988.



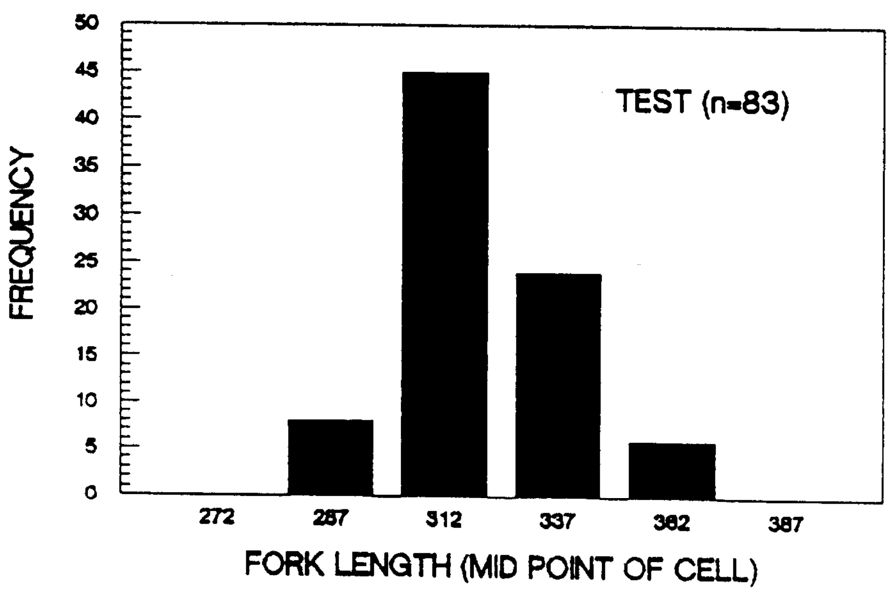


Figure 15. Length distributions of control and test least cisco, Chatanika River, 1988.

Table 10. Mortality and injury rates of humpback whitefish captured by control and electrofishing gears on the Chatanika River, 1988.

Mortality or Injury Comparison	Frequency		Value of X^2	Level of Significance
	Control	Electrofishing		
<u>Immediate Mortality</u>				
Live	108 (100.0)	278 (100.0)		
Dead	0 (0.0)	0 (0.0)	< 0.01[a]	p = 1.00
<u>Short Term Mortality</u>				
Live[b]	95 (88.0)	263 (94.6)		
Dead[b]	13 (12.0)	5 (5.4)	4.16	p = 0.04
Live[c]	108 (100.0)	267 (96.4)		
Dead[c]	0 (0.0)	11 (3.6)	3.09	p = 0.08
<u>Spinal Injury (X-ray)</u>[d]				
No injury	55 (91.7)	58 (96.7)		
Minor Compression	0 (0.0)	0 (0.0)		
Moderate Compression	2 (3.3)	2 (3.3)	0.61[a,e]	p = 0.44
Major Compression	3 (5.0)	0 (0.0)		
Dislocation	0 (0.0)	0 (0.0)		
<u>Spinal Hemorrhage (Autopsy)</u>[d]				
None	57 (95.0)	56 (93.3)		
Minor	3 (5.0)	4 (6.7)	< 0.01[a,e]	p = 1.00
Moderate	0 (0.0)	0 (0.0)		
Major	0 (0.0)	0 (0.0)		
<u>Electrofishing Caused Injury</u>[d,f]				
Not Injured	60 (100.0)	60 (100.0)		
Injured	0 (0.0)	0 (0.0)	< 0.01[a]	p = 1.00
<u>Cumulative Effect</u>[d,g]				
Not Affected[b]	55 (91.7)	56 (93.3)	< 0.01[a]	p = 1.00
Affected[b]	5 (8.3)	4 (7.7)		
Not Affected[c]	60 (100.0)	56 (93.3)	2.33	p = 0.13
Affected[c]	0 (0.0)	4 (7.7)		

[a] More than one-fifth of cells have frequencies less than five.
[b] Results from 7 days holding.
[c] Results from 3 days holding.
[d] Randomly sampled fish only.
[e] To reduce the number of cells with low frequencies, this table was collapsed to a 2 X 2 table for analysis (D.F. = 1).
[f] Defined as spinal injury (determined from X-rays) combined with spinal hemorrhage (determined from autopsy) at the same location on the spine.
[g] Defined as mortality plus electrofishing-caused injury to survivors.

died. The rate of short term mortality of control fish (12.0%) was significantly higher than that of test fish (5.4%; Table 10).

Daily mortality between test and control humpback whitefish was quite different (Figure 16). All 13 mortalities from the control group died during the last 3 days of the holding experiment. On the other hand, only four of the 15 mortalities of test fish occurred on the last 3 days, while nine fish died on the first day of the holding experiment. If mortality is associated with sampling injuries (rather than stress associated with crowding in the holding pens) a decline in numbers of fish dying over the course of the holding experiment (such as occurred with the test fish) would be expected. By redefining the length of the holding experiment to only 3 days, the rates of mortality are 4.0% for test and 0% for control fish. These rates of mortality are no longer significantly different ($\chi^2 = 3.09$, df = 1, P = 0.08).

Further evidence that mortality of controls was due to holding stress is provided by comparing rates of fungal infection. Ten of the 60 humpback whitefish from the control group (16.7%) developed fungal infections; only one fish (1.6%) from the test group developed a similar infection. The rate of fungal infection was significantly higher for fish from the control group ($\chi^2 = 6.41$, df = 1, P = 0.01).

Four of 48 least cisco from the control group (8.3%) and 12 of 118 from the test group (10.2%) died immediately during sampling (Table 11). These rates of capture mortality were not significantly different ($\chi^2 = 0.01$, df = 1, P = 0.93). Seven days after capture, 20 least cisco from the control group and 18 least cisco from the test group had died. The rate of short term mortality of controls (41.7%) was significantly higher than that of the test fish (15.3%; Table 11).

As with humpback whitefish, the patterns of mortality for least cisco during the holding experiment differed between test and control groups. All but five test fish died during sampling or on the first day after sampling (Figure 17). For controls, the number of fish dying increased throughout the holding experiment. This indicates that stress associated with holding caused increased mortality among the controls. This is further supported by the much higher rate of fungal infection suffered by control fish (22.9%) versus test fish (0%). Controls also had a higher rate of external hemorrhaging (41.7%) than test fish (29.9%), although the rates of external hemorrhaging suffered by the two groups were not significantly different ($\chi^2 = 1.71$, df = 1, P = 0.19). If mortality is associated with major injuries (rather than stress associated with crowding) a decline in numbers of fish dying over the course of the holding experiment would be expected. By redefining the length of the holding experiment to only 3 days, the rates of total mortality (immediate and short term) for controls (12.5%) and for test fish (11.1%) are no longer significantly different (Table 11).

Injury and Cumulative Effect:

Five of 60 humpback whitefish from the control group (8.3%) had some type of spinal abnormality apparent on X-rays; only two of 60 fish from the test group

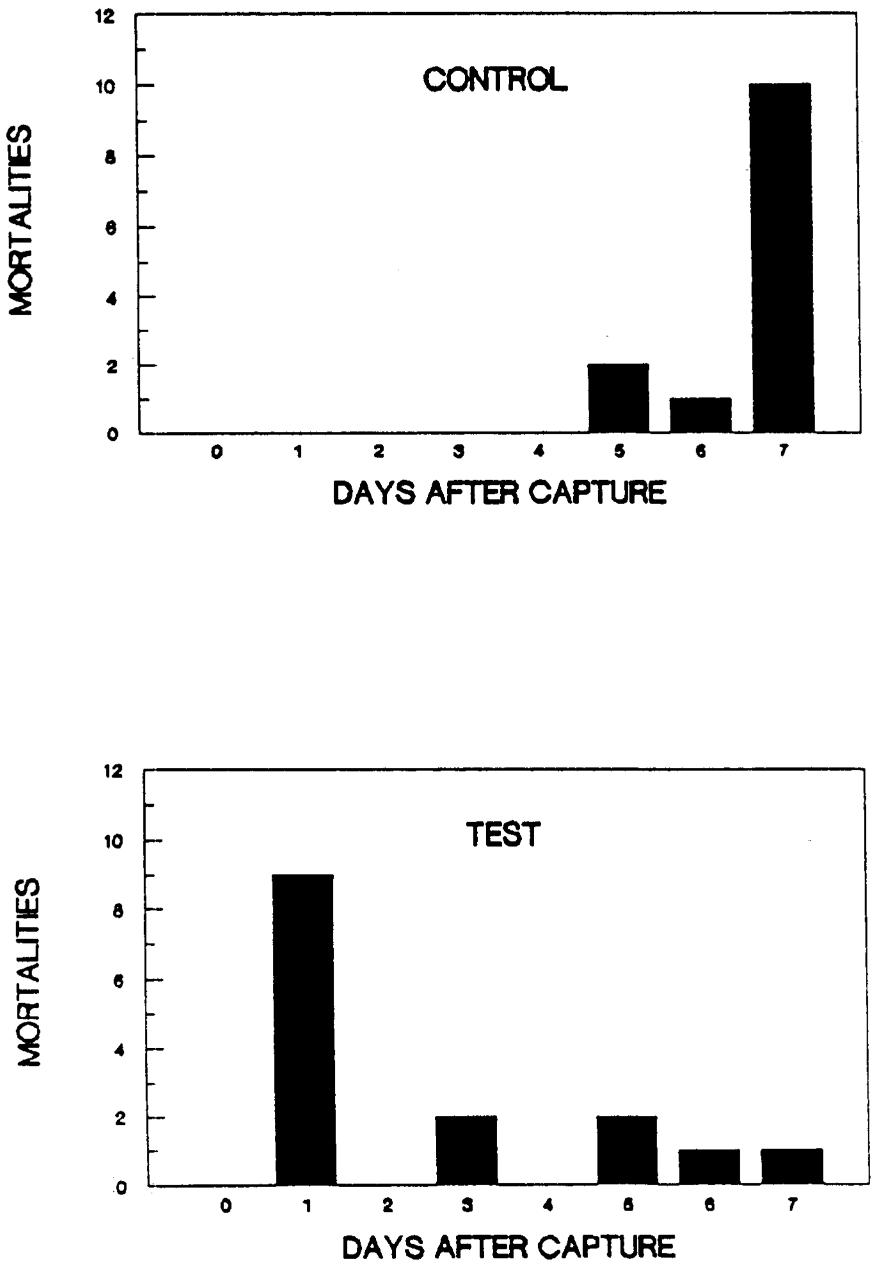


Figure 16. Mortalities over time of control and test humpback whitefish, Chatanika River, 1988.

Table 11. Mortality and injury rates of least cisco captured by control and electrofishing gears on the Chatanika River, 1988.

Mortality or Injury Comparison	Frequency Control	Frequency Electrofishing	Value of X^2	Level of Significance
<u>Immediate Mortality</u>				
Live	44 (91.7)	106 (89.8)		
Dead	4 (8.3)	12 (10.2)	0.01[a]	p = 0.93
<u>Short Term Mortality</u>				
Live[b]	28 (58.3)	100 (84.7)		
Dead[b]	20 (41.7)	18 (15.3)	12.03	p < 0.01
Live[c]	42 (87.5)	105 (89.0)		
Dead[c]	6 (12.5)	13 (11.1)	0.02	p = 0.89
<u>Spinal Injury (X-ray)</u>[d]				
No injury	47 (97.9)	79 (95.2)		
Minor Compression	0 (0.0)	0 (0.0)		
Moderate Compression	1 (2.1)	3 (3.6)	0.10[a,e]	p = 0.75
Major Compression	0 (0.0)	0 (0.0)		
Dislocation	0 (0.0)	1 (1.2)		
<u>Spinal Hemorrhage (Autopsy)</u>[d]				
None	39 (81.2)	74 (89.2)		
Minor	7 (14.6)	8 (9.6)	1.01[a,e]	p = 0.32
Moderate	2 (4.2)	1 (1.2)		
Major	0 (0.0)	0 (0.0)		
<u>Electrofishing Caused Injury</u>[d,f]				
Not Injured	60 (100.0)	60 (100.0)		
Injured	0 (0.0)	0 (0.0)	0.00[a]	p = 1.00
<u>Cumulative Effect</u>[d,g]				
Not Affected[b]	28 (58.3)	70 (84.3)	9.57	p < 0.01
Affected[b]	20 (41.7)	13 (15.7)		
Not Affected[c]	42 (87.5)	70 (84.3)	0.06	p = 0.81
Affected[c]	6 (12.5)	13 (15.7)		

[a] More than one-fifth of cells have frequencies less than five.
[b] Results from 7 days holding.
[c] Results from 3 days holding.
[d] Randomly sampled fish only.
[e] To reduce the number of cells with low frequencies, this table was collapsed to a 2 X 2 table for analysis (D.F. = 1).
[f] Defined as spinal injury (determined from X-rays) combined with spinal hemorrhage (determined from autopsy) at the same location on the spine.
[g] Defined as mortality plus electrofishing-caused injury to survivors.

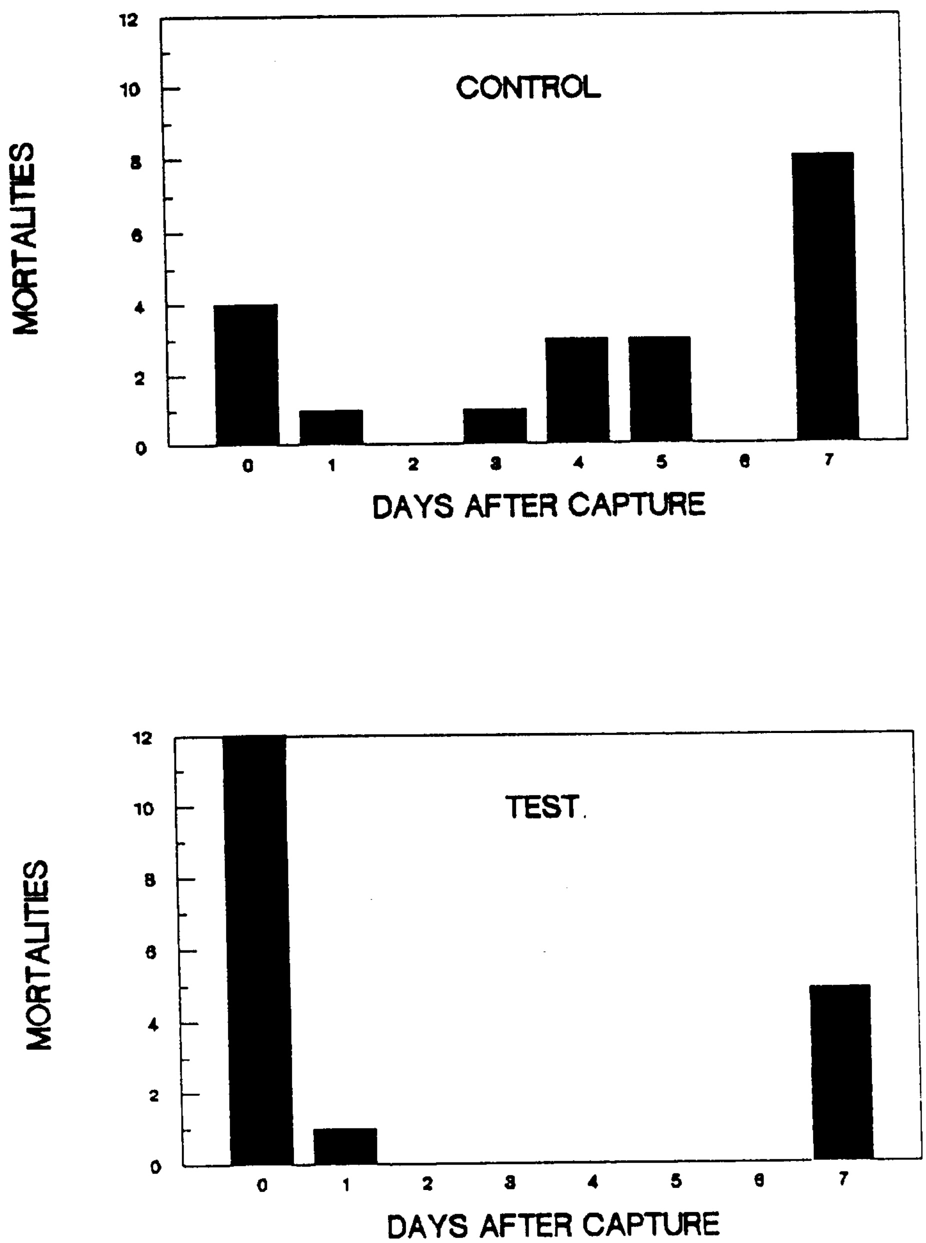


Figure 17. Mortalities over time of control and test least cisco, Chatanika River, 1988.

(3.3%) had spinal injuries (Table 10). These rates of injury were not significantly different (χ^2 = 0.61, df = 1, P = 0.44). Rates of hemorrhages associated with the spine were also not significantly different between humpback whitefish from control (5.0%) and test groups (6.7%; Table 10). None of the fish with spinal injuries had associated hemorrhages (Appendix A4). This indicates that all spinal injuries were the result of natural deformities or past injuries that had healed, and that the rate of electrofishing-caused injury was zero for both test and control gears. Five of the randomly sampled control humpback whitefish (8.3%) and four of the randomly sampled test fish (7.7%) suffered some cumulative effect of sampling; these rates of cumulative effect were not significantly different (Table 10).

Only one of 48 least cisco in the control group (2.1%) had some type of spinal abnormality; four of 83 least cisco from the test group (4.8%) had spinal injuries (Table 11). These rates of injury were not significantly different (χ^2 = 0.10, df = 1, P = 0.75). Hemorrhages associated with the spine occurred in nine control (18.8%) and nine test least cisco (10.8%; Table 11). Only one fish with a spinal injury also had a hemorrhage (test group fish tag number 92484), but the two injuries were located in different areas of the spine (Appendix A5). This indicates that all spinal injuries apparent on X-rays in both control and test group least cisco were the result of natural deformities or past injuries that had healed, and that the rate of electrofishing-caused injury was zero for both test and control fish. Twenty of 48 (41.7%) control least cisco suffered some cumulative effect of sampling, and only 13 of 83 (15.7%) test least cisco suffered some cumulative effect. The rate of cumulative effect of sampling was significantly higher for control fish than for test fish (Table 11).

Discussion

Total mortality was higher in control fish than for test fish. No difference in spinal injury was noted among test and control fish.

Mortality:

Total mortality (immediate and short term) was higher for both species of whitefish caught with the control gear than for fish caught with electrofishing gear (Figure 18). The higher mortality for control group fish was probably related to a combination of injury suffered during seining and stress associated with crowding in holding pens. The increased incidence of fungal infections and external hemorrhaging among the controls was apparently caused by abrasions suffered during capture in a beach seine. These injuries were undoubtedly exacerbated by the crowded conditions in the holding pen. If the effect of holding was controlled for (by comparing only mortalities that occurred during the first 3 days of the holding experiment) the resultant mortality rates were not significantly different between fish caught with control and electrofishing gear. The first and second hypotheses regarding mortality rates between gear types were therefore accepted.

Although rates of immediate and short term mortality were not significantly different between gear types when only mortalities that occurred during the first 3 days of holding were compared, the rates of total mortality for least

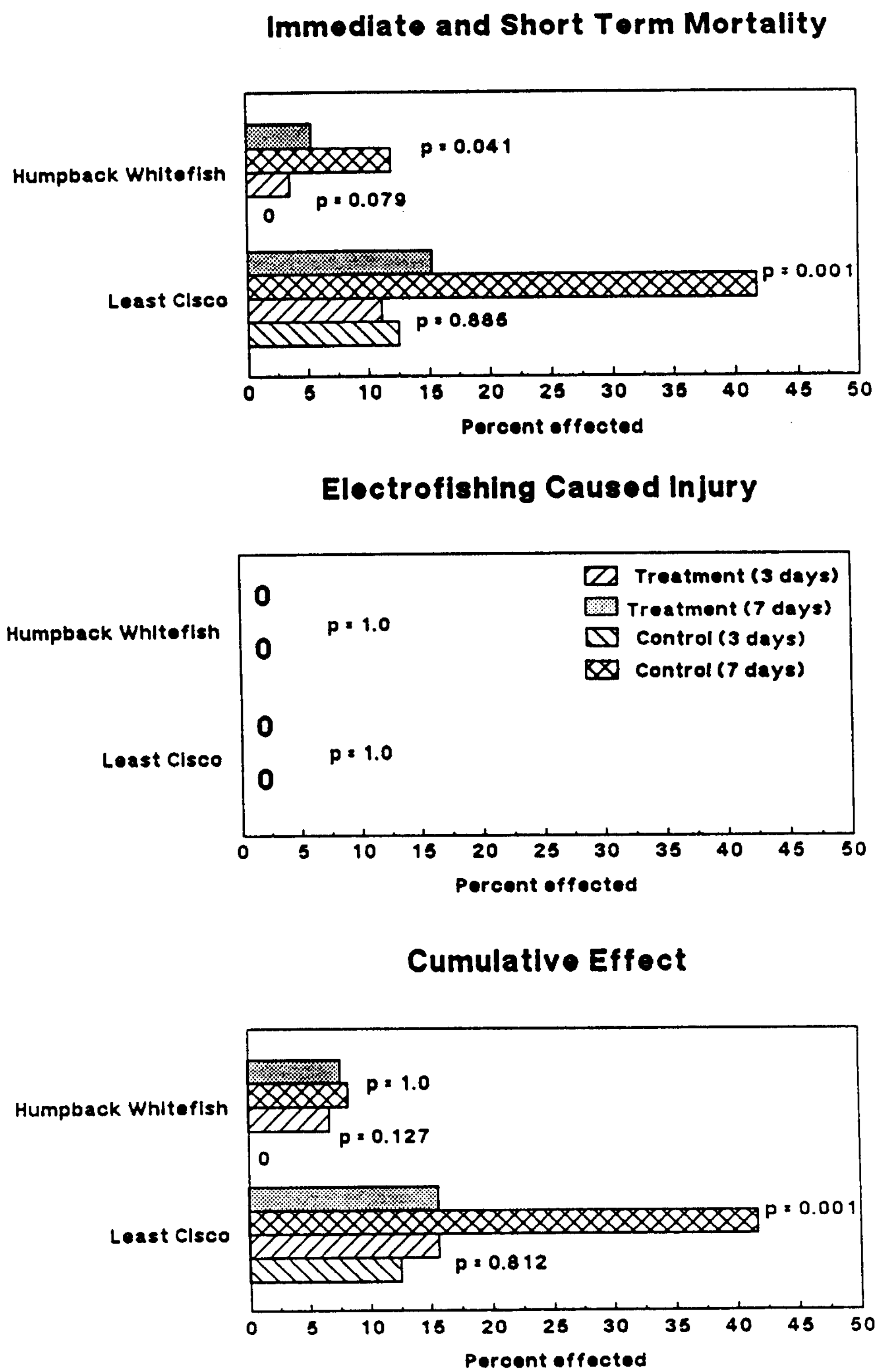


Figure 18. Summary of electrofishing injury and mortality in humpback whitefish and least cisco, Chatanika River, 1988.

cisco for the entire holding period were somewhat high (15.3% for electrofishing, 41.7% for seining, Figure 18). The mortalities for control least cisco were probably mostly due to post capture stress, since only 8.3% died immediately after capture. Barrett and Grossman (1988) indicated that post-capture handling stress was a greater determinant of mortality than electrofishing for mottled sculpin *Cottus bairdi*. The rate of immediate mortality for least cisco captured by electrofishing was 10.2%, which suggests that most of the mortality suffered by least cisco captured by electrofishing was capture-related, rather than a result of post-capture handling. While this immediate mortality rate was higher than that seen for humpback whitefish, the total mortality rate was lower for fish captured by electroshocking than for fish captured by seine, for both species.

Injury and Cumulative Effect:

Observed rates of spinal injury or spinal hemorrhage for humpback whitefish and least cisco were not significantly different between control and test fish (Figure 18). In no case was there a test or control fish with a combination of a spinal abnormality and hemorrhage located in the same area of the spine. Thus, no injuries were attributable to electrofishing, and the hypothesis regarding electrofishing-caused injury was accepted. The rates of spinal injury were low when compared with those for grayling (from this study, Chapter 2), and with the rate reported for rainbow trout by Sharber and Carothers (1988). Whitefish have a substantially different cross-sectional shape than Arctic grayling or rainbow trout, and this could be one reason that injury rates for whitefish were lower than for grayling.

The rate of cumulative effect did not differ significantly for test and control groups of humpback whitefish, but was significantly higher for least cisco captured with control gear (Figure 18). Rates of cumulative effect were not significantly different between test and control fish of either species if only fish that died within 3 days holding time are considered. Since mortality was the only component of cumulative effect for both species of whitefish, and since most of the mortality to least cisco was probably related to post-capture stress, the hypothesis regarding cumulative effect was accepted. Since rates of mortality, electrofishing-caused injury, and cumulative effect were not significantly different between gear types, we conclude that electrofishing is preferable over seining for sampling humpback whitefish and least cisco.

CHAPTER 4 - NORTHERN PIKE

Introduction

Northern pike are the second most sought after native sport fish species in interior Alaska. Concern about overharvest of the state's largest northern pike fishery (Minto Flats) prompted ADFG to begin a stock monitoring program there in 1986. Electrofishing was one of the sampling gears employed. This study was designed to evaluate the rates of electrofishing-induced injury and possible effects of electrofishing on long term mortality and growth of northern pike.

Methods

Two separate experiments were designed to evaluate the effects of electrofishing on northern pike. Both experiments were conducted in Minto Flats, which is composed of a myriad of lakes, sloughs and rivers, located about 50 km southwest of Fairbanks (Figure 19). Hypotheses tested by each experiment and methods (where they differ from those listed in the general methods section) follow.

Experiments were conducted to estimate: (1) injury rates; and (2) short term mortality, long term survival, and growth. In each experiment, these parameters were estimated for fish caught with electrofishing gear and tested against a control group.

Experiment 1 (Injury Rates):

One hypothesis was tested (Table 1): electrofishing-caused injury rate is equal between northern pike caught with electrofishing and control gears.

The test of this hypothesis was conducted as follows. Northern pike caught with control gears (February 1988-May 1989) were frozen for X-ray and autopsy analysis. Thirty control fish were caught during each of three separate sampling periods: 6 February through 16 March (all fish were caught on hook and line); 13 May (15 fish each were caught in fyke and gill nets); and 3 June through 15 June (all caught in gill nets; Table 12). Thirty-two test fish were caught using electrofishing gear (Boat B) on 20 September 1988. Water conductivity in Goldstream Creek (where all electrofishing samples were obtained) was 210 μmho/cm. VVP settings were: voltage 150 to 180; 60 hertz; and 50% pulse width. Output current ranged between 3.5 and 4.0 amperes. All test and control fish were killed immediately and frozen. Only fish longer than 400 mm were sampled, since previous data indicate that the average length at maturity for northern pike in Alaska is at least 400 mm. Overall length distributions of control and test fish were significantly different ($\chi = 12.60$, DF = 3, $p < 0.01$), with larger fish being more common in the control sample (Figure 20). X-rays (lateral view only) were taken of a random sample of 69 of the control and all 32 test fish. Fish were frozen when X-rayed. Autopsies were performed the following day, after samples had thawed.

Experiment 2 (Immediate Mortality, Long Term Survival, and Growth Rates):

Three hypotheses were tested (Table 1):

2. immediate mortality rate of northern pike caught with electrofishing gear equals immediate mortality rate of northern pike caught with control gears (gill nets, trap nets, and hook and line);

3. the rate of tag recoveries after 1 year for northern pike captured with electrofishing gear equals that of fish caught using control gear; and,

4. average growth of northern pike captured with electrofishing gear equals that of northern pike caught with control gears.

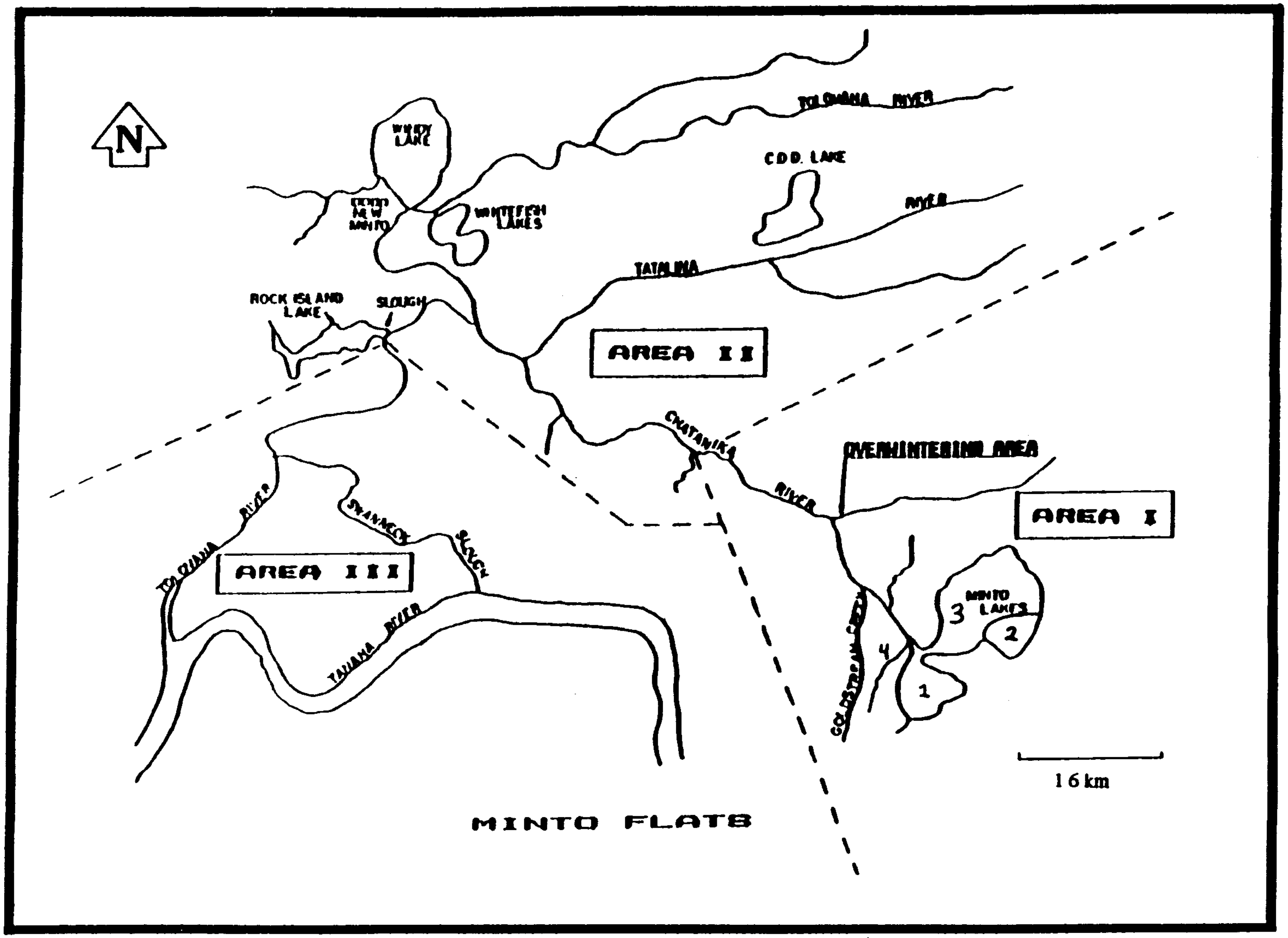


Figure 19. Minto Flats area.

Table 12. Sampling dates and sample sizes by gear type for northern pike captured from Minto Flats, Alaska, for electrofishing injury and mortality studies.

Date	Gear	Sample Sizes		
		Catch	Release	Kill
March 1988	Hook and Line	30	0	30[a]
May 1988	Fyke Net	15	0	15[a]
May 1988	Gill Net	15	0	15[a]
June 1988	Gill Net	30	0	30[a]
	Total Controls	90	0	90[a]
Sept. 1988	Electrofishing	32	0	32[a]
Aug.- Oct. 1987	Hook and Line	89	87	2[b]
	Gill Net	226	223	3[b]
	Trap Net	53	41	12[b]
	Total Controls	368	351	17[b]
	Electrofishing	527	526	1[b]

[a] These fish were sacrificed for autopsy and X-ray.
[b] These fish were killed immediately by the sampling gear.

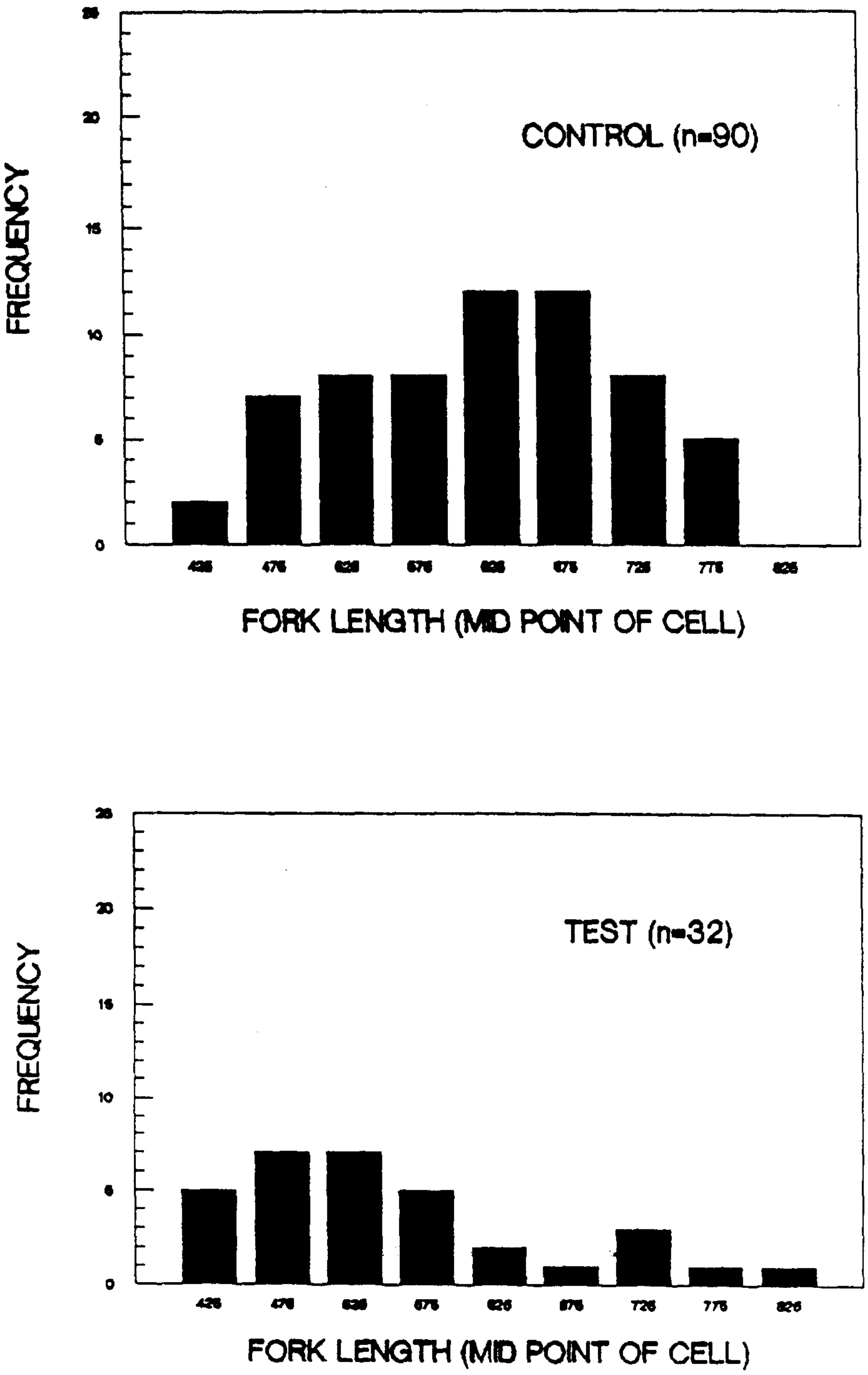


Figure 20. Length distributions of control and test northern pike in studies of injury rates due to electrofishing, Minto Flats, 1988.

It was not possible to estimate the cumulative short term effect of sampling (total mortality plus injury) because: (1) short term mortality was not estimated, and (2) the mortality and injury rate experiments were conducted at different times on different fish.

The test of hypotheses (2), (3), and (4) was conducted as follows. During 1 August through 13 October 1987, 368 fish were caught using three control gears; gill nets, trap nets, and hook and line gear (Table 12). In addition, 527 fish were caught using electrofishing gear (Boat B). The length distribution of control fish was not significantly different from that of test fish (χ^2 = 5.03, df = 3, p = 0.17; Figure 21). Fish that were killed by the sampling gear were noted and others were tagged and released. The rate of immediate mortality between fish caught using control and test gears was compared using chi-square contingency table analysis. During May through October 1988, 59 of the fish tagged and released in 1987 were recaptured. Relative growth and survival between control and test fish tagged and released in 1987 were evaluated.

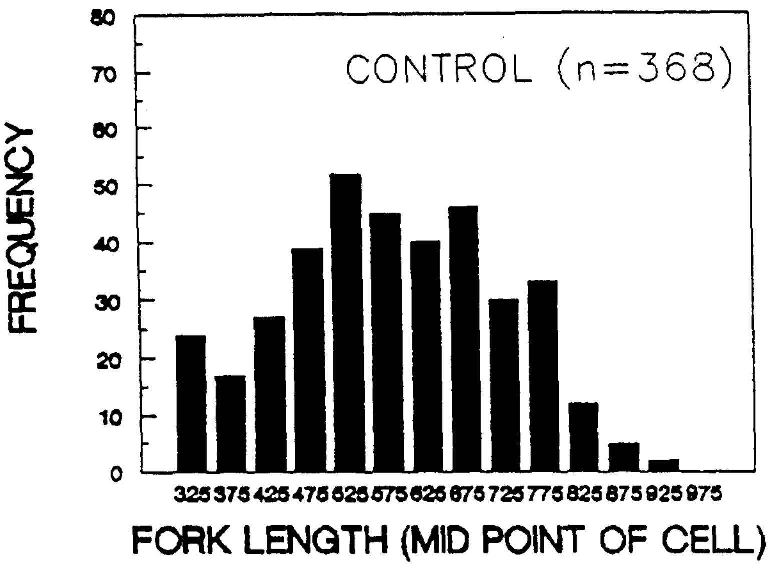
Results

Injury rates, immediate mortality, long term survival, and growth rates were examined for test and control fish.

Experiment 1 (Injury Rates):

X-rays revealed that only one of 69 fish from the control group (1.4%) had some type of spinal abnormality; five of 32 fish from the test group (15.6%) had spinal injuries (Table 13). The rate of injury of fish caught using electrofishing gear was significantly higher than that suffered by fish caught using control gears (χ^2 = 5.53, DF = 1, p = 0.02). Hemorrhages associated with the spine occurred significantly more frequently in the test group (18.8%) than in the control group (2.9%) (χ^2 = 5.52, DF = 1, p = 0.02). Injuries were more severe among test fish. Two of the injuries to test fish were dislocations involving three vertebrae and three were compression fractures involving two to four vertebrae (Table 13). Autopsies revealed that none of the control fish had electrofishing-caused injuries and four (12.5%) of the test fish had electrofishing-caused injuries. The rate of electrofishing-caused injury was significantly higher for test fish than for control group fish (χ^2 = 5.99, DF = 1, p = 0.01).

The four test fish that received spinal injuries ranged from 540 to 720 mm. They averaged 625.0 mm (SE = 38.8), while the 28 test fish that were not injured averaged 536.3 mm (SE = 21.4). Even though these values are not significantly different (t = 1.62, P < 0.10), it is an indication that larger northern pike are more susceptible to injury by electrofishing. Thus, the higher rate of injury of fish from the test group as compared to controls should be evaluated in light of the larger average size of the control fish (632.8; SE = 13.0).



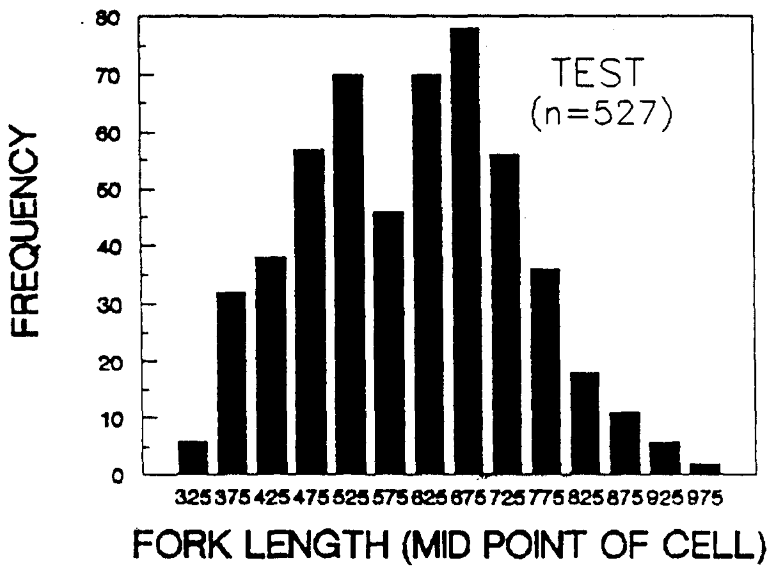


Figure 21. Length distributions of control and test northern pike in studies of immediate mortality, long term survival and growth rates, Minto Flats, 1988.

Table 13. Injury rates of northern pike captured by control and electrofishing gears in Minto Flats, 1988.

Injury Comparison	Frequency (%) Control	Electrofishing	Value of $X2$	Signif. Level
Spinal Injuries (X-ray)				
No injury	68 (98.6)	27 (84.4)		
Minor Compression	0 (0.0)	0 (0.0)		
Moderate Compression	1 (1.4)	3 (9.4)	5.53[a,b]	p = 0.02
Major Compression	0 (0.0)	0 (0.0)		
Dislocation	0 (0.0)	2 (6.2)		
Hemorrhage (Autopsy)				
None	67 (97.1)	26 (81.2)		
Minor	2 (2.9)	2 (6.3)	5.52[a,b]	p = 0.02
Moderate	0 (0.0)	2 (6.2)		
Major	0 (0.0)	2 (6.3)		
Electrofishing-caused Injury				
Injured	0 (0.0)	4 (12.5)	5.99[a]	p = 0.01
Not Injured	69 (100.0)	28 (87.5)		

[a] More than one-fifth of cells are sparse (frequency less than five)
[b] To reduce the number of cells with low frequencies, this table was collapsed to a 2 X 2 table for analysis (D.F. = 1).

Experiment 2 (Immediate Mortality, Long Term Survival, and Growth Rates):

Immediate mortality of fish caught using control gears was significantly higher than mortality of fish caught by electrofishing (Table 14). Of 368 fish caught with control gear, 17 were killed (4.6%). Twelve of these (71%) were fish that were gilled in the mesh of the trap nets. Only one of 527 test fish was killed immediately. No holding experiment was performed, so delayed mortality was not evaluated.

The rate of recapture of fish originally caught using control gears (9.4%) was significantly higher than that of fish originally caught using test gear (4.9%; Table 14). Length distributions of the recaptured fish were not significantly different ($\chi^2 = 6.04$, DF = 3, $p = 0.11$). The average monthly growth of fish caught using electrofishing gear was 3.30 mm (SE = 1.08 mm); the average monthly growth of control fish was 2.72 mm (SE = 0.53 mm). These growth rates are not significantly different ($t = 1.08$, $p > 0.25$).

Discussion

Results of the experiments on northern pike indicate that severe injuries may be caused by electrofishing and that electrofishing may have adverse long term effects on northern pike. The rate of electrofishing-caused injury for test fish was significantly higher than that of controls (Figure 22). The first hypothesis regarding injury rates was therefore rejected. The magnitude of these injuries was relatively severe (similar to that observed for large rainbow trout). As with other species (Ellis 1975), larger fish tended to suffer more severe injuries. Since the average size of the control fish was significantly larger than that of the test group, our estimate of injury rates due to electrofishing is probably conservative.

Immediate survival of northern pike was higher with test than control gears (Figure 22). This resulted mainly because numerous small northern pike were killed when they became gilled in the leads of hoop traps. If these mortalities are excluded from the analysis, the rate of immediate mortality between test and control fish is no longer significant. The second hypothesis regarding immediate mortality was therefore accepted.

The estimate of long term survival of test fish was significantly lower than that of controls (Figure 22). The third hypothesis regarding long term survival was therefore rejected. There was no significant difference in growth of northern pike captured with test or control gears, and the fourth hypothesis regarding growth was therefore accepted. These results indicate that electrofishing may cause severe injury to northern pike and may adversely affect the survival of northern pike. Thus, it is recommended that electrofishing be avoided as a sampling tool for northern pike until such time as the methodology is sufficiently advanced to assure minimum injury rates and maximum survival.

Table 14. Rates of immediate mortality and long term survival for northern pike captured with control and electrofishing gears in Minto Flats, 1987 and 1988.

Comparison	Frequency (%) Control	Electrofishing	Value of X^2	Significance Level
Immediate Mortality[a]				
Live	351 (95.4)	526 (99.8)	19.39	$p < 0.01$
Dead	17 (4.6)	1 (0.2)		
Long-term Survival[a,b]				
Recaptured	33 (9.4)	26 (4.9)	6.67	$p = 0.01$
Not Recaptured	318 (90.6)	500 (95.1)		

[a] Fish were captured between 1 August and 10 October 1987. Control gears were gill nets (n = 226), hook and line (n = 89), and trap nets (n = 54).
[b] Recapture sampling took place between 15 May and 1 October 1988.

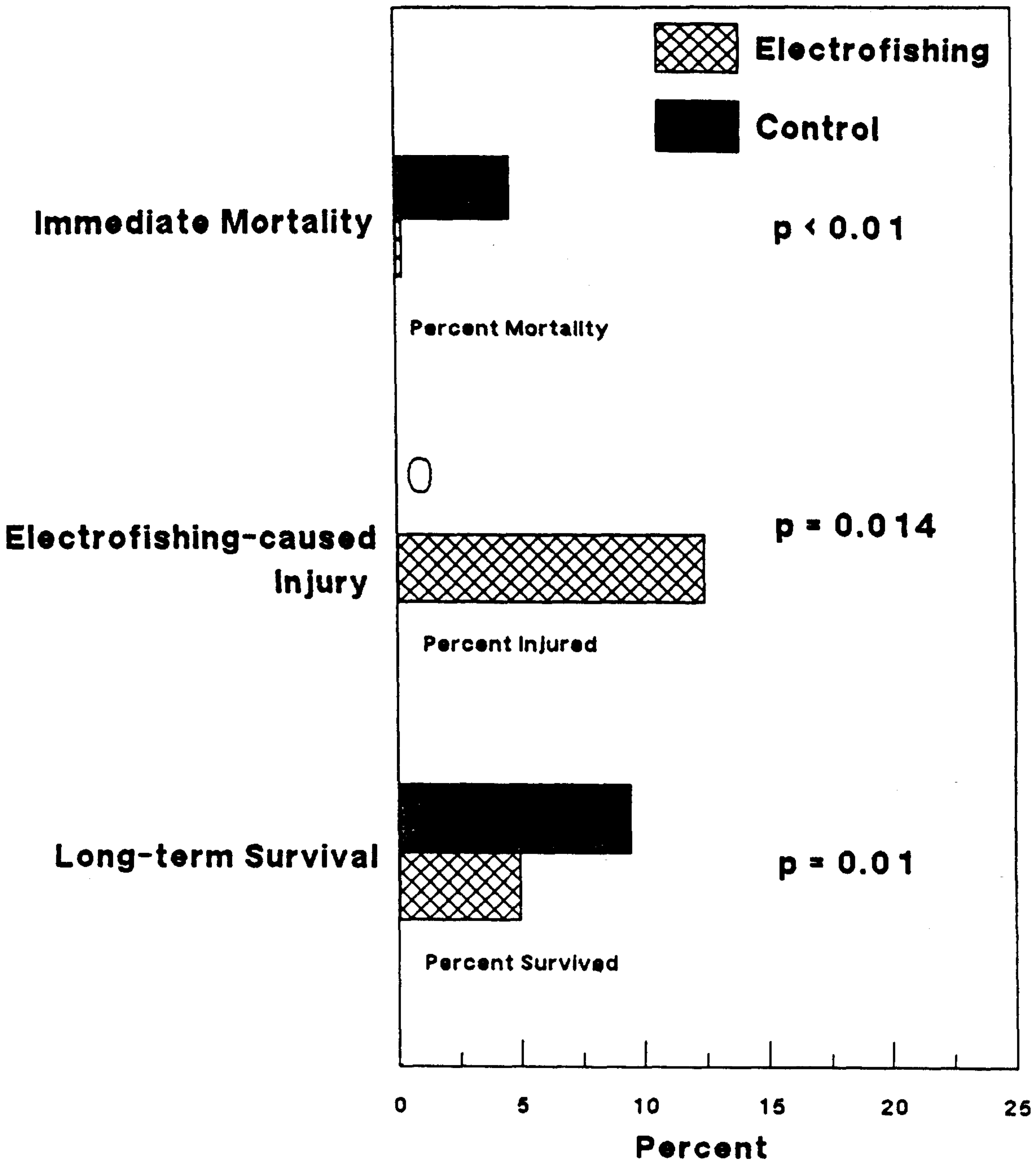


Figure 22. Percent injury, immediate mortality and long term survival in test and control northern pike, Minto Flats, 1988.

CHAPTER 5 - THRESHOLD POWER

Introduction

As part of the electrofishing evaluation for rainbow trout in the Kenai River, we evaluated the threshold power needed to stun rainbow trout for capture. We felt that rigorous estimation of threshold power was important in that sampled fish could sustain unnecessary mortality or injury as a result of excessive power usage.

Methods

Our experimentation to define threshold power was limited only to the electronic and logistic hardware that we had on hand. We made no attempt to reduce threshold power by substantially changing our existing equipment. Boat design is described in the general methods section. Duty cycle and pulse rate were kept at 70% and 100 pulses/second throughout the experiment.

Two experiments were conducted. Since our existing electrofishing equipment employed cables as the anodes, we first investigated the field properties of two different sets of anodes: 9.5 mm (3/8 inch) and 19.1 mm (3/4 inch) cables. The VVP was set at 400 volts and the voltage gradient was measured along several axes from one of the anodes. Voltage gradients were measured with a probe attached to an oscilloscope. The plateaus of the pulsed direct current were then read from the oscilloscope.

In the second experiment, we estimated threshold power to stun rainbow trout for capture under controlled conditions. Fish were captured in the wild by electroshocking, and then placed in a 1 x 1 x 2 m net pen in slow water. The electroshocking boat was then anchored at one end of the pen with the anodes just outside of the pen. One fish at a time was placed at the opposite end of the pen so that they were approximately 2 m away from the anodes. The fish were positioned so that they were facing either away from or toward the anodes and subjected to a 3-second shock at each of one to four voltage settings. Output voltage was systematically increased until the fish was stunned. A period of at least several minutes elapsed between electric shocks. Voltage was measured at the VVP box and ranged from 100 to 400 volts in 50-volt increments. The reaction of the fish to each of these tests was subjectively classified as one of the following: no reaction (NONE, fish exhibited no visible reaction to the test); mild reaction (TWITCH, fish visibly responded to the test); attempt to escape the field (ESCAPE, fish attempted to swim away from the anodes); or narcosis (STUN, fish was rendered unconscious and lost equilibrium).

In addition to measuring voltage at the VVP and voltage gradients with the probe and oscilloscope, we also estimated power densities (μwatts/cm^3) as follows (Kolz and Reynolds 1989):

$$P = E^2 c \qquad (1)$$

where:

P - power densities;

E - voltage gradient (v/cm), and

c - water conductivity (μS/cm)

Results

The electrofishing field was mapped and threshold power required to stun rainbow trout was noted.

Electrofishing Field:

Water temperature and conductivity at the time of the experiment were 6.6°C and 67 μmho/cm, respectively.

The voltage gradient was uniform in all directions from the anodes. Therefore, we mapped the voltage gradient curve in only one direction: from the center anode back 4 m toward the bow of the boat. Voltage gradients for both the 9.5 mm and 19.1 mm cables were fairly uniform from 0.4 m to 2.0 m from the anodes (Table 15 and Figure 23). Voltage gradients were highest within 0.2 m and extreme voltage gradients existed within the first few centimeters around the anodes. Voltage gradients quickly dissipated at distances greater than 0.2 m.

Differences in voltage gradients between the different diameter cables occurred only in the area immediately adjacent to the electrodes: average 18.4 volts/cm and 12.1 volts/cm for the 9.5 mm and 19.1 mm cables, respectively. At 0.4 m distance and beyond there was little difference in voltage gradient between the two electrode diameters.

Threshold Power:

Water temperature and conductivity at the time of the experiment were 7.5°C and 80 μmho/cm, respectively.

Two meters from the anode, rainbow trout were usually stunned at 200 volts (0.35 volts/cm voltage gradient or 10 μwatts/cm^3 power density) and all fish were stunned at 300 volts (0.53 volts/cm voltage gradient or 22 μwatts/cm^3 power density; Table 16).

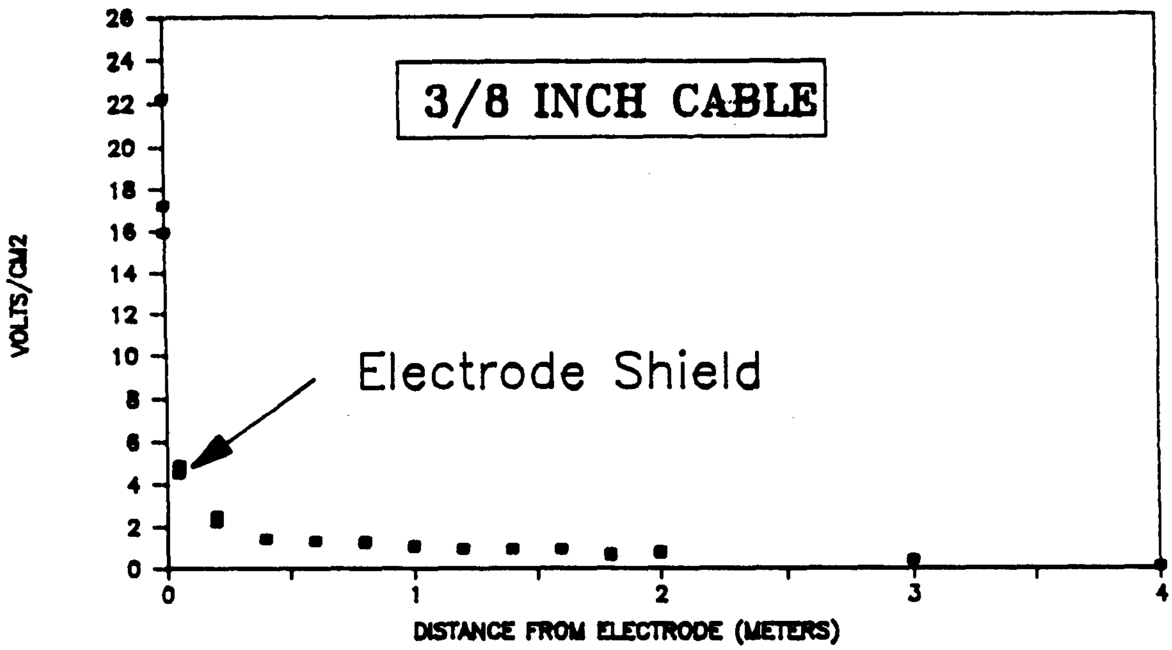
Discussion

To reduce the area of extreme voltage gradient immediately adjacent to the electrodes, we fabricated electrode shields made from 100 mm (4 inch) diameter PVC pipe (Figure 24). We field tested these shields for practical use in the strong currents of the Kenai River and found them acceptable in terms of being able to still handle the boat and effectively fishing the electrodes.

Table 15. Voltage gradients and power densities for 9.5 mm (3/8 in) and 19.1 mm (3/4 in) cable anodes[a].

Distance (m)	9.5 mm Anodes[b] Voltage Gradient (V/cm)	9.5 mm Anodes[b] Power Density ($\mu W/cm^3$)	19.1 mm Anodes[c] Voltage Gradient (V/cm)	19.1 mm Anodes[c] Power Density ($\mu W/cm^3$)
0.0	17.2	19,821	12.8	10,977
0.0	22.2	33,020	11.3	8,555
0.0	15.9	16,938	12.3	10,136
0.05	4.9	1,609	5.0	1,675
0.05	4.8	1,544	5.6	2,101
0.05	4.5	1,357	4.5	1,357
0.2	2.5	419	1.9	242
0.2	2.2	324	2.1	295
0.4	1.4	131	1.4	131
0.4	1.4	131	1.3	113
0.6	1.3	113	1.2	96
0.6	1.3	113	1.2	96
0.8	1.3	113	1.1	81
0.8	1.2	96	1.0	67
1.0	1.0	67	0.9	54
1.0	1.1	81	1.0	67
1.2	0.9	54	0.9	54
1.2	0.9	54	0.9	54
1.4	0.9	54	0.8	43
1.4	0.9	54	0.9	54
1.6	0.9	54	0.8	43
1.6	0.9	54	0.8	43
1.8	0.7	33	0.8	43
1.8	0.6	24	0.7	33
2.0	0.8	43	0.7	33
2.0	0.7	33	0.8	43
3.0	0.4	11	0.4	11
4.0	0.1	1	0.2	3

[a] Temperature = 6.6 C, Conductivity = 67 μmhos.
[b] VVP: 400 V, 3.5 A.
[c] VVP: 400 V, 3.0 A.



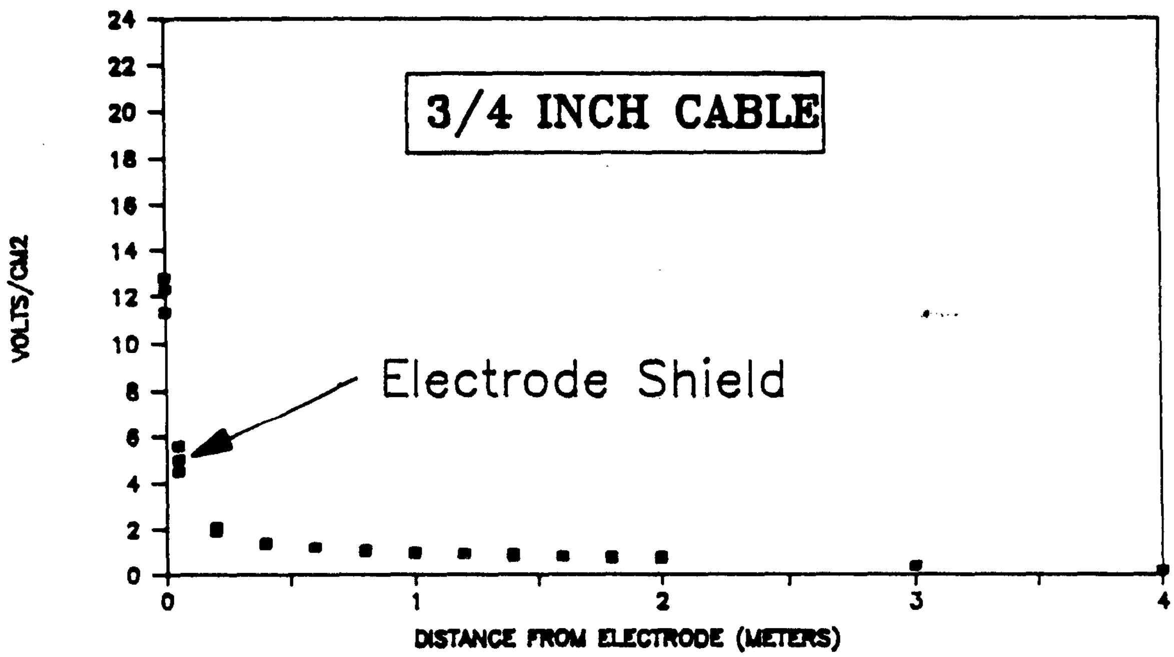


Figure 23. Voltage gradients for cables of different diameters, used in studies on the Kenai River, 1988.

Table 16. Response of rainbow trout to various levels of electric power[a], Kenai River, 1988.

Fork Length (mm)		Response[b]				
	Voltage[c]:	100	150	200	250	300
	Voltage Gradient[d]:	0.12	0.19	0.25	0.31	0.38
	Power Density[e]:	1	3	5	8	12
315		Twitch		Stun		Stun
421		None		Escape		Stun
560		Escape		Stun		
605			Stun	Twitch	Stun	
482		Escape	Escape	Stun		
425				Stun		
420					Twitch	Stun
365				Escape	Escape[f]	Stun
364						Stun
398					Stun	

[a] Temperature 7.5 C, Conductivity 80μmho/cm.

[b] Subjectively classified as follows:
NONE - fish exhibited no visible reaction to the treatment
TWITCH - fish visibly responded to the treatment
ESCAPE - fish attempted to swim away from the anode
STUN - fish was sufficiently stunned for capture

[c] Measured at VVP.

[d] V/cm, voltage gradient proportional to voltage, assuming 0.5 V/cm at 400 V.

[e] μW/cm3

[f] Swam towards anode and was stunned 0.3 m from anode.

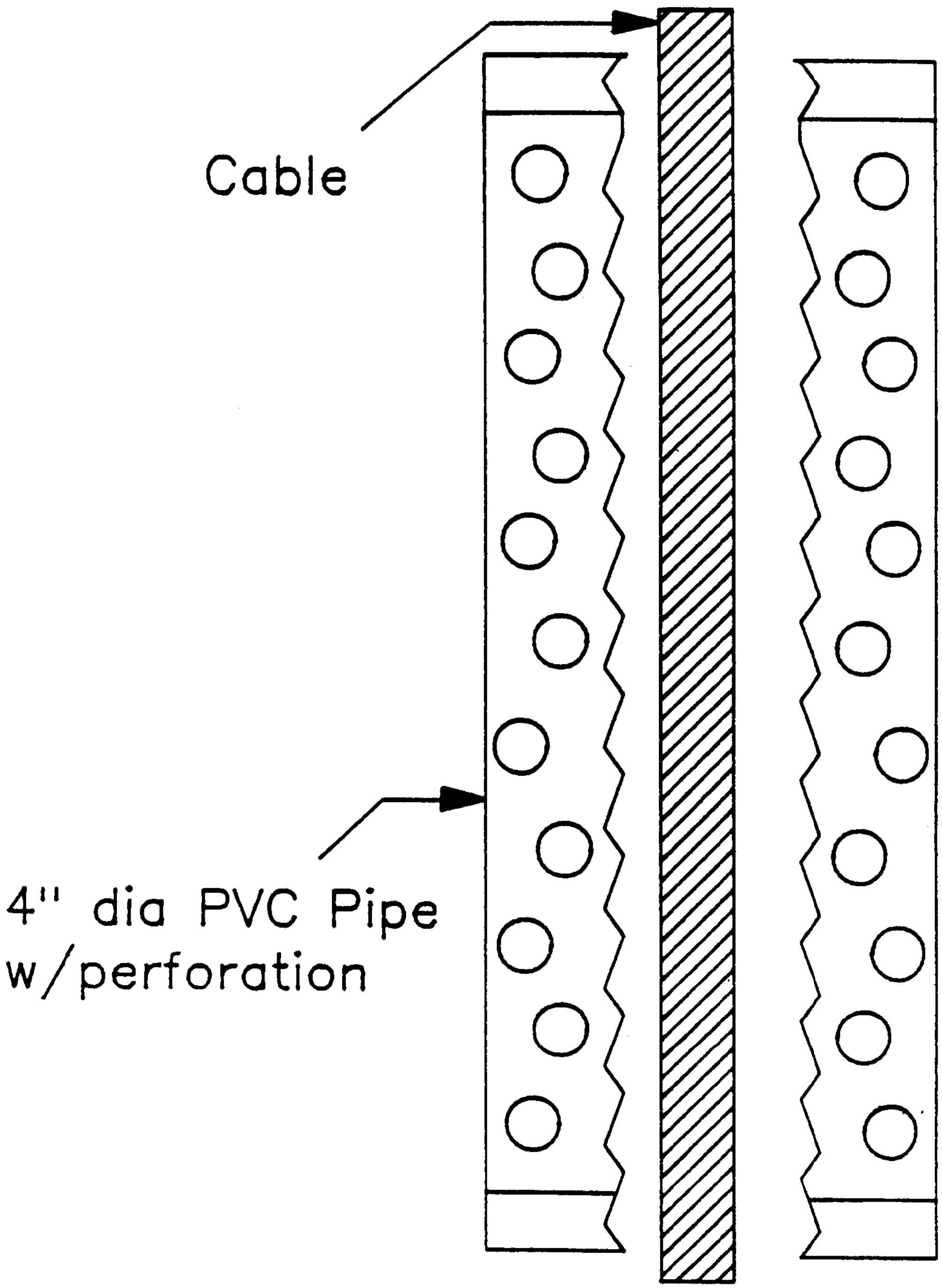


Figure 24. Schematic of electrode shield used in studies on the Kenai River, 1988.

The only difference in the configuration of the electrical field between the 9.5 mm and 19.1 mm cables was the severity of the voltage gradient immediately adjacent to the anode. Since this area was not available to the fish with the use of the shields, we chose the 9.5 mm cables due to their ease of use. We also measured the field produced by the three anode cables as opposed to five anode cables and concluded that the five cables were necessary to produce a field of sufficient size to efficiently capture fish.

Most rainbow trout were put into a state of narcosis (stunned) at voltages greater than 200 volts (10 μwatts/cm^3); and all rainbow trout were stunned at 300 volts (22 μwatts/cm^3). Therefore, we chose 250 volts (15 μwatts/cm^3) as the optimum setting for capturing rainbow trout in these water conditions with this equipment. This produced a current of 1 to 1.5 amperes as measured at the VVP.

This configuration was used to conduct the experiments described in Chapter 1 of this report and clearly resulted in a high rate of internal injury for rainbow trout. Although the shields effectively prevented fish from being subjected to the highest voltage gradients and power densities, they still experienced levels that were excessive for that species. The field mapping shows that power densities at 1.0 m from the electrode were approximately 4.5 times the level required to stun these fish.

The power densities at which rainbow trout were stunned (8 to 22 μwatts/cm^3) are low in comparison to other species. For example, experimental results for goldfish *Carassius auratus* show that they are stunned at approximately 125 μwatts/cm^3 (Kolz and Reynolds 1989) which is almost an order of magnitude greater than for rainbow trout. Some experimentation was also accomplished for Dolly Varden *Salvelinus malma* in conjunction with the experimentation for rainbow trout. Dolly Varden required approximately 20 μwatts/cm^3 before succumbing - approximately two times that for rainbow trout. These comparisons, in addition to the direct estimates of short term mortality and internal injury discussed elsewhere in this report, illustrate the high susceptibility of large rainbow trout to electrical energy.

CHAPTER 6 - CONCLUSIONS

While these experiments were conducted to estimate the impact of electrofishing as a capture gear, it was clear in several experiments that the control gears (here seines and hoop traps) had a greater detrimental impact as measured by mortality rates on some species of fish than did the electrofishing gear in question. Other methods of capture for non-destructive sampling of fish, notably hook and line, have been shown to have detrimental impact in some instances (Mongillo 1984). We think it important to note that any method of capture probably has some negative effect on fish and successful non-destructive sampling involves, in part, usage of gears which are least detrimental.

Methodology

In order to make comparisons between different species and study sites, capture methods, sampling protocols, and sample tests must be as uniform as possible. Because the sampling for some of the different experiments that comprised this study were undertaken in conjunction with other studies, sampling protocols differed somewhat between species and study sites. This resulted in different hypotheses being tested for different populations or species. Despite these inconsistencies, this study is one of very few in which test and control fish were captured under true field conditions, and systematically examined for effects of sampling-caused injury.

The other problem encountered in attempting to compare results among different studies relates to the definitions of injuries. Most other studies of injury to fish from electroshocking used X-rays and autopsy to examine fish for injury, but some studies only examined fish using X-rays. Results from this study show that injuries apparent from X-rays are often not accompanied by hemorrhage, and are therefore probably either natural deformities or old injuries that have healed. In this study, electrofishing-caused injury was defined as spinal injury (apparent from X-ray) combined with spinal hemorrhage (apparent from autopsy) at the same location on the spine. This definition was similar to that of Sharber and Carothers (1988). Because of the problems of objectively assessing the degree of injury, we feel that the best method of assessing the effects of electrofishing are at the population level, by testing for differential survival and growth over time of test and control groups of fish.

Rainbow Trout

Total short-term mortality to large electrofished rainbow trout was 13.9%, which is probably high enough by itself to raise serious questions about using electrofishing as a capture method for large rainbow trout. Major spinal injuries were found in 40.9% of the survivors, which is an injury rate similar to that reported by Sharber and Carothers (1988). The combined rate of mortality and major injury of 53.1% found in this study is sufficient evidence to conclude that electrofishing should not be used for non-destructive sampling of large rainbow trout. Despite the high rate of mortality and injury, survival to the creel 1 and 2 years later, as measured from voluntary angler returns, was not significantly different from that for fish caught by hook and line. Additional study should be conducted to determine if electrical parameters can be adjusted to reduce rates of mortality and injury while still providing for an efficient means of capture.

Arctic Grayling

Results from the studies on grayling were somewhat mixed, but total mortality for test fish was below 3.5% for all study areas, and was not significantly different from total mortality for control fish in any study area. The rates of electrofishing-caused injury in test fish were somewhat high for the Gulkana River (17%) and Delta River (18.3%), and were significantly higher for test fish compared to control fish in the Delta River. However, the majority of these injuries were minor. Rates of survival were not significantly related to capture method in any study area, and average growth was not significantly related to capture method in the one area where average growth was measured. Because rates of mortality were low and not related to capture gear, and because most injuries from electrofishing were minor, and particularly because long-term survival was not related to capture gear, we believe that the sampling of grayling by electrofishing normally done by ADFG does not have a substantial detrimental effect on grayling populations.

Whitefish

Results from the study on whitefish indicate that whitefish are not seriously affected by electroshocking. Rates of total mortality were significantly higher for control fish if mortality was calculated for 7 days holding time, but were not related to capture gear when mortality was calculated for 3 days holding time. This shows that post capture handling was probably a greater determinant of mortality than capture method. This is further supported by the zero rate of electrofishing caused injury to either species. Cumulative effect of sampling was only related to capture gear for least cisco, and again, only if mortality was calculated for 7 days holding time. Because of these results, we feel that sampling whitefish using electrofishing is no more detrimental, or in fact less detrimental, than other gear types that ADFG has available. Further study is not recommended.

Northern Pike

The rate of immediate mortality for test northern pike was quite low (0.2%), and was significantly lower than for control fish. Test fish had a significantly higher rate of electrofishing-caused injury than control fish. Estimated survival of test fish was significantly lower than for control fish. Because the injuries seen in northern pike were relatively severe, and because the estimated survival of test fish was lower than for control fish, we recommend that electrofishing only be used as a capture method for northern pike when it is not possible to use other gear types. Also, we recommend that a study be initiated to assess electrical-induced stress and injury in northern pike, involving controlled experiments to isolate stress and injury thresholds.

Threshold Power

It may be possible to modify the present system used in these experiments to reduce the level of mortality and injury, particularly for large rainbow trout, and still maintain an efficient means of capture. An increase in the surface area of the anodes should reduce the extreme voltage gradients that exist around the cables currently in use. This might be accomplished through the use of a metallic sphere as the anode. It may also be possible to modify the form of electrical energy transmitted into the water. Any modification will also have to be tested for efficiency of capture.

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Appendix A1. Summary of fish sampled in 1988 from the Chatanika River for electrofishing injury and mortality studies.

Date	Tag #	Fork Length	Gear[a] Type	Samp[b] Mort	Samp[c] Stat	Brand[d]	Spinal[e] Inj.	Spinal[e] Hem.	Location[f] Inj.	Location[f] Hem.
8/16	91253	246	9	0	1	0	6	5	3	--
8/16	91255	252	9	0	1	0	5	5	--	--
8/16	91257	280	9	0	1	0	5	5	--	--
8/16	91259	264	9	0	1	0	5	5	--	--
8/16	91263	246	9	0	1	0	5	5	--	--
8/16	91264	235	9	0	1	0	2	5	3	--
8/16	91267	200	9	0	1	0	5	5	--	--
8/16	91268	250	9	0	1	0	5	5	--	--
8/16	91269	218	9	0	1	0	3,4	5	1,3	--
8/16	91270	272	9	0	1	0	3,4	5	3,4	--
8/16	91271	272	9	0	1	0	5	5	--	--
8/16	91272	274	9	0	1	0	5	5	--	--
8/16	91274	266	9	0	1	0	5	5	--	--
8/16	91276	230	9	0	1	0	5	5	--	--
8/17	91281	211	9	1	1	0	5	1	--	3
8/17	91282	204	9	1	2	0	5	5	--	--
8/17	91283	208	9	1	1	0	5	5	--	--
8/17	91284	203	9	1	2	0	5	5	--	--
8/17	91285	236	9	1	2	0	6	5	2,3,4	--
8/17	91286	272	9	0	1	0	5	2	--	3
8/17	91287	258	9	1	1	0	3	5	2,3,4	--
8/17	91288	236	9	0	1	0	5	5	--	--
8/17	91289	213	9	1	1	0	5	5	--	--
8/17	91291	225	9	1	1	0	5	1	--	4
8/17	91292	215	9	1	1	0	5	5	--	--
8/18	91900	297	9	0	1	0	5	5	--	--
8/18	91903	204	9	0	1	0	5	5	--	--
8/18	91905	212	9	0	1	0	5	5	--	--
8/18	91906	256	9	1	1	0	3	1	3,4	2
8/18	91907	254	9	0	1	0	5	5	--	--
8/18	91909	225	9	0	1	0	5	5	--	--
8/18	91912	325	9	0	1	0	5	5	--	--
8/18	91913	291	9	0	1	0	5	5	--	--
8/18	91914	282	9	0	1	0	5	5	--	--
8/18	91915	307	9	0	1	0	5	5	--	--
8/18	91916	296	9	0	1	0	5	5	--	--
8/18	91917	301	9	0	1	0	5	5	--	--
8/18	91918	280	9	0	1	0	5	5	--	--
8/18	91919	269	9	0	1	0	5	5	--	--
8/18	91920	222	9	0	1	0	5	5	--	--
8/18	91921	241	9	1	1	0	6	5	4	--
8/18	91922	248	9	1	1	0	5	5	--	--
8/18	91924	236	9	0	1	0	5	5	--	--

-Continued-

Date	Tag #	Fork Length	Gear[a] Type	Samp[b] Mort	Samp[c] Stat	Brand[d]	Spinal[e] Inj.	Spinal[e] Hem.	Location[f] Inj.	Location[f] Hem.
8/18	91925	258	9	0	1	0	5	5	--	--
8/18	91926	274	9	0	1	0	5	5	--	--
8/18	91928	198	9	0	1	0	5	5	--	--
8/18	91929	213	9	0	1	0	5	5	--	--
8/18	91930	239	9	0	1	0	5	5	--	--
8/15	92003	222	3	0	1	0	5	5	--	--
8/15	92004	290	3	0	1	0	5	5	--	--
8/15	92006	262	3	0	1	0	5	5	--	--
8/15	92007	233	9	0	1	0	3	1	3	4
8/15	92008	316	9	0	1	0	3	5	3	--
8/15	92009	210	9	0	1	0	6	5	4	--
8/15	92010	216	9	0	1	0	5	5	--	--
8/15	92013	242	9	0	1	0	5	5	--	--
8/15	92014	214	9	0	1	0	5	5	--	--
8/15	92016	275	9	0	1	0	5	5	--	--
8/15	92018	215	9	0	1	0	5	5	--	--
8/16	92092	313	3	0	1	0	5	5	--	--
8/16	92093	262	3	1	1	0	5	5	--	--
8/16	92094	270	3	0	1	0	5	1	--	4
8/16	92095	226	3	0	1	0	6	5	2,4	--
8/17	92220	304	2	0	1	0	5	5	--	--
8/17	92222	210	2	0	1	0	5	5	--	--
8/17	92223	270	2	0	1	0	5	5	--	--
8/17	92224	215	2	0	1	0	5	5	--	--
8/17	92250	222	2	0	1	0	5	5	--	--
8/17	92252	262	2	0	1	0	5	5	--	--
8/17	92253	256	2	0	1	0	5	5	--	--
8/17	92254	247	2	0	1	0	6	5	2,3,4	--
8/17	92306	318	2	0	1	0	5	5	--	--
8/17	92307	236	2	1	2	0	3	5	2,3	--
8/17	92308	352	2	0	1	0	1	5	5	--
8/17	92310	243	2	0	1	0	5	1	--	3
8/17	92311	253	2	0	1	0	5	5	--	--
8/17	92312	288	2	0	1	0	5	5	--	--
8/17	92314	242	2	0	1	0	5	5	--	--
8/17	92316	212	2	0	1	0	5	5	--	--
8/18	92362	276	2	0	1	0	5	5	--	--
8/18	92364	222	2	0	1	0	5	5	--	--
8/18	92410	283	2	0	1	0	5	5	--	--
8/18	92485	296	2	0	1	0	5	5	--	--
8/18	92486	315	2	0	1	0	5	5	--	--
8/18	92488	340	2	0	1	0	5	5	--	--
8/18	92534	308	2	0	1	0	5	5	--	--
8/18	92535	250	2	0	1	0	5	5	--	--

-Continued-

Appendix A1. (Page 3 of 3).

Date	Tag #	Fork Length	Gear[a] Type	Samp[b] Mort	Samp[c] Stat	Brand[d]	Spinal[e] Inj.	Spinal[e] Hem.	Location[f] Inj.	Location[f] Hem.
8/18	92536	327	2	0	1	0	5	5	--	--
8/18	92538	235	2	0	1	0	5	5	--	--
8/18	92540	260	2	0	1	0	5	5	--	--
8/18	92541	233	2	0	1	0	5	5	--	--
8/18	92542	250	2	0	1	0	5	5	--	--
8/18	92546	305	2	0	1	0	5	5	--	--
8/19	92564	272	2	0	1	0	5	5	--	--
8/19	92566	301	2	0	1	0	5	5	--	--
8/19	92568	242	2	0	1	0	5	5	--	--
8/19	92570	213	2	0	1	0	5	5	--	--
8/19	92572	286	2	0	1	0	5	5	--	--
8/19	92672	268	2	1	1	0	5	5	--	--
8/19	92674	243	2	0	1	0	5	5	--	--
8/19	92675	238	2	0	1	0	5	5	--	--
8/19	92676	251	2	0	1	0	5	5	--	--
8/19	92678	272	2	0	1	0	5	5	--	--
8/19	92679	223	2	0	1	0	5	5	--	--
8/19	92680	204	2	0	1	0	5	5	--	--
8/19	92716	207	2	0	1	0	5	5	--	--
8/19	92740	304	2	0	1	0	5	5	--	--
8/19	92742	282	2	0	1	0	6	5	2	--
8/19	92744	292	2	0	1	0	5	5	--	--
8/19	92746	305	2	0	1	0	5	5	--	--
8/19	92748	285	2	0	1	0	5	5	--	--
8/19	92749	292	2	0	1	0	5	1	--	3
8/19	92750	267	2	0	1	0	5	5	--	--
8/19	92752	257	2	0	1	0	3	5	3	--
8/19	92764	246	2	0	1	0	5	5	--	--
8/19	92765	272	2	1	2	0	5	5	--	--
8/19	92766	265	2	0	1	0	5	5	--	--
8/19	92768	242	2	0	1	0	5	5	--	--
8/19	92770	293	2	0	1	0	5	5	--	--
8/19	92772	197	2	0	1	0	5	5	--	--
8/19	92774	246	2	0	1	0	5	5	--	--
8/19	92776	260	2	0	1	0	5	5	--	--
8/19	92778	252	2	1	1	0	5	5	--	--
8/17	99206	259	2	0	1	0	5	1	--	1
8/17	99207	238	2	0	1	0	5	5	--	--

[a] 2 = electrofished, 9 = hook and Line, 3 = seine.
[b] 0 = no, 1 = yes.
[c] 1 = part of random sample, 2 = not part of random sample.
[d] 0 = no brand, 1 = brand.
[e] 1 = minor, 2 = moderate, 3 = major, 4 = dislocation, 5 = none, 6 = natural deformity as described by Sharber and Carothers, (1988).
[f] 1 = vertebrae 1-19, 2 = 20-29, 3 = 30-39, 4 = 40-49, 5 = 50-60

Appendix A2. Summary of fish sampled in 1987 from the Gulkana River for electrofishing injury and mortality studies.

Date	Tag #	Fork Length (mm)	Gear[a] Type	Samp[b] Mort	Samp[c] Stat	Brand[d]	Spinal[e] Inj.	Spinal[e] Hem.	Location[f] Inj.	Location[f] Hem.
6/22	1	248	2	0	1	0	3	1	3,4	3
6/22	2	160	2	0	1	0	1	5	4	--
6/22	3	157	2	0	1	0	1	5	2	--
6/22	4	126	2	0	1	0	3	1	3,5	4
6/22	5	135	9	0	1	0	5	5	--	--
6/23	1080	302	2	0	1	0	5	5	--	--
6/22	31146	226	2	0	1	0	1	1	2,3	3
6/22	35066	326	9	0	1	0	3	5	3,4	--
6/22	35513	240	2	1	1	0	2	5	2	--
6/23	37243	325	9	0	1	0	5	5	--	--
6/23	37419	298	9	0	1	0	5	5	--	--
6/22	38005	319	2	0	1	0	5	5	--	--
6/22	38270	321	2	0	1	0	5	1	--	3
6/22	38751	284	2	0	1	0	5	5	--	--
6/22	38752	271	2	0	1	0	5	5	--	--
6/22	38753	235	2	0	1	1	3	1	3,4	3
6/22	38754	246	2	0	1	0	1	5	2,3	--
6/22	38755	306	2	0	1	0	5	5	--	--
6/22	38756	228	2	0	1	0	1	5	2	--
6/22	38757	235	2	1	1	1	1	1	2,3,4	1
6/22	38758	314	2	0	1	0	5	1	--	2
6/22	38759	279	2	0	1	0	3	5	3	--
6/22	38760	366	2	0	1	0	5	1	--	1
6/22	38761	263	2	0	1	0	5	5	--	--
6/22	38762	206	2	0	1	1	3	1	2,3,4	3
6/22	38763	221	2	0	1	0	5	5	--	--
6/22	38764	236	2	0	1	0	5	5	--	--
6/22	38765	205	2	0	1	0	1	1	2,3,4	4
6/22	38766	290	2	0	1	0	3	5	2,3	--
6/22	38767	200	2	0	1	0	1	5	2	--
6/22	38768	284	2	0	1	0	5	5	--	--
6/22	38769	226	2	0	1	0	5	5	--	--
6/22	38770	284	2	0	1	0	5	5	--	--
6/22	38771	344	2	0	1	0	2	5	3	--
6/22	38772	302	2	0	1	0	1	5	3,4	--
6/22	38773	223	2	0	1	0	3	1	3	3
6/22	38774	287	2	0	1	0	5	5	--	--
6/22	38775	235	2	0	1	0	5	5	--	--
6/22	38776	243	2	0	1	0	5	5	--	--
6/22	38777	334	2	0	1	0	5	5	--	--
6/22	38778	236	2	0	1	1	1	1	3,4	4

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Appendix A2. (Page 2 of 3).

Date	Tag #	Fork Length (mm)	Gear[a] Type	Samp[b] Mort	Samp[c] Stat	Brand[d]	Spinal[e] Inj.	Spinal[e] Hem.	Location[f] Inj.	Location[f] Hem.
6/22	38779	279	2	0	1	0	5	5	--	--
6/22	38780	260	2	0	1	0	1	5	2	--
6/22	38780	260	2	0	1	0	5	5	--	--
6/22	38781	224	2	0	1	0	1	5	1,3,4	--
6/22	38782	304	2	0	1	0	5	5	--	--
6/22	38783	219	2	0	1	0	3	5	2,3,4	--
6/22	38784	235	2	0	1	0	5	5	--	--
6/22	38785	222	2	0	1	0	1	5	2	--
6/22	38786	284	2	0	1	0	1	1	3,4	2
6/22	38787	270	2	0	1	0	3	5	3,4	--
6/22	38788	243	2	0	1	1	1	1	2,3	3
6/22	38789	270	2	0	1	0	3	5	2,3,4	--
6/22	38790	219	2	0	1	0	1	1	2	2
6/22	38791	223	2	0	1	0	1	5	1,3,4	--
6/22	38792	240	2	0	1	0	5	5	--	--
6/22	38793	222	2	0	1	0	3	5	1,2,4	--
6/22	38794	225	2	0	1	0	5	5	--	--
6/22	38795	205	2	0	1	0	1	5	1,2	--
6/22	38796	195	2	0	1	1	3	1	2,3	4
6/22	38798	189	2	0	1	0	1	1	4	1
6/22	38799	185	2	0	1	0	1	1	2,4	2
6/23	38802	322	9	0	1	0	5	5	--	--
6/23	38804	273	9	0	1	0	5	5	--	--
6/22	38805	295	2	0	1	0	5	5	--	--
6/23	38806	227	9	0	1	0	5	5	--	--
6/22	38807	291	9	0	1	0	1	5	2	--
6/23	38808	260	9	0	1	0	5	5	--	--
6/23	38809	216	9	0	1	0	5	5	--	--
6/23	38810	251	9	0	1	0	5	5	--	--
6/22	38811	322	2	0	1	0	1	5	3	--
6/22	38813	297	2	0	1	0	5	5	--	--
6/22	38814	253	2	0	1	1	1	5	2,3,4	--
6/22	38815	266	2	0	1	1	1	5	2,3,4	--
6/22	38816	227	2	0	1	0	3	1	2,3,4	3
6/22	38817	280	2	0	1	0	5	1	--	2
6/22	38818	223	2	0	1	1	1	5	2,3	--
6/22	38820	222	2	1	1	0	5	5	--	--
6/22	38821	249	2	0	1	0	1	5	3,4	--
6/22	38822	264	2	0	1	0	1	5	2,3	--
6/22	38823	229	2	0	1	0	3	5	4	--
6/22	38824	238	2	0	1	0	3	5	2,3	--

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Appendix A2. (Page 3 of 3).

Date	Tag #	Fork Length (mm)	Gear[a] Type	Samp[b] Mort	Samp[c] Stat	Brand[d]	Spinal[e] Inj.	Spinal[e] Hem.	Location[f] Inj.	Location[f] Hem.
6/23	38825	278	2	0	1	0	5	5	--	--
6/22	38979	228	2	0	1	0	1	5	2,3,4	--
6/22	38979	228	2	0	1	0	5	5	--	--
6/22	105851	270	2	0	1	1	1	5	2,3,4	--
6/22	106675	215	2	0	1	0	5	5	--	--
6/22	107647	255	2	0	1	0	3	5	1,2	--
6/22	107701	300	2	0	1	0	2	5	4	--
6/22	107884	223	2	0	1	0	1	5	3,4	--
6/22	108561	273	2	0	1	0	5	5	--	--
6/22	108733	295	2	0	1	0	5	5	--	--
6/22	108811	274	2	0	1	0	5	5	--	--
6/22	109076	265	2	0	1	0	3	1	2,3,4	3
6/22	109097	265	2	0	1	1	3	1	3,4	2,3
6/22	109645	285	2	0	1	1	1	1	2,3,4	2
6/22	109729	262	2	0	1	1	1	5	2,3	--
6/22	109959	267	2	0	1	1	1	5	2,3,4	--
6/22	110359	276	2	0	1	0	1	1	2,3	3
6/22	110574	252	2	0	1	0	1	5	3,4	--
6/22	110818	269	2	0	1	0	5	5	--	--

[a] 2 - electrofished, 9 - hook and line, 3 - seine.
[b] 0 - no, 1 - yes.
[c] 1 - part of random sample, 2 - not part of random sample.
[d] 0 - no brand, 1 - brand.
[e] 1 - minor (compression, fracture, or hemorrhage), 2 - moderate, 3 - major, 4 - dislocation, 5 - none.
[f] 1 - vertebrae 1-19, 2 - 20-29, 3 - 30-39, 4 - 40-49, 5 - 50-60; location of hemorrhage (vertebrae number) determined by comparing photograph of injury to the X-ray.

Appendix A3. Summary of fish sampled from the Delta River in 1988 for electrofishing injury and mortality study.

Date	Tag#	Fork Length	Gear[a] Type	Samp[b] Mort	Samp[c] Stat.	Brand[d]	Spinal[e] Inj.	Spinal[e] Hem.	Location[f] Inj.	Location[f] Hem.
8/26	78504	259	2	1	2	0	2	5	2,3,4	--
8/25	78506	258	9	1	2	0	5	5	--	--
8/25	78507	276	9	1	2	0	5	5	--	--
8/25	78508	280	9	1	2	0	5	5	--	--
8/25	78509	321	9	1	2	0	5	5	--	--
8/24	78510	344	3	1	2	0	5	5	--	--
8/25	78511	344	9	1	2	0	5	5	--	--
8/25	78512	343	9	1	2	0	5	5	--	--
8/24	83832	336	3	0	1	0	5	5	--	--
8/24	83833	326	3	0	1	0	5	5	--	--
8/24	83851	321	3	0	1	0	5	5	--	--
8/24	83860	353	3	0	1	0	5	1	--	3
8/24	83867	312	3	0	1	0	5	5	--	--
8/24	83872	318	3	0	1	0	5	5	--	--
8/24	83876	301	3	0	1	0	5	5	--	--
8/24	83906	325	3	0	1	0	5	5	--	--
8/24	83913	275	3	0	1	0	5	5	--	--
8/24	83914	334	3	0	1	0	5	5	--	--
8/24	83942	329	3	0	1	0	5	5	--	--
8/25	83960	258	9	0	1	0	5	5	--	--
8/25	83964	329	9	0	1	0	5	5	--	--
8/25	83988	283	9	0	1	0	5	5	--	--
8/25	83997	328	9	0	1	0	5	1	--	3
8/25	84001	336	9	0	1	0	5	5	--	--
8/25	84010	255	9	0	1	0	5	5	--	--
8/25	84013	349	9	0	1	0	5	5	--	--
8/25	84014	366	9	0	1	0	5	5	--	--
8/25	84021	254	9	1	2	0	5	5	--	--
8/25	84040	320	9	0	1	0	5	5	--	--
8/25	84044	255	9	0	1	0	5	5	--	--
8/25	84073	276	9	0	1	0	5	5	--	--
8/25	84074	257	9	0	1	0	5	5	--	--
8/25	84080	266	9	0	1	0	5	1	--	3
8/25	84081	249	9	0	1	0	5	1	--	3
8/25	84083	280	9	0	1	0	5	5	--	--
8/25	84102	273	9	0	1	0	5	5	--	--
8/25	84105	215	9	0	1	0	5	5	--	--
8/25	84117	329	9	0	1	0	5	5	--	--
8/25	84126	352	9	0	1	0	5	5	--	--
8/25	84133	232	9	0	1	0	5	5	--	--
8/25	84135	340	9	0	1	0	5	5	--	--

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Date	Tag#	Fork Length	Gear[a] Type	Samp[b] Mort	Samp[c] Stat.	Brand[d]	Spinal[e] Inj.	Spinal[e] Hem.	Location[f] Inj.	Location[f] Hem.
8/25	84143	280	9	0	1	0	5	5	--	--
8/25	84153	330	9	0	1	0	5	5	--	--
8/25	84155	263	9	0	1	0	5	5	--	--
8/25	84159	358	9	0	1	0	5	5	--	--
8/25	84163	262	9	1	2	0	5	5	--	--
8/25	84174	308	9	0	1	0	5	5	--	--
8/25	84177	326	9	0	1	0	5	5	--	--
8/25	84182	311	9	0	1	0	5	5	--	--
8/25	84200	312	9	0	1	0	2	5	4	--
8/26	84210	276	9	0	1	0	2	5	3	--
8/25	84212	311	9	0	1	0	5	5	--	--
8/25	84213	365	9	0	1	0	5	1	--	2
8/25	84214	298	9	0	1	0	5	5	--	--
8/25	84215	209	9	0	1	0	5	5	--	--
8/25	84217	323	9	0	1	0	5	5	--	--
8/25	84226	264	9	0	1	0	5	5	--	--
8/25	84235	267	9	0	1	0	5	5	--	--
8/25	84249	343	9	0	1	0	5	1	--	3
8/25	84257	268	9	0	1	0	5	1	--	3
8/25	84259	329	9	0	1	0	5	5	--	--
8/25	84270	329	9	0	1	0	5	5	--	--
8/25	84273	338	9	0	1	0	5	5	--	--
8/25	84280	272	9	0	1	0	5	1	--	4
8/25	84282	322	9	0	1	0	5	5	--	--
8/25	84286	288	9	0	1	0	5	5	--	--
8/25	84298	283	9	0	1	0	5	5	--	--
8/25	84322	254	9	0	1	0	1	5	4	--
8/25	84326	205	9	0	1	0	5	5	--	--
8/25	84339	302	9	0	1	0	5	5	--	--
8/26	84350	337	2	0	1	0	5	1	--	3
8/26	84356	333	2	0	1	1	1	5	3,4	--
8/26	84357	293	2	0	1	1	1	5	1,2,3,4	--
8/26	84358	286	2	0	1	1	1	1	3,4	3
8/26	84362	249	2	0	1	0	1	5	3,4	--
8/26	84366	338	2	0	1	1	1	1	2,3,4	2
8/26	84373	279	2	0	1	0	1	5	3,4	--
8/26	84376	303	2	0	1	1	1	2	3,4	3
8/26	84380	334	2	0	1	0	5	5	--	--
8/26	84383	269	2	0	1	0	5	5	--	--
8/26	84384	286	2	0	1	0	5	2	--	3,4
8/26	84385	270	2	0	1	0	1	5	4,5	--
8/26	84386	334	2	0	1	0	5	5	--	--

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Appendix A3. (Page 3 of 4).

Date	Tag#	Fork Length	Gear[a] Type	Samp[b] Mort	Samp[c] Stat.	Brand[d]	Spinal[e] Inj.	Spinal[e] Hem.	Location[f] Inj.	Location[f] Hem.
8/26	84387	307	2	1	2	0	5	5	--	--
8/26	84389	324	2	0	1	0	1	1	2,3,4,5	2
8/26	84391	340	2	0	1	0	5	5	--	--
8/26	84392	342	2	0	1	0	1	5	2,3,4,5	--
8/26	84397	312	2	0	1	1	4	3	2	2
8/26	84398	337	2	0	1	0	5	5	--	--
8/26	84401	333	2	0	1	0	1	5	3,4	--
8/26	84403	374	2	0	1	0	1	5	2,3,4	--
8/26	84404	250	2	0	1	0	1	5	3,4,5	--
8/26	84408	323	2	0	1	0	1	2	2,3,4,5	2
8/26	84412	327	2	0	1	0	1	5	1,2	--
8/26	84413	337	2	0	1	0	1	5	4	--
8/26	84420	352	2	0	1	0	5	5	--	--
8/26	84421	337	2	0	1	0	1	5	2,3,4	--
8/26	84424	334	2	0	1	0	5	5	--	--
8/26	84425	336	2	0	1	0	5	5	--	--
8/26	84426	291	2	0	1	0	1	5	4,5	--
8/26	84428	306	2	0	1	0	1	1	2,3,4,5	5
8/26	84429	298	2	0	1	0	1	5	2,3,4,5	--
8/26	84431	354	2	0	1	0	5	5	--	--
8/26	84432	322	2	0	1	0	5	5	--	--
8/26	84435	315	2	0	1	0	1	5	2,3,4,5	--
8/26	84437	281	2	0	1	0	1	1	2,3,4,5	1
8/26	84438	326	2	0	1	0	5	5	--	--
8/26	84449	328	2	0	1	0	1	5	3,4,5	--
8/26	84450	309	2	0	1	0	1	1	2,3,4,5	3
8/26	84454	256	2	0	1	0	5	5	--	--
8/26	84455	267	2	0	1	0	1	1	2	4
8/26	84461	252	2	1	2	0	1	5	2	--
8/25	84462	278	9	1	2	0	5	5	--	--
8/26	84500	288	2	0	1	0	5	5	--	--
8/26	84504	318	2	0	1	0	1	5	2,3,4	--
8/26	84508	328	2	0	1	0	5	5	--	--
8/26	84515	307	2	0	1	0	1	5	3,4	--
8/26	84516	301	2	0	1	1	1	5	3,4,5	--
8/26	84517	345	2	0	1	0	5	5	--	--
8/26	84518	260	2	0	1	0	1	5	2,3,4	--
8/26	84519	278	2	0	1	0	1	5	3,4,5	--
8/26	84521	323	2	0	1	0	5	5	--	--
8/26	84524	269	2	0	1	0	1	1	2,3,4	3
8/26	84525	316	2	0	1	1	1	1	3,4,5	3
8/26	84528	276	2	0	1	0	1	5	2,3,4,5	--

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Appendix A3. (Page 4 of 4).

Date	Tag#	Fork Length	Gear[a] Type	Samp[b] Mort	Samp[c] Stat.	Brand[d]	Spinal[e] Inj.	Spinal[e] Hem.	Location[f] Inj.	Location[f] Hem.
8/26	84529	366	2	0	1	0	5	5	--	--
8/26	84531	338	2	0	1	0	5	5	--	--
8/26	84533	304	2	0	1	1	1	2	2,3,4	3
8/26	84534	325	2	0	1	0	5	5	--	--
8/26	84537	285	2	0	1	0	1	5	3,4,5	--
8/26	84538	343	2	0	1	0	5	5	--	--
8/26	84542	340	2	0	1	0	5	5	--	--
8/26	84544	254	2	0	1	0	1	5	3,4	--
8/26	84546	257	2	1	2	0	1	1	3,4	2
8/25	84577	291	9	1	2	0	5	5	--	--
8/27	84739	291	2	1	2	1	1	1	4	2
8/27	84819	316	2	1	2	1	1	5	3,4,5	--
8/27	84820	300	2	1	2	1	1	5	3,4,5	--
8/27	84882	307	2	1	2	0	2	5	3	--
8/24	87234	326	3	0	1	0	5	5	--	--

[a] 2 - electrofished, 9 - hook and line, 3 - seine.
[b] 0 - no, 1 - yes.
[c] 1 - part of random sample, 2 - not part of random sample.
[d] 0 - no brand, 1 - brand.
[e] 1 - minor (compression, fracture, or hemorrhage), 2 - moderate, 3 - major, 4 - dislocation, 5 - none.
[f] 1 - vertebrae 1-19, 2 - 20-29, 3 - 30-39, 4 - 40-49, 5 - 50-60; location of hemorrhage (vertebrae number) determined by comparing photograph of injury to the X-ray.

Appendix A4. Summary of humpback whitefish sampled for electrofishing injury and mortality study from the Chatanika River, 1988.

Date	Tag #	Fork Length	Gear Type[a]	Sample Mortality[b]	Sample Status[c]	Spinal Injury[d]	Spinal Hemorr.[d]	Location Injury[e]	Location Hemorr.[e]
8/16	92022	411	3	1	1	5	5	--	--
8/16	92024	372	3	0	1	5	5	--	--
8/16	92026	396	3	0	1	5	5	--	--
8/16	92027	416	3	0	1	5	5	--	--
8/16	92028	388	3	0	1	5	5	--	--
8/16	92032	415	3	1	1	5	5	--	--
8/16	92033	420	3	0	1	5	5	--	--
8/16	92034	381	3	0	1	5	5	--	--
8/16	92036	393	3	0	1	5	5	--	--
8/16	92039	369	3	0	1	5	5	--	--
8/16	92040	402	3	0	1	5	5	--	--
8/16	92041	376	3	0	1	5	5	--	--
8/16	92042	362	3	0	1	5	5	--	--
8/16	92043	428	3	0	1	5	5	--	--
8/16	92049	415	3	0	1	5	5	--	--
8/16	92051	412	3	0	1	5	5	--	--
8/16	92052	392	3	0	1	5	5	--	--
8/16	92056	387	3	1	0	5	5	--	--
8/16	92058	378	3	1	0	5	5	--	--
8/16	92060	377	3	0	1	5	5	--	--
8/16	92063	386	3	0	1	5	5	--	--
8/16	92065	379	3	0	1	5	5	--	--
8/16	92068	400	3	0	1	6	5	1	--
8/16	92069	395	3	0	1	5	5	--	--
8/16	92073	403	3	0	1	5	5	--	--
8/16	92074	376	3	0	1	5	5	--	--
8/16	92076	411	3	0	1	5	5	--	--
8/16	92077	356	3	0	1	5	5	--	--
8/16	92089	407	3	0	1	5	5	--	--
8/16	92090	416	3	0	1	5	5	--	--
8/16	92091	365	3	1	1	5	5	--	--
8/17	92097	413	3	0	1	5	5	--	--
8/17	92098	395	3	0	1	5	5	--	--
8/17	92099	398	3	0	1	5	5	--	--
8/17	92100	398	3	1	1	5	5	--	--
8/17	92102	396	3	0	1	5	5	--	--
8/17	92104	385	3	1	1	5	1	--	5
8/17	92106	375	3	0	1	2	5	3,4	--
8/17	92107	404	3	0	1	5	5	--	--
8/17	92108	388	3	0	1	5	5	--	--
8/17	92109	367	3	0	1	5	1	--	4
8/17	92110	385	3	1	0	5	5	--	--

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Appendix A4. (Page 2 of 4).

Date	Tag #	Fork Length	Gear Type[a]	Sample Mortality[b]	Sample Status[c]	Spinal Injury[d]	Spinal Hemorr.[d]	Location Injury[e]	Location Hemorr.[e]
8/17	92113	385	3	0	1	3	5	4,5	--
8/17	92115	412	3	0	1	5	5	--	--
8/17	92117	407	3	0	1	5	5	--	--
8/17	92118	361	3	0	1	5	1	--	3
8/17	92121	380	3	1	0	5	5	--	--
8/17	92122	379	3	0	1	5	5	--	--
8/17	92125	400	3	0	1	3	5	1	--
8/17	92127	377	3	0	1	5	5	--	--
8/17	92129	382	3	1	0	5	5	--	--
8/17	92130	355	3	1	0	5	5	--	--
8/17	92131	348	3	0	1	5	5	--	--
8/17	92133	386	3	0	1	5	5	--	--
8/17	92137	397	3	0	1	5	5	--	--
8/17	92138	389	3	0	1	5	5	--	--
8/17	92139	366	3	0	1	3	5	2,3,4	--
8/17	92140	384	3	0	1	5	5	--	--
8/17	92141	411	3	0	1	5	5	--	--
8/17	92142	409	3	0	1	5	5	--	--
8/17	92143	442	3	0	1	5	5	--	--
8/17	92145	340	3	0	1	5	5	--	--
8/17	92146	375	3	0	1	5	5	--	--
8/17	92147	381	3	0	1	5	5	--	--
8/17	92148	371	3	1	0	5	5	--	--
8/17	92187	352	3	0	1	5	5	--	--
8/17	92188	376	3	0	1	5	5	--	--
8/17	92190	370	3	1	0	5	5	--	--
8/17	92195	393	2	0	1	5	5	--	--
8/17	92204	396	2	0	1	5	5	--	--
8/17	92205	400	2	0	1	5	5	--	--
8/17	92215	402	2	0	1	5	5	--	--
8/17	92225	450	2	0	1	5	5	--	--
8/17	92226	418	2	1	0	5	5	--	--
8/17	92230	380	2	0	1	5	5	--	--
8/17	92235	385	2	0	1	5	5	--	--
8/17	92237	369	2	1	0	5	5	--	--
8/17	92240	416	2	0	1	5	5	--	--
8/17	92245	419	2	0	1	5	5	--	--
8/17	92256	368	2	1	0	5	5	--	--
8/17	92260	397	2	0	1	5	5	--	--
8/17	92263	370	2	1	0	5	5	--	--
8/17	92265	398	2	0	1	5	5	--	--
8/17	92266	431	2	1	0	5	5	--	--
8/17	92269	409	2	1	0	5	5	--	--

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Appendix A4. (Page 3 of 4).

Date	Tag #	Fork Length	Gear Type[a]	Sample Mortality[b]	Sample Status[c]	Spinal Injury[d]	Spinal Hemorr.[d]	Location Injury[e]	Location Hemorr.[e]
8/17	92270	391	2	1	1	5	5	--	--
8/17	92273	390	2	1	0	5	5	--	--
8/17	92275	407	2	1	1	5	5	--	--
8/17	92280	380	2	0	1	5	5	--	--
8/17	92282	397	2	1	0	5	5	--	--
8/17	92283	409	2	1	0	5	5	--	--
8/17	92285	436	2	1	1	5	5	--	--
8/17	92290	392	2	1	1	5	5	--	--
8/17	92291	393	2	1	0	5	5	--	--
8/17	92295	351	2	0	1	2	5	--	--
8/17	92300	397	2	0	1	5	5	--	--
8/18	92320	394	2	0	1	5	5	--	--
8/18	92324	375	2	0	1	5	5	--	--
8/18	92330	386	2	0	1	5	5	--	--
8/18	92335	422	2	0	1	5	5	--	--
8/18	92340	405	2	0	1	5	1	--	4
8/18	92345	370	2	0	1	5	5	--	--
8/18	92350	363	2	0	1	5	5	--	--
8/18	92355	387	2	0	1	5	1	--	3
8/18	92365	444	2	0	1	5	5	--	--
8/18	92370	379	2	0	1	2	5	3	--
8/18	92372	418	2	1	0	5	1	--	3
8/18	92375	366	2	0	1	5	5	--	--
8/18	92380	345	2	0	1	5	5	--	--
8/18	92382	392	2	0	1	5	1	--	3
8/18	92385	385	2	0	1	5	5	--	--
8/18	92390	365	2	0	1	5	5	--	--
8/18	92399	367	2	0	1	5	5	--	--
8/18	92400	418	2	0	1	5	5	--	--
8/19	92550	392	2	0	1	5	5	--	--
8/19	92555	400	2	0	1	5	5	--	--
8/19	92560	372	2	0	1	5	5	--	--
8/19	92575	440	2	0	1	5	5	--	--
8/19	92580	392	2	0	1	5	5	--	--
8/19	92585	396	2	0	1	5	5	--	--
8/19	92590	380	2	0	1	5	5	--	--
8/19	92600	380	2	0	1	5	5	--	--
8/19	92605	402	2	0	1	5	5	--	--
8/19	92610	374	2	0	1	5	5	--	--
8/19	92615	406	2	0	1	5	5	--	--
8/19	92625	455	2	0	1	5	5	--	--
8/19	92630	406	2	0	1	5	5	--	--
8/19	92635	422	2	0	1	5	5	--	--

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Appendix A4. (Page 4 of 4).

Date	Tag #	Fork Length	Gear Type[a]	Sample Mortality[b]	Sample Status[c]	Spinal Injury[d]	Spinal Hemorr.[d]	Location Injury[e]	Location Hemorr.[e]
8/19	92640	375	2	0	1	5	5	--	--
8/19	92643	394	2	0	1	5	5	--	--
8/19	92645	398	2	0	1	5	5	--	--
8/19	92595	401	2	0	1	5	5	--	--
8/19	92665	377	2	0	1	5	5	--	--
8/19	92685	400	2	0	1	5	5	--	--
8/19	92690	382	2	0	1	5	5	--	--
8/19	92695	402	2	0	1	5	5	--	--
8/19	92700	362	2	0	1	5	5	--	--
8/19	92705	378	2	0	1	5	5	--	--
8/19	92706	342	2	0	1	5	5	--	--

[a] 2 = electrofished, 3 = seine.
[b] 0 = no, 1 = yes.
[c] 0 = not part of random sample, 1 = part of random sample.
[d] 1 = minor, 2 = moderate, 3 = major, 4 = dislocation, 5 = none, 6 = natural deformity as described by Sharber and Carothers, (1988).
[e] 1 = vertebrae 1-19, 2 = 20-29, 3 = 30-39, 4 = 40-49, 5 = 50-60

Appendix A5. Summary of least cisco sampled for electrofishing injury and mortality study from the Chatanika River, 1988.

				Sample		Spinal		Location	
Date	Tag #	Length (mm)	Gear Type[a]	Mortality[b]	Status[c]	Injury[d]	Hemorr.[d]	Injury[e]	Hemorr.[e]
8/16	92019	321	3	0	1	5	5	--	--
8/16	92044	348	3	0	1	5	5	--	--
8/16	92045	335	3	0	1	2	5	3	--
8/16	92046	318	3	0	1	5	5	--	--
8/16	92082	320	3	0	1	5	5	--	--
8/16	92083	317	3	0	1	5	5	--	--
8/16	92084	337	3	0	1	5	5	--	--
8/16	92085	306	3	0	1	5	5	--	--
8/16	92086	355	3	0	1	5	5	--	--
8/16	92087	314	3	0	1	5	5	--	--
8/16	92088	325	3	1	1	5	5	--	--
8/17	92152	300	3	0	1	5	5	--	--
8/17	92154	330	3	1	1	5	5	--	--
8/17	92155	330	3	1	1	5	5	--	--
8/17	92156	334	3	1	1	5	5	--	--
8/17	92157	309	3	0	1	5	5	--	--
8/17	92158	311	3	1	1	5	1	--	4
8/17	92159	304	3	1	1	5	5	--	--
8/17	92160	345	3	0	1	5	5	--	--
8/17	92161	320	3	1	1	5	5	--	--
8/17	92162	329	3	1	1	5	5	--	--
8/17	92163	354	3	0	1	5	5	--	--
8/17	92164	328	3	1	1	5	5	--	--
8/17	92165	315	3	1	1	5	5	--	--
8/17	92166	310	3	0	1	5	5	--	--
8/17	92167	323	3	1	1	5	1	--	3
8/17	92168	331	3	1	1	5	5	--	--
8/17	92169	310	3	1	1	5	5	--	--
8/17	92170	321	3	1	1	5	5	--	--
8/17	92171	330	3	0	1	5	1	--	2
8/17	92172	322	3	0	1	5	5	--	--
8/17	92173	320	3	0	1	5	5	--	--
8/17	92174	304	3	1	1	5	5	--	--
8/17	92175	345	3	0	1	5	5	--	--
8/17	92176	324	3	0	1	5	5	--	--
8/17	92177	331	3	0	1	5	5	--	--
8/17	92178	306	3	1	1	5	5	--	--
8/17	92179	322	3	0	1	5	5	--	--
8/17	92180	317	3	1	1	5	2	--	3
8/17	92181	305	3	0	1	5	5	--	--
8/17	92182	325	3	1	1	5	5	--	--

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Appendix A5. (Page 2 of 4).

Date	Tag #	Length (mm)	Gear Type[a]	Mortality[b]	Sample Status[c]	Spinal Injury[d]	Spinal Hemorr.[d]	Location Injury[e]	Location Hemorr.[e]
8/17	92183	325	3	1	1	5	1	--	3
8/17	92184	303	3	0	1	5	5	--	--
8/17	92185	312	3	0	1	5	5	--	--
8/17	92186	299	3	0	1	5	5	--	--
8/17	92317	330	3	1	1	5	5	--	--
8/17	92318	307	3	0	1	5	5	--	--
8/17	92319	325	3	0	1	5	5	--	--
8/17	92304	314	2	1	1	5	5	--	--
8/18	92360	296	2	0	1	5	5	--	--
8/18	92361	345	2	0	1	5	5	--	--
8/18	92404	346	2	0	1	5	5	--	--
8/18	92405	335	2	0	1	5	5	--	--
8/18	92407	324	2	0	1	5	5	--	--
8/18	92408	315	2	0	1	5	5	--	--
8/18	92411	325	2	0	1	5	5	--	--
8/18	92412	317	2	0	1	5	5	--	--
8/18	92414	319	2	0	1	5	5	--	--
8/18	92415	320	2	0	1	5	5	--	--
8/18	92417	317	2	0	1	5	5	--	--
8/18	92418	316	2	0	1	5	5	--	--
8/18	92420	311	2	0	1	5	5	--	--
8/18	92421	326	2	0	1	5	1	--	3
8/18	92422	340	2	1	1	5	5	--	--
8/18	92424	300	2	0	1	5	5	--	--
8/18	92425	335	2	0	1	5	5	--	--
8/18	92426	314	2	1	0	5	5	--	--
8/18	92427	309	2	0	1	5	1	--	3
8/18	92428	298	2	1	1	5	5	--	--
8/18	92430	322	2	0	1	5	1	--	4
8/18	92431	310	2	0	1	5	1	--	3
8/18	92432	295	2	0	1	5	5	--	--
8/18	92433	301	2	1	0	5	5	--	--
8/18	92434	320	2	0	1	5	5	--	--
8/18	92435	340	2	1	1	5	5	--	--
8/18	92436	320	2	1	0	5	5	--	--
8/18	92437	291	2	0	1	5	5	--	--
8/18	92438	317	2	0	1	5	5	--	--
8/18	92440	320	2	0	1	5	5	--	--
8/18	92441	313	2	1	1	5	5	--	--
8/18	92442	328	2	0	1	5	5	--	--
8/18	92444	329	2	0	1	5	5	--	--
8/18	92445	323	2	0	1	5	5	--	--

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Appendix A5. (Page 3 of 4).

Date	Tag #	Length (mm)	Gear Type[a]	Sample Mortality[b]	Sample Status[c]	Spinal Injury[d]	Spinal Hemorr.[d]	Location Injury[e]	Location Hemorr.[e]
8/18	92447	355	2	0	1	5	5	--	--
8/18	92448	345	2	0	1	5	5	--	--
8/18	92482	308	2	0	1	5	5	--	--
8/18	92484	365	2	0	1	2	1	1	3
8/18	92524	310	2	1	1	2	5	4	--
8/18	92525	313	2	1	1	5	1	--	3
8/18	92527	306	2	0	1	5	5	--	--
8/18	92528	305	2	0	1	5	5	--	--
8/18	92529	325	2	1	0	5	1	--	3
8/18	92530	328	2	0	1	5	1	--	3
8/18	92531	344	2	0	1	5	5	--	--
8/19	92620	310	2	0	1	5	5	--	--
8/19	92621	334	2	0	1	4	5	4	--
8/19	92622	326	2	0	1	5	5	--	--
8/19	92650	300	2	0	1	5	5	--	--
8/19	92651	330	2	0	1	5	5	--	--
8/19	92652	337	2	0	1	5	5	--	--
8/19	92654	316	2	0	1	5	5	--	--
8/19	92655	312	2	0	1	5	5	--	--
8/19	92657	358	2	0	1	5	5	--	--
8/19	92658	314	2	0	1	5	5	--	--
8/19	92660	345	2	0	1	5	5	--	--
8/19	92670	328	2	0	1	5	5	--	--
8/19	92707	316	2	0	1	5	5	--	--
8/19	92708	305	2	0	1	5	5	--	--
8/19	92710	306	2	0	1	5	5	--	--
8/19	92711	342	2	0	1	2	5	4	--
8/19	92712	324	2	1	1	5	5	--	--
8/19	92714	320	2	0	1	5	5	--	--
8/19	92715	290	2	0	1	5	5	--	--
8/19	92718	317	2	1	1	5	5	--	--
8/19	92720	322	2	0	1	5	5	--	--
8/19	92721	354	2	0	1	5	5	--	--
8/19	92722	372	2	0	1	5	5	--	--
8/19	92724	311	2	1	1	5	5	--	--
8/19	92725	314	2	0	1	5	5	--	--
8/19	92727	304	2	0	1	5	5	--	--
8/19	92728	297	2	0	1	5	5	--	--
8/19	92730	322	2	0	1	5	5	--	--
8/19	92731	330	2	1	1	5	5	--	--
8/19	92732	304	2	0	1	5	5	--	--
8/19	92734	304	2	1	1	5	5	--	--

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Appendix A5. (Page 4 of 4).

Date	Tag #	Length (mm)	Gear Type[a]	Mortality[b]	Sample Status[c]	Spinal Injury[d]	Spinal Hemorr.[d]	Location Injury[e]	Location Hemorr.[e]
8/19	92735	350	2	0	1	5	5	--	--
8/19	92737	297	2	0	1	5	5	--	--
8/19	92738	335	2	1	1	5	5	--	--
8/19	92754	286	2	0	1	5	5	--	--
8/19	92755	312	2	0	1	5	5	--	--
8/19	92756	337	2	1	0	5	5	--	--
8/19	92757	325	2	0	1	5	5	--	--
8/19	92758	327	2	0	1	5	5	--	--
8/19	92760	311	2	0	1	5	5	--	--
8/19	92761	320	2	0	1	5	5	--	--
8/19	92762	317	2	0	1	5	5	--	--

[a] 2 - electrofished, 3 - seine.
[b] 0 - no, 1 - yes.
[c] 0 - not part of random sample, 1 - part of random sample.
[d] 1 - minor, 2 - moderate, 3 - major, 4 - dislocation, 5 - none, 6 - natural deformity as described by Sharber and Carothers, (1988).
[e] 1 - vertebrae 1-19, 2 - 20-29, 3 - 30-39, 4 - 40-49, 5 - 50-60

Appendix A6. Summary of autopsy results from northern pike sampled from Minto Flats for electrofishing injury study.

Date	Tag Number	Length (mm)	Gear Type[a]	Sample Status[b]	Spinal Injury[c]	Spinal Hemorr.[c]	Location Injury[d]	Location Hemorr.[d]
	C1	450	C	1	0	0	--	--
	C2	530	C	1	0	0	--	--
	C3	630	C	1	0	0	--	--
3/14	C4	722	C	1	0	0	--	--
	C5	495	C	1	0	0	--	--
	C6	615	C	1	0	0	--	--
	C7	715	C	1	0	0	--	--
	C8	710	C	1	0	0	--	--
	C9	709	C	1	0	0	--	--
3/15	C10	620	C	1	0	0	--	--
	C11	510	C	1	0	0	--	--
	C12	680	C	1	0	0	--	--
	C13	510	C	1	0	0	--	--
	C14	470	C	1	0	0	--	--
	C15	420	C	1	0	0	--	--
	C16	770	C	1	0	0	--	--
6/3	C17	687	C	1	0	0	--	--
	C18	750	C	1	0	0	--	--
	C19	610	C	1	0	0	--	--
	C20	580	C	1	0	0	--	--
	C21	660	C	1	0	0	--	--
6/3	C22	590	C	1	0	0	--	--
	C23	535	C	1	0	0	--	--
	C24	675	C	1	0	0	--	--
	C25	695	C	1	0	0	--	--
	C26	620	C	1	0	0	--	--
	C27	470	C	1	0	0	--	--
	C28	550	C	1	0	1	--	4
	C29	545	C	1	0	0	--	--
	C30	450	C	1	0	0	--	--
	C31	535	C	1	0	0	--	--
	C32	415	C	1	0	0	--	--
	C33	520	C	1	0	0	--	--
	C34	820	C	1	0	0	--	--
	C35	550	C	1	0	0	--	--
	C36	605	C	1	0	0	--	--
	C37	600	C	1	0	0	--	--
	C38	810	C	1	0	0	--	--
	C39	635	C	1	0	0	--	--
	C40	660	C	1	0	0	--	--
	C41	720	C	1	0	0	--	--
	C42	760	C	1	0	0	--	--

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Appendix A6. (Page 2 of 3).

Date	Tag Number	Length (mm)	Gear Type[a]	Sample Status[b]	Spinal Injury[c]	Spinal Hemorr.[c]	Location Injury[d]	Location Hemorr.[d]
	C43	710	C	1	0	1	--	4
	C44	550	C	1	0	0	--	--
	C45	640	C	1	0	0	--	--
	C46	540	C	1	0	0	--	--
	C47	780	C	1	0	0	--	--
	C48	470	C	1	0	0	--	--
	C49	690	C	1	0	0	--	--
	C50	660	C	1	0	0	--	--
	C51	770	C	1	0	0	--	--
	C52	780	C	1	0	0	--	--
	C53	800	C	1	0	0	--	--
	C54	710	C	1	0	0	--	--
6/15	C55	650	C	1	0	0	--	--
	C56	700	C	1	0	0	--	--
	C57	670	C	1	0	0	--	--
	C58	620	C	1	0	0	--	--
	C59	540	C	1	0	0	--	--
	C60	560	C	1	0	0	--	--
	C61	490	C	1	0	0	--	--
3/13	C62	670	C	1	1	0	4	--
	C63	590	C	1	0	0	--	--
	C64	640	C	1	0	0	--	--
	C65	690	C	1	0	0	--	--
	C66	740	C	1	0	0	--	-
	C67	580	C	1	0	0	--	--
	C68	650	C	1	1	0	4	--
	C69	640	C	1	0	0	--	--
	C70	840	C	1	0	0	--	--
	C71	790	C	1	0	0	--	--
	C72	820	C	1	0	0	--	--
9/15	E2	570	T	1	0	0	--	--
9/15	E3	490	T	1	0	0	--	--
9/15	E4	830	T	1	0	0	--	--
9/15	E5	740	T	1	0	0	--	--
9/15	E6	570	T	1	0	0	--	--
9/15	E7	620	T	1	0	0	--	--
9/15	E8	500	T	1	0	0	--	--
9/15	E9	485	T	1	0	0	--	--
9/15	E10	400	T	1	0	1	--	4
9/15	E11	480	T	1	0	0	--	--
9/15	E12	415	T	1	0	0	--	--
9/15	E13	590	T	1	1	2	2	2
9/15	E14	520	T	1	0	0	--	--

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Appendix A6. (Page 3 of 3).

Date	Tag Number	Length (mm)	Gear Type[a]	Sample Status[b]	Spinal Injury[c]	Spinal Hemorr.[c]	Location Injury[d]	Location Hemorr.[e]
9/15	E15	720	T	1	4	3	2	2
9/15	E16	540	T	1	4	2	2	2
9/15	E17	400	T	1	0	0	--	--
9/15	E18	570	T	1	1	0	14	--
9/15	E19	760	T	1	0	0	--	--
9/15	E20	430	T	1	0	0	--	--
9/15	E21	460	T	1	0	0	--	--
9/15	E22	410	T	1	0	0	--	--
9/15	E23	500	T	1	0	0	--	--
9/15	E24	490	T	1	0	1	--	1
9/15	E25	520	T	1	0	0	--	--
9/15	E26	600	T	1	0	0	--	--
9/15	E27	520	T	1	0	0	--	--
9/15	E28	460	T	1	0	0	--	--
9/15	E29	450	T	1	0	0	--	--
9/15	E30	650	T	1	1	3	1	1
9/15	E31	535	T	1	0	0	--	--
9/15	E32	740	T	1	0	0	--	--
9/15	E33	550	T	1	0	0	--	--

[a] C - control (hook and line, gill net, or fyke trap), T - test (electrofishing).

[b] All fish captured were sampled.

[c] 1 - minor, 2 - moderate, 3 - major, 4 - dislocation.

[d] 1 - vertebrae 1-19, 2 - vertebrae 20-29, 3 - vertebrae 30-39, 4 - vertebrae 40-49, 5 - vertebrae 50-60.