Fishery Data Series No. 00-01

Influences of Beaver Dams on Arctic Grayling in Piledriver Slough, 1998-1999

by

Klaus G. Wuttig

April 2000

Alaska Department of Fish and Game **Division of Sport Fish**

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Weights and measures (metric)

Centimeter	cm
Deciliter	dL
Gram	g
Hectare	ha
Kilogram	kg
Kilometer	km
Liter	L (see Gregg 537)
Meter	m
metric ton	mt
Milliliter	ml
Millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
Foot	ft
Gallon	gal
Inch	in
Mile	mi
Ounce	oz
Pound	lb
Quart	qt
Yard	yd

Spell out acre and ton.

Time and temperature

Day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
Minute	min
Second	s

Spell out year, month, and week.

Physics and chemistry

all atomic symbols	
alternating current	AC
Ampere	A
Calorie	cal
direct current	DC
Hertz	Hz
Horsepower	hp
hydrogen ion activity	pH
parts per million	ppm
parts per thousand	ppt, ‰
Volts	V
Watts	W

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	Etc.
exempli gratia (for example)	e.g.,
id est (that is)	i.e.,
latitude or longitude	Lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

alternate hypothesis	H_A
base of natural logarithm	E
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	F, t, χ^2, etc.
confidence interval	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	Ln
logarithm (base 10)	log
logarithm (specify base)	$log_{2,}$ etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	X
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
standard length	SL
total length	TL
variance	Var

FISHERY DATA SERIES REPORT NO. 00-01

INFLUENCES OF BEAVER DAMS ON ARCTIC GRAYLING IN PILEDRIVER SLOUGH, 1998-1999

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ABSTRACT

Due to sharp declines in Arctic grayling *Thymallus arcticus* abundances coincident with the encroachment of several new beaver dams in Piledriver Slough, an experimental study was initiated to determine the response of instream habitat and Arctic grayling to dam removals. In 1998, locations and dimensions of beaver dams and impoundments were documented, electronic thermographs recorded water temperatures, and the distributions and relative abundance (CPUE) of adult and age-0 Arctic grayling using visual inspections, hook and line gear, and a beach seine were examined. Eight dams were documented with an attenuation of Arctic grayling observed moving upstream from the lowermost dam with no fish documented above the sixth dam. In the fall, early season trapping permits were issued to remove beavers, and the two lowermost dams were breached. In 1999, Arctic grayling sampling and temperature monitoring was repeated. Relative abundance of Arctic grayling increased notably, particularly for age-0 fish in reclaimed riffle-run habitat. Beaver dams appeared to have a negligible effect on water temperatures, Arctic grayling responded positively to dam breaching, and beaver control measures appeared to be effective. Given these results it is likely that the judicious removal of the remaining dams could ultimately translate into increased production and abundance of Arctic grayling in Piledriver Slough if an acceptable beaver maintenance program is manageable. Removal of the remaining dams, active beaver management by aggressive trapping, and continued monitoring of beaver activity and Arctic grayling distributions are recommended.

Key words: Arctic grayling, *Thymallus arcticus*, beaver, *Castor canadendis*, Piledriver Slough, beaver dams, habitat, abundance, distribution

INTRODUCTION

Before 1940, Chena Slough was one of several side channels of the Tanana River that carried large volumes of glacial water. As early as 1909, floods in the Chena River at Fairbanks were attributed to overflow from the Tanana River flowing through connecting side sloughs. In 1943, Chena Slough was bisected by construction of the Moose Creek Dike, a flood control project to divert waters back into the Tanana River. This project created both Badger and Piledriver sloughs. The Tanana River continued to flow into Piledriver Slough until construction of the Chena River Flood Control Project in 1976 when dikes cut off the upper end of Piledriver Slough. These dikes converted Piledriver Slough from a glacial side channel of the Tanana River into a controlled and low (1-2 m^3/s) flow groundwater system fed by upwellings from the Tanana River aquifer. Piledriver Slough is 34 km long, has an average channel slope of 0.00077 m/km draining approximately 75 km^2, and consists of a long series of pools intermittently broken by shallow riffles and glides (Wuttig 1997). Adjacent to the slough are limited agricultural lands and urban development. Much of the land adjacent to Piledriver Slough lies within the Eielson Air Force Reservation.

The conversion of Piledriver Slough to a groundwater-fed system substantially enhanced the productivity of Arctic grayling *Thymallus arcticus* and the recreational value for sport fishing. It is likely that Piledriver Slough was colonized by Arctic grayling by straying from nearby streams and rivers. Since its conversion to a clearwater slough, Piledriver Slough has begun to exhibit many common problems associated with regulated flows, namely the absence of flushing flows (Wuttig 1997). Flushing flows are necessary for channel maintenance (particularly removal of fines from gravel substrates and control of aquatic macrophytes and algae), riparian habitat maintenance, and maintenance of fishery habitat (Reiser et al. 1989). More recently, beaver populations and the number of beaver dams have increased, compounding the problem associated with a lack of flushing flows. Early signs of eutrophication have been documented in the lower reaches of Piledriver Slough (Wuttig 1997).

Arctic grayling move into the slough to spawn in the spring, and also inhabit the slough during summer. In a study conducted by Merritt (1993) Arctic grayling radio-tagged in Piledriver Slough in August migrated to the Tanana River and adjacent streams to overwinter. Sport Fish Division has conducted population estimates of spawning Arctic grayling in Piledriver Slough since 1990 (Timmons and Clark 1991; Fleming 1991, 1994, 1995, 1997 and 1998; Fleming and Schisler 1993; Table 1). In 1990 and 1991, the stock was sampled and assessed beginning upstream of Stringer Loop Road crossing, downstream 32 km toward the confluence with the Tanana River (Figure 1). In 1992 and subsequent years, stock assessment was done in areas adjacent to and upstream of the Eielson Farm Road. Assessments in 1992-1994 included a 16 km section bordered upstream by a large beaver dam (#5) and downstream to the Eielson Farm Road. In 1996 and 1997, the areas for stock assessment were reduced to a study reach 13.8 km in length, located downstream from the lowermost beaver dam (#8). Dramatic declines in abundance of Arctic grayling have been apparent since 1992 and seem to be correlated with new beaver dams. Of the original habitat utilized by Arctic grayling in the summer and spring of 1990 and 1991, approximately 48% remains (Figure 1). Concerns are that further encroachment by beavers and construction of new dams in downstream areas could result in a lower carrying capacity for Arctic grayling in Piledriver Slough.

It is unknown how effective beaver dams are in blocking upstream migration of fish. Information from sampling (D. Fleming, ADF&G, Fairbanks, personal communication) and anecdotal information from anglers suggests that some adult Arctic grayling and sterile rainbow trout, which are stocked annually, may reside and over-winter in some of the beaver ponds. It is not known whether Arctic grayling that reside in these ponds successfully reproduce, or if so, whether the offspring survive to a desirable size for anglers (at least 200 mm).

Instream habitat can be greatly altered by beavers, resulting in both beneficial or detrimental effects on fish populations. Beavers in boreal forests can modify stream hydrology, increase retention of sediment and organic matter by reducing stream velocity, increase standing stocks of carbon, alter stream acidity and temperature, and inhibit fish passage (D' Efron et al. 1995).

McRae and Edwards (1994) observed higher temperatures at the outlets of beaver ponds than at the inlets, and warmer downstream temperatures influenced the distribution of brook trout. There is a potential for beaver dams to block access to overwintering refuges in the Tanana River and coldwater refuges during summer. The warming of downstream reaches by beaver impoundments is affected by the degree of shading, air temperature, groundwater flow, and stream volume. Leidholt-Bruner et al. (1992) found that beaver dams increased summer pool habitat for rearing coho salmon fry. In addition, beaver impoundments can result in an increase in benthic insect density and diversity.

The purpose of this study was to initiate an experimental habitat management project to determine the responses of instream habitat and the Arctic grayling population to habitat alteration (dam breaching) over the span of several years. Following careful study of the watershed, judicious removal of a few key beaver impoundments may have a strong effect on the distribution and abundance of Arctic grayling in Piledriver Slough. A measure of project success would be if Arctic grayling recolonized habitat that was displaced by beaver dam complexes. Increased habitat availability of the slough for feeding, rearing and/or spawning should ultimately translate into additional Arctic grayling production.

Table 1.-Fishery characteristics and abundance estimates for Arctic grayling in Piledriver Slough, 1990-1997.

Fishery (Year)	Fishery (Status)	Abundance (≥ 150 mm)	Harvest (Mills)	Habitat assessed (Km)
1990	Open	16,435	2,380	31.0
1991	Open	17,323	3,987	34.6
1992	Open	14,030	1,030	16.1
1993	C&R[a]	10,587	759	16.1
1994	C&R	11,747	57	16.1
1995	C&R	nd	0	nd
1996	C&R	9,981	0	13.8
1997	C&R	8,660	nd	13.8

[a] In 1993 the fishery was open until 23 June when it was closed to harvest by Emergency Order and catch and release (C&R) regulation were implemented.

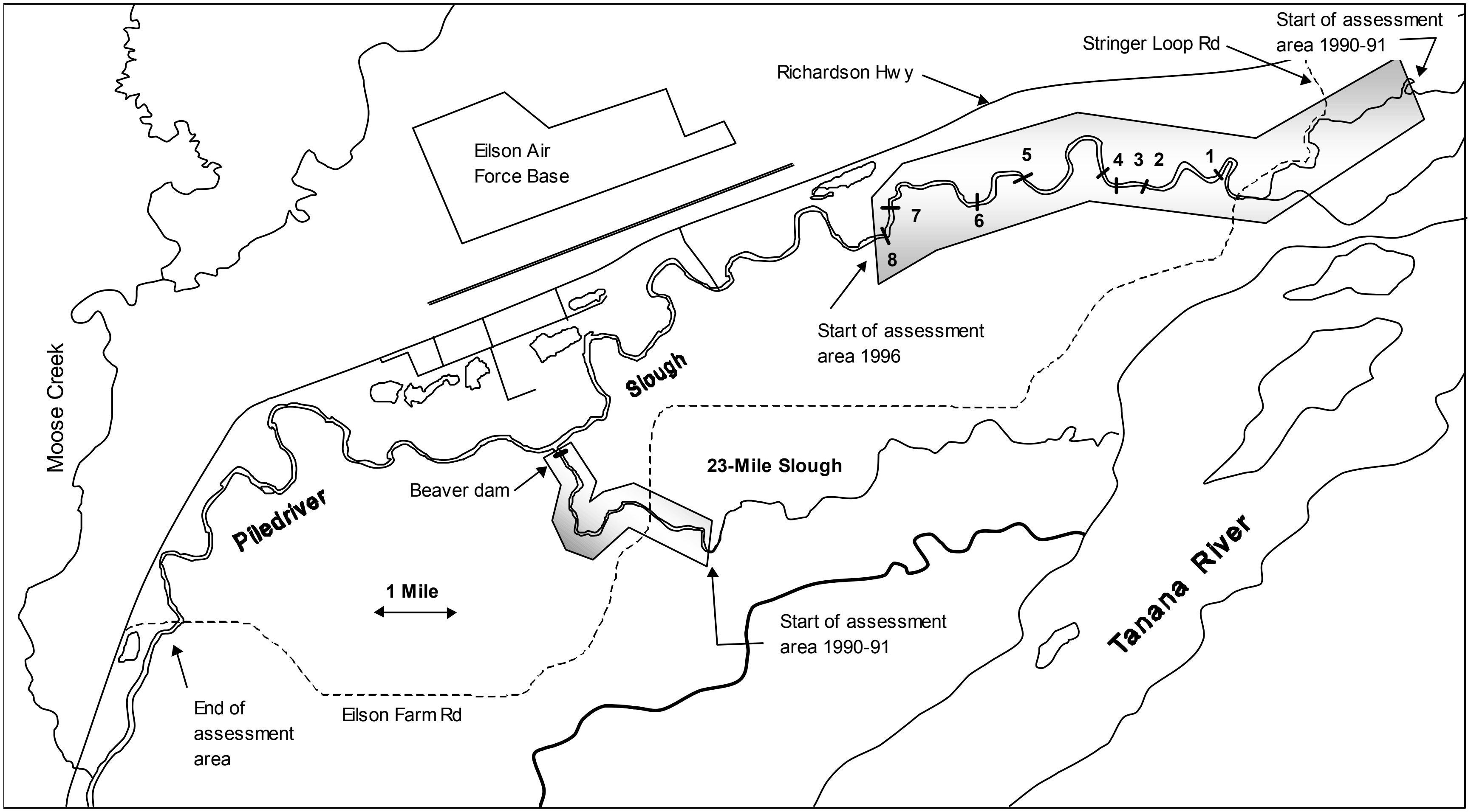

Figure 1.-Assessment areas and locations of beaver dams in Piledriver Slough. Numbers indicate beaver dam locations. Shaded areas indicate sections of stream that supported Arctic grayling prior to dam construction. The mouth of 23-Mile Slough was dammed in 1992 and was not assessed after 1991.

OBJECTIVES

Project objectives were to:

1. in 1998, determine the spatial distribution of juvenile and adult Arctic grayling in relation to beaver dam complexes of Piledriver Slough between the Stringer Loop Road and the most downstream dam during midsummer by inspection, angling, and seine hauls; and,
2. in 1999, repeat objective “1” after breaching the two lowermost beaver dams in the fall of 1998.

In addition, project tasks are to:

1. map all locations and measure dimensions of beaver dams complexes in Piledriver Slough; and,
2. monitor water temperature in two beaver dam complexes during the summer of 1998 and 1999.

METHODS

In 1998, a reach of Piledriver Slough from Stinger Road to Bailey Bridge Slough was surveyed to determine the locations and dimensions of all beaver dams encountered, document stream characteristics, and to determine the presence and absence of Arctic grayling in relation to the impoundments encountered (Figure 1). In the fall of 1998, a beaver control program was initiated and the two lowermost beaver dams were breached. In July 1999, fieldwork was repeated to assess the responses of the instream habitat and the Arctic grayling population to dam breaching.

On 28 and 29 July 1998, two two-person crews canoed a 9.3 km reach of Piledriver Slough from the Stringer Road crossing to Bailey Bridge (Figure 1). The locations of beaver dams were recorded with a GPS and then were transcribed onto a 1:25,000-scale topographic map. Dam dimensions were measured with a 50 m tape measure. The height of each dam was measured at approximately five equally spaced intervals and at is maximum height. Dam height was measured on the downstream side of the dam from the bottom of the stream channel to the top of the dam. In addition, differences in water surface levels above and below the dam were measured. All dams and ponded areas were numbered sequentially from upstream to downstream such that pond number one was impounded by dam number one.

The large size of the beaver dam impoundments and the limited sampling time budgeted precluded measurements of beaver dam pond and stream characteristics (area, width, depth, and velocity). Ponds often exceeded 500 m in length and 50 m in width. The upstream and downstream endpoints of all ponds and unimpounded sections of the study area were recorded with a GPS. Unimpounded areas are those reaches of the slough between beaver dams that are not flooded. Using a digitizing table, the length of each pond and unimpounded reach was estimated by measuring the distance between the upstream and downstream endpoints transcribed on a 1:25000 scale topographic map.

Four temperature data loggers were placed within the study section to measure stream temperatures. Optic StowAway Temp data loggers manufactured by Onset Corporation were used with temperatures being recorded at 2-hr intervals. In 1998, loggers were deployed on

July 29 and placed immediately below dam #1, above pond #6, below dam #6 and below dam #8. In 1999 loggers were deployed on June 6 and placed below dam # 3, above pond # 5, below dam # 5, and in a riffle above dam # 7. Distances between the three lowermost data loggers were approximately equal.

In 1998, the presence or absence of Arctic grayling between two dams was determined by a variety of methods. On 28 and 29 July, presence of Arctic grayling was determined from visual inspections, using small mesh beach seines (10 m long, 1 m deep, and 3 mm mesh), and from hook and line sampling. Visual observations were made from the canoe as well as on foot. Areas of the most suitable habitat (riffles and heads of pools) were closely inspected. Water visibility was very high and polarized sunglasses were worn to decrease glare. Three seine hauls were conducted between each dam, usually at the heads of riffles and pools. Two-hours (1-hr x two persons) were spent angling between each set of dams and four-hours were spent below the lower most dam. Terminal gear consisted of a combination of artificial flies, spinners, and mini jigs. A relative measure of abundance in each pond was inferred from catch per unit effort data. In 1999, the sampling protocol for Arctic grayling was repeated on 20 to 23 July using a single two-person crew.

All captured Arctic grayling were measured to the nearest 1 mm FL length and examined for tags. All fish < 100 mm FL were assumed to be age-0 fish. The number and location of fish < 100 mm captured was recorded. Fish ≥ 150 mm FL were tagged with an individually numbered Floy™ FD-67 internal anchor tag and released. Tags deployed were gray and tag numbers ranged from 29660 to 29500 in 1998, and were blue ranging from 32700 to 32775 in 1999. Two scales were taken from each captured fish ≥ 100 mm FL and mounted directly on gum cards for aging. Scales were taken from the preferred area approximately six scale rows above the lateral line just posterior to the insertion of the dorsal fin (W. Ridder, Alaska Department of Fish and Game, Delta Junction, unpublished information on refinement of methods described by Brown 1943). Scales were briefly cleaned removing slime and dirt and mounted directly on gum cards. The gum cards were used to make triacetate impressions of the scales (30 seconds at 137, 895 kPa, at a temperature of 97°C). Ages are determined by counts of annuli from impressions of scales magnified to 40X with the aid of a microfiche reader. Criteria for determining the presence of an annulus are: 1) complete circuli cutting over incomplete circuli; 2) clear areas or irregularities in circuli along the anterior and posterior fields; and, 3) regions of closely spaced circuli followed by a region of widely spaced circuli (Kruse 1959).

On 19 September, 1998 a float trip down Piledriver Slough was conducted to retrieve temperature data loggers and to observe fish distributions. Areas of known fish aggregations from the July sampling occasions were reinspected.

In October, 1998 and in September, 1999, working cooperatively with Eielson Air Force Base personnel and the Alaska Department of Fish and Game (ADF&G), Division of Wildlife, preseason trapping permits (nuisance permits) were issued to recreational trappers to aid in the removal of beavers within the study area. On 2 and 4 November 1998, crews of four to six persons worked to remove 7.5 m sections of dam from dams #6 and #8. Dam #7 was inactive and was already breached. In 1998, dam material was removed with the use of hand tools (axes, chainsaws, shovels, polaskies, and crowbars) and using a 10,000 lb truck winch tethered to a large grappling hook. In 1999, dam #5 was pulled using similar hand tools and a chainsaw winch tethered to a smaller grappling hook. Breaching of dams was conducted in late fall to allow trappers sufficient time to trap the resident beavers, and before the onset of winter conditions (thick ice cover) which could preclude any remaining (untrapped) beavers from repairing dams. Furthermore, it was thought that dewatering the ponds might aid in eradicating any remaining beavers by excluding their winter food caches and over-wintering habitat, and by freezing dens by exposing den openings.

RESULTS

1998

A total of eight dams were observed within the 9.3 km study area (Figure 2). The tallest dams were dams #3, #6, and #8 (Table 2). Each of these dams had the greatest differential in water surface levels above and below the dams, approximately 1.5 meters. The ponded areas behind the beaver dams were extensive and tended to reach the next upstream impoundment. Between dam #1 and dam #8 (5.83 km), approximately 88 % (5.1 km) of the slough was ponded, and 12% (1.5 km) of the slough contained unimpounded sections. Unimpounded sections containing riffles of various lengths were found below dam #1 (200 m), #3 (75 m), #4 (380 m), and #6 (800 m) (Figure 2).

A progression of increasing densities of age 0 and adult Arctic grayling was observed moving downstream along the study area with no Arctic grayling found (observed or captured) above dam #3 (Table 3). Of all the Arctic grayling captured or observed, none were seen or captured within the large ponded areas above the dams. The adult Arctic grayling tended to occupy the riffle-run habitat located in the unimpounded areas immediately below a beaver dam and at the heads of pools immediately below riffles located between dams. Age-0 fish were found primarily along the margins of riffle-run habitat and immediately below beaver dams. The largest concentrations of age-0 fish were located in the rivulets that flowed out of the dams which are heavily vegetated with alder *alnu*s spp. All Arctic grayling captured (> 100 mm FL) ranged from 2 to 10 years with age-4 as the median and mean age and sizes ranged from 122 to 368 mm (Tables 4 and 5).

From 29 July to 30 August 1998, average daily slough temperatures increased slightly (2.2 C^{o}) from dam #1 to #8. The difference in the average daily maximum temperatures between dam #1 to dam #8 was 1.6 C^{o} (Figure 3). Weather conditions during this period were uncharacteristically cloudy and cool.

During the retrieval of the data loggers on 19 September, no Arctic grayling were observed above dam #6. Below dam #6 a small group of adult Arctic grayling (<5) were observed feeding in a riffle below the dam and one age-0 fish was seen where numerous large schools (>100 fish) were observed in July. Similarly, a few adult Arctic grayling (<5 fish) and no age-0 fish were observed below dam #8.

On 2 and 4 November a 7.5 m section of dam was removed from dam #6 and dam #8. Extensive freezing of the dam face limited the amount of material that could be effectively removed. The breach in each dam did not extend down to the stream bottom. In dam #8, approximately 0.3 m of dam material remained, but did not appear that it would hinder fish passage. Similarly, with dam #6, not all the material could be removed down to the stream bottom, but was judged sufficient to allow for fish passage. During the winter, October through February, area trappers had reportedly captured a total of 20 beavers within or near the study area.

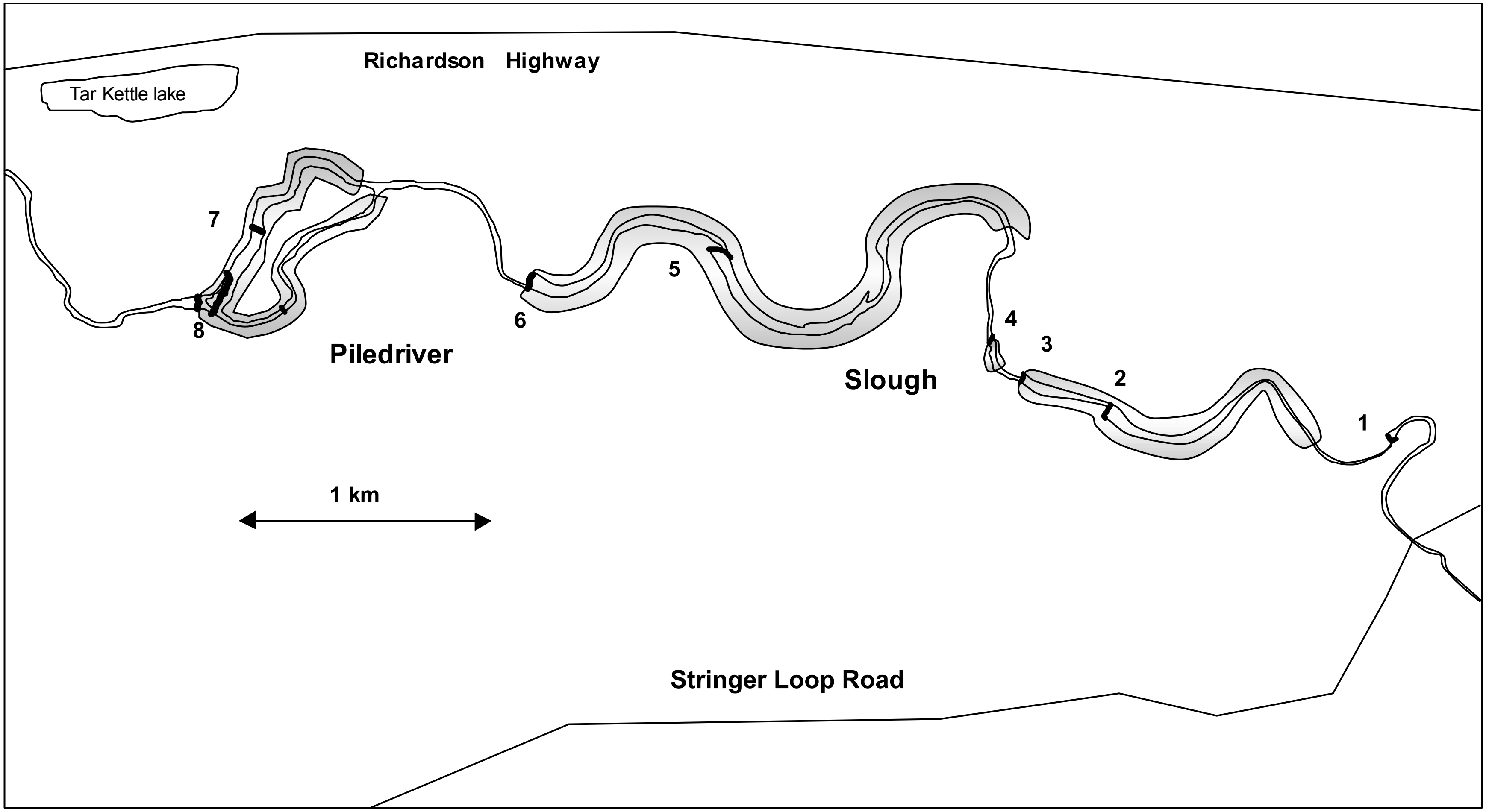

Figure 2.-Locations of beaver dams in study area along Piledriver Slough, 1998. Shaded areas represent ponded areas and beaver dams are numbered.

Table 2.-Piledriver Slough beaver dam and pond dimensions, July 1998.

Dam #	Width (m)	Max height (m)	Water level differential[b] (m)	Length of pond (km)
1[a]	15.2	0.46	0.00	-
2	68.6	1.13	0.21	0.92
3	55.5	1.58	1.22	0.33
4	29.0	0.52	0.15	0.13
5	105.2	1.37	0.52	1.37
6	69.5	1.52	1.19	0.78
7[a]	44.5	0.94	0.00	-
8	168.2	1.65	1.16	0.48

[a] Beaver dam has been breached.

[b] Difference in height of water levels above and below dam.

Table 3.-Number of Arctic grayling observed and captured in slough reaches between dams within Piledriver Slough, 1998 and 1999.

	Number of fish > 100 mm captured		Number of age-0 fish observed and/or captured	
				1999
Dam #1 - #3	0	0	0	0
Dam #3 - #4	1	1	0	300+
Dam #4 - #5	1	1	60	100+
Dam #5 - #6	0	10	0	1000+
Dam #6 - #7	42	20	500+	250+
Dam #7 - #8	0	0	0	25+
Below dam #8	38	34	2,000+	500+

Table 4.-Number of Arctic grayling ≥ 100 mm FL by 15 mm incremental size class captured in Piledriver Slough, 1998 and 1999.

	Below dam #8
	0
	34

Table 5.-Number of Arctic grayling 100 mm FL by age class captured in Piledriver Slough, 1998 and 1999.

Below dam #8
0
30

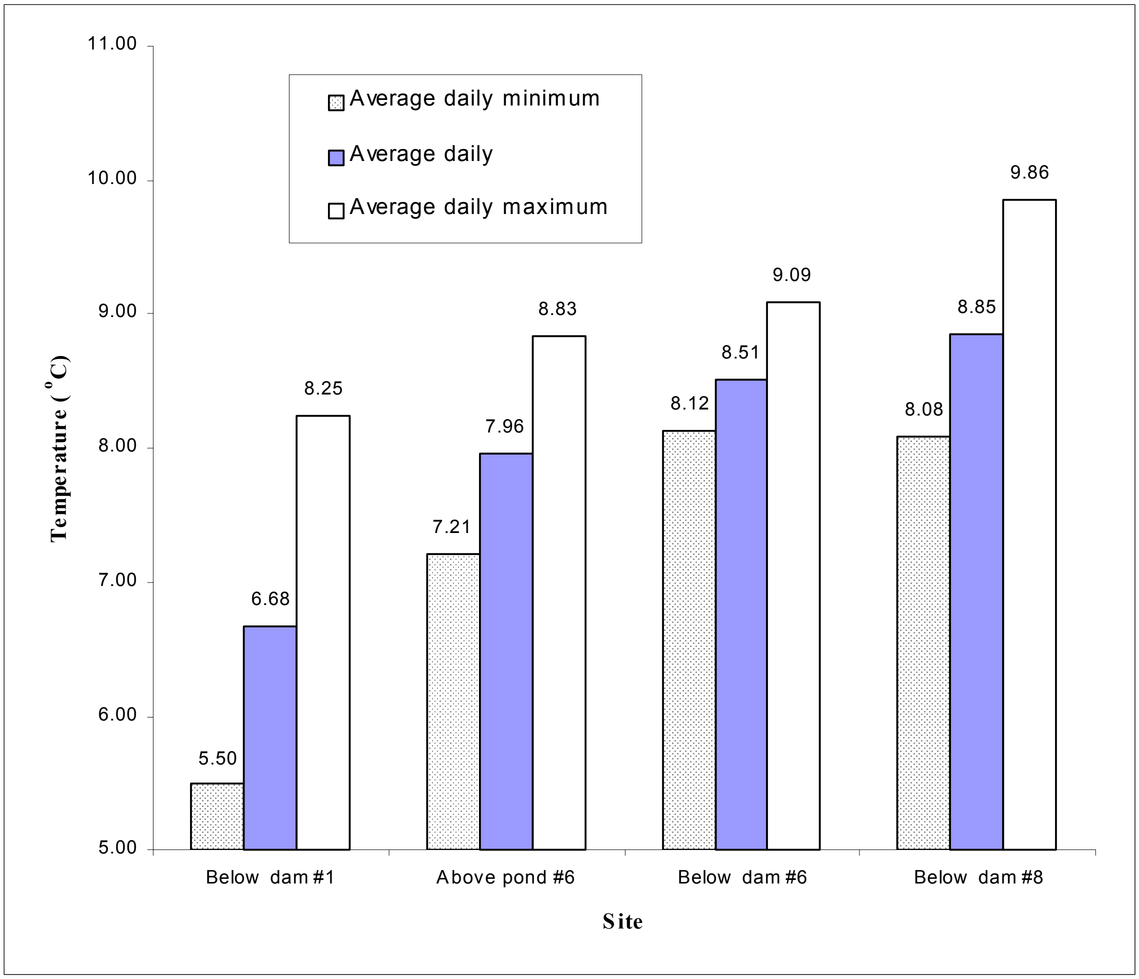

Figure 3.-Average, average maximum, and average minimum water temperatures in Piledriver Slough, 29 July – 31 August, 1998.

1999

Periodic examinations throughout the summer and fall revealed no signs of beaver activity at the lodges, food caches, and dams where the dams had been breached. Food caches appeared untouched, no fresh tracks or cuttings were observed, and the breaches remained opened. Large areas of gravel bars and shoreline that had been submerged were exposed as well as openings into the bank dens. Relatively deep scour holes (1-2 m) had formed below breached openings and gravel substrates had been scoured well below the breaches (100 m). Breaching of dams #8 and #6 reclaimed 2.4 km of slough and added five new riffle sections (Figure 4). Breaching of dam #5 reclaimed 1.6 km of slough. Exposed riffle sections from breaching dam #5 will be examined in 2000. Water velocities in previously ponded areas increased noticeably after breaching, from velocities that were previously immeasurable up to velocities of approximately 1 m/s. Large masses of aufeis (1 m thick) remained in the active channel through June 10, particularly above dam #8 where the entire channel was covered with aufeis forcing the water to flow through spruce and alder growths along the shore margins.

In 1999, the distribution of Arctic grayling was similar to 1998, except that the pattern had shifted, or "leapfrogged" upstream to the next unbreached dam (#5) that was not breached during the summer of 1999. No Arctic grayling were found (observed or captured) above dam #3, more fish were observed between dams #3 and #5, and fish were distributed throughout the entire length of the reclaimed section of slough between dams #5 to dam #8. As in 1998, the highest concentrations of age-0 fish were observed in the rivulets below the lowermost unbreached dam (#5). All Arctic grayling captured (> 100 mm FL) ranged from 2 to 7 years with age-4 as the median and mean age with sizes ranging from 198 to 320 mm (Table 4).

From 10 June to 10 August, 1999, average daily slough temperatures increased slightly (2.3 C^o) from dam #3 to #7. The difference in the average daily maximum temperatures between dam #3 to dam #7 was 1.6 C^o (Figure 5). Weather conditions during this period were considered normal.

DISCUSSION

The beaver dams on Piledriver Slough are likely influencing Arctic grayling by: hindering or blocking fish passage to spring spawning grounds, summer feeding areas, and overwintering areas; changing of thermal regimes; silting in of gravel areas (riffles); and, altering food availability. Beaver dams may impede fish migrations and cause flooding of spawning areas (Arvey 1992, Churchill 1980). It is apparent from prior stock assessment work and from this study that there is a substantial impact of beaver dams on the distributions of Arctic grayling in Piledriver Slough. Most notable were the differences in relative abundance and distribution of Arctic grayling between the three largest dams (dam #3, #6, and #8) during historical stock assessment work compared to recent years before and after dam breaching. Stock assessment work conducted prior to this study already suggested that the construction of these three dams were hindering or blocking migration of Arctic grayling to spring spawning and summer feeding areas. In the spring of 1991, prior to the establishment of any dams, abundance of Arctic grayling ≥150 mm FL was estimated at 561 in a 3 km reach of Piledriver Slough upstream of Stringer Road and 570 fish between Stringer Road and Bailey Bridge (Fleming 1991). It is suspected that dam #3 was constructed during the summer of 1991, and during spring assessment the following year almost no Arctic grayling were found above Dam #3 (Fleming and Schisler 1993). It is thought that the construction of dam #6 started during 1992 and completely blocked fish passage by 1994. During stock assessment work in 1992-94 insufficient numbers of Arctic

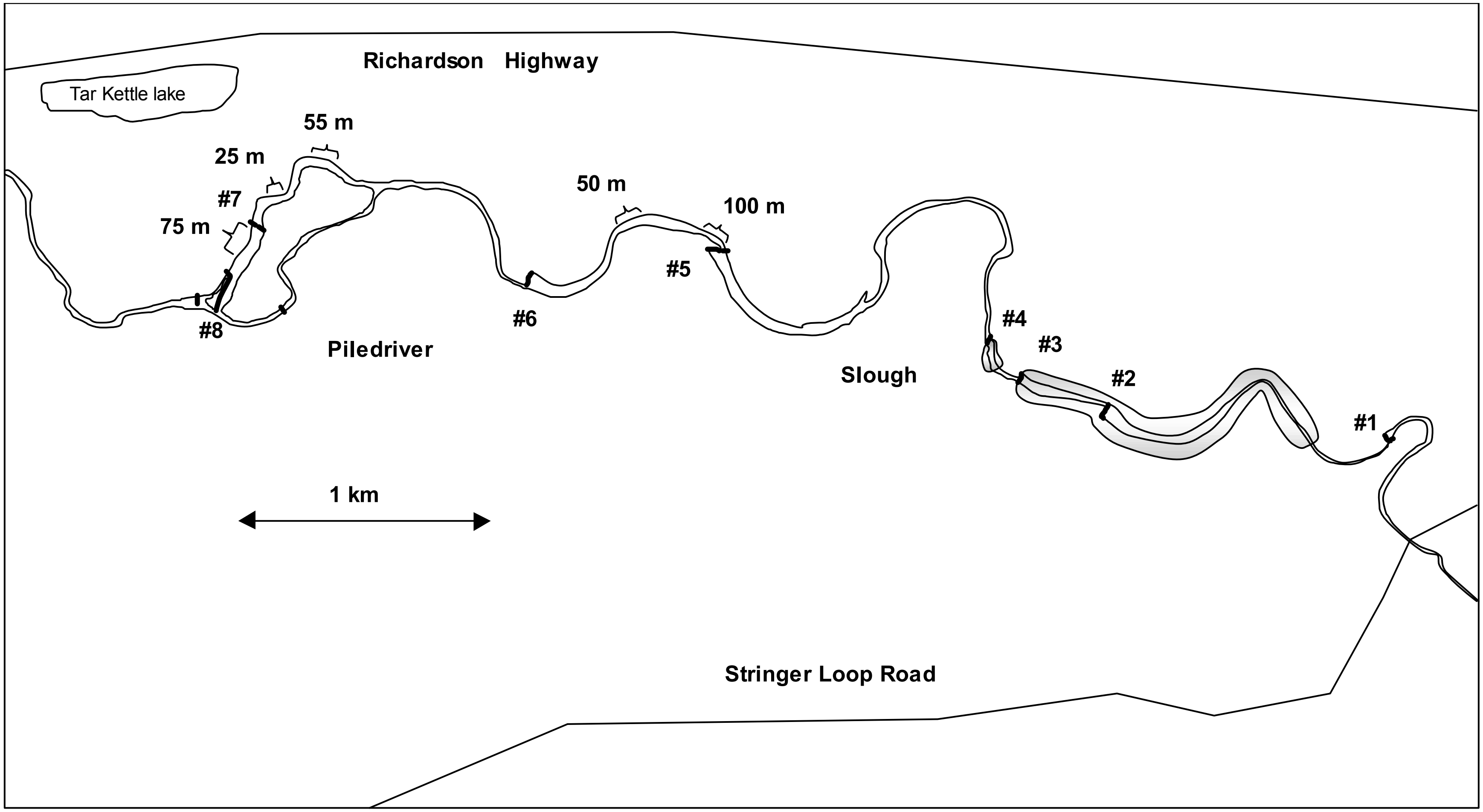

Figure 4.-Locations of beaver dams in study area along Piledriver Slough, 1999. Shaded areas represent ponded areas and newly exposed riffle sections are indicated with brackets and labeled by their length (m).

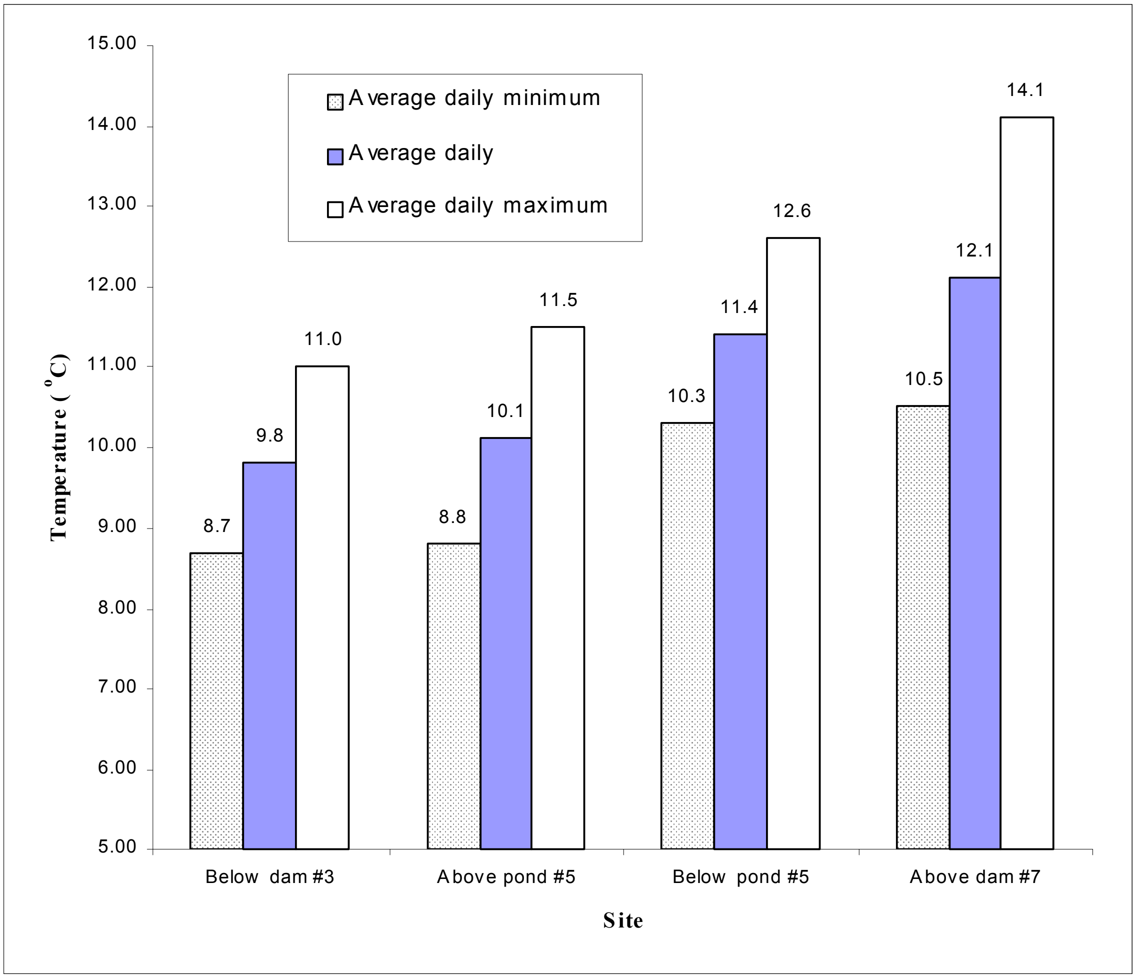

Figure 5.-Average daily, average maximum, and average minimum water temperatures in Piledriver Slough, 10 June – 10 August, 1999.

grayling were found between dam #3 and #6 to attain an estimate, therefore, the estimates were germane to below Dam #6 (Fleming1994).

Distribution and abundance of Arctic grayling from the prior assessment work is consistent with what was observed in this study. In 1998, no fish were captured or observed above dam #3, between dam #3 and #6 only two adult Arctic grayling were captured and one school of age-0 fish was observed, and between dam #6 and #8 juvenile and adult Arctic grayling were captured, however in lesser numbers than below the lowermost dam (dam #8). The distribution pattern observed in 1998 appeared to have shifted upstream in 1999, after pulling dams #6 and #8, to the lowermost unbreached dam, dam #5. Still, no fish were captured nor seen above dam #3, there was an increased number of fish between dams #3 and #5, and a "normal" dispersal or distribution of fish below dam #5. Whether the Arctic grayling found within the impounded sections prior to this study had migrated there, were remnant populations, or progeny thereof is not certain. However, it is evident that fish movement and possibly fish spawning further upstream are the primary mechanisms causing numbers of adult and age-0 Arctic grayling to increase after dam breaching.

Beaver activities may be further affecting Arctic grayling by displacing preferred spawning, feeding, and rearing habitat and by changing food availability due to flooding and increased retention of sediments and organic materials. Of all the Arctic grayling captured or observed within the study section, no fish were captured or seen in the large ponded areas above the dams. The adult Arctic grayling tended to occupy riffles and glides or reside in pools immediately below riffles. Flooding of riffle areas above the dams would in effect remove these areas of preferred habitat used for feeding and spawning. Adult Arctic grayling were shown to preferentially spawn over pea-sized gravel associated with riffle areas (Armstrong 1986) while age-0 fish prefer to feed within the channel over exposed substrates (Lucko 1992). Age-0 fish were found along the margins of riffle-run habitat and immediately below the beaver dams. The largest concentrations of age-0 fish were found occupying the numerous rivulets that flowed out of the dams, which are heavily vegetated with alder and provide excellent cover. Breaching of dams would remove these rivulets. However, the loss of this habitat would likely be offset by the additions of riffle-run habitat. Beaver activities can also influence invertebrate community structure by replacing running-water taxa by pond taxa (primarily a response to finer sediments and decrease in current speed) (Naiman et al. 1988). Wuttig (1997) found large numbers of planktonic organisms (mainly chyorids, copepods, and daphnids) in drift samples from Piledriver Slough, and Walker (1983) found that age-0 Arctic grayling in Piledriver and Badger sloughs tended preyed on all these food items, but preferred copepods.

Respiratory demands from the increased retention of organic matter can rapidly deplete the supply of oxygen during ice cover (Welch 1992). Areas of depleted oxygen levels (< 1.0 mg/l) were identified below the study area during 1991 and 1997 (Merritt 1993, Wuttig 1997). If unsuitable oxygen conditions develop within impoundents, excessive mortality may occur if the dams could inhibit migrations to more suitable overwintering habitat.

In 1998, small increases in stream temperatures were measured in stream reaches below beaver ponds and the degree of warming seemed to increase with distance. Between the uppermost and lowermost data loggers, an increase of 2.2 C^o (average daily temperatures) was noted, whereas the difference between the inlet and outlet of ponds number #5 and #8 was 0.5 and 0.3 degrees respectively. These relatively small increases in water temperature at the outlet of the beaver ponds are likely attributed to an uncharacteristically cloudy and cool August. Inputs of cool groundwater and vegetative shading can make it difficult to generalize the effect of beaver impoundments on water temperatures (McRae and Edwards 1994). However, in 1999 a slightly more pronounced warming effect was observed particularly during June. The increase in average water temperatures was greater between the inlet and outlet of dam #5 (1.7 C^{o}), than for a similar length of slough below dam #5 (0.7 C^{o}). In contrast, the unimpounded sections experienced greater rates of heating and cooling (higher temperatures during mid-day and cooler at night) than did the outlet of the impoundment. Therefore, the impoundments appear to be warming water temperatures slightly and dampening or buffering the diel temperature fluctuations immediately downstream of the dam. Concerns for salmonids in regards to water temperatures are generally raised when temperatures exceed their thermal tolerances. Thermal tolerances for Arctic grayling range from 20 to 24 C^{o} (LaPerriere and Carlson 1973). Temperatures exceeding 20 C^{o} were only measured at one station for a period of four days. Other areas of the slough remained well below 20 C^{o}. This is consistent with maximum daily water temperatures observed during 1996 when average temperatures never exceeded 16 C^{o} (Wuttig 1997).

Complete removal of the beaver dams was recommended for this study. This would have restored hydrological conditions prior to dam construction. Permits for the removal of dams with explosives by Eielson Air Force Base personnel were denied, and the use of hand tools for dam removal was required. The manpower, budgeting, and weather (frozen dams) constraints allowed only a 7.5 m section from each of the dams to be removed. These breaches were judged adequate to allow for fish passage and to drain most of the ponds. However, these breaches could be easily repaired by beavers in the spring and maintenance of the breached sections may prove to be a formidable task. Currently, control of the beaver population using early season trapping permits appears to have been successful. The trapping of beavers was found to be the most successful method for beaver removal (D' Efron et al. 1995) and continued issuance of early season trapping permits is recommended.

In the fisheries literature, little hard data exists to document a positive response in salmonid production to control of beavers (Dubois and Schramm 1993). However, it is evident that a sizeable portion (approximately 52%) of the habitat utilized by Arctic grayling for spawning, rearing, and feeding, and potentially overwintering in Piledriver Slough has been excluded because of beaver dams. The benefits to salmonid habitat derived from beavers is generally associated with additions of pool habitat in high gradient streams where little or none existed before, and increased water temperatures in areas where water temperatures are characteristically too cold to support adequate salmonid production (Leidholt-Bruner et al. 1992 and Hammerson 1994). These potential benefits likely do not benefit Arctic grayling in Piledriver Slough and the beaver impoundments are viewed as habitat degradation. Whether or not the removal of beaver dams would translate into additional production of Arctic grayling has yet to be determined. However, Arctic grayling observed utilizing the reclaimed habitat (riffles and runs) previously excluded by the lower two beaver dams strongly suggests a potential for increased production. To what extent the beaver dams would have to be removed for a measurable increase in Arctic grayling production in Piledriver Slough is unclear. By breaching dams #5, #6, and #8, 4.0 km of slough has been "reclaimed" and it represents only a small portion of the original 32 km of habitat available to Arctic grayling prior to 1991. Removal of the remaining dams would add approximately 9 km of available habitat. Indices of increased production from mark-recapture abundance estimates may be too imprecise to reveal any true increases in production from removing the dams. Moreover, abundance estimates are costly and more qualitative and cost effective indices of increased production would likely provide enough information to judge project success. These indices would include increases in CPUE using hook and line gear, increases in preferred habitat (riffles and glides), and the presence or absence of Arctic grayling in newly breached sections of Piledriver Slough based on field observations. Removal of the remaining dams, continued monitoring of beaver activity and active beaver management by aggressive trapping, and continued monitoring of Arctic grayling distributions are recommended.

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APPENDIX A

Appendix A.-Periodic average daily, average maximum, average minimum water temperatures in Piledriver Slough, 1999.

Period	Below dam #3	Above pond #5	Below pond #5	Above dam #7
	Average			
6/10 - 7/10	11.2	11.6	13.3	14.0
7/11 - 8/10	8.4	8.6	9.6	10.3
8/11 - 9/10	6.6	6.6	7.2	7.7
9/10 - 10/5	3.8	3.5	3.9	4.0
	Average maximum			
6/10 - 7/10	12.2	13.2	14.5	16.4
7/11 - 8/10	9.7	9.7	10.6	11.9
8/11 - 9/10	7.6	7.7	8.1	9.2
9/10 - 10/5	4.4	4.6	4.3	5.0
	Average minimum			
6/10 - 7/10	10.2	10.0	12.1	11.5
7/11 - 8/10	7.3	7.7	8.6	8.4
8/11 - 9/10	5.7	5.6	6.5	6.0
9/10 - 10/5	3.3	2.7	3.0	2.6