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Inventory of Resident Fish Species in Tributaries to the Nenana River along the Western Denali Highway, Alaska, 2010

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Abstract

Roadway stream crossings with poorly designed or improperly placed culverts are known to impact fish populations and their habitats, and may be migration barriers. Within the western 68 km of the Denali Highway, numerous culverts serve as fish passage structures that cross Nenana River tributaries. In previous assessments, 10 of the culverts had been classified as inadequate for fish passage, but none of the associated streams were adequately sampled for fish species presence. Therefore, to establish species presence and life stage, each stream was sampled for fish species presence upstream and downstream of culverts during 7–12 July and 8–11 August 2010. Capture gear included a backpack electrofisher, baited minnow traps, beach seine, and observation. The four fish species captured were: Dolly Varden *Salvelinus malma*, Arctic grayling *Thymallus arcticus*, burbot *Lota lota*, and slimy sculpin *Cottus cognatus*. Among all sampled tributaries, Dolly Varden were the most common species and had the widest distribution followed by Arctic grayling and slimy sculpin, and all three species were found upstream and downstream of culverts. Water temperature, specific conductivity, pH, stream order, gradient, and Rosgen stream classification were determined for each stream during 7–12 July.

Introduction

The Nenana River and its tributaries support spawning, rearing, and migratory habitat for a variety of fish species, including juvenile and adult chum *Oncorhynchus keta* and coho *O. kisutch* salmon, whitefish *Coregoninae*, Arctic grayling *Thymallus arcticus*, burbot *Lota lota*, and other resident species (Barton 1992). The documentation of habitats important to these species is incomplete and jeopardizes permitting agencies' ability to recommend site-specific mitigation measures associated with development projects (ADFG 2006). Since the completion of the George Parks Highway in 1972, the Nenana River drainage has experienced an increase in human population with the associated increases in housing, roads, and commercial development. Habitat alterations resulting from road-way development are notably visible including rock-armored river banks, riparian vegetation removal, soil erosion, and inadequate passage structures for fish and other aquatic organisms.

Man-made stream crossing structures alter fish habitat and may impede normal fish movements. Stream crossings can result in increased sedimentation, create alterations in channel morphology, and become potential barriers to migration (Harper and Quigley 2000). Barriers to migration in stream systems may induce habitat fragmentation causing ecological alterations to stream characteristics and aquatic organisms (Jackson 2004). Arctic grayling that were intentionally

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delayed enroute to their spawning grounds in Fish Creek near Cantwell, Alaska migrated shorter distances than their control group counterparts, potentially causing the fish to use less desirable spawning habitat (Fleming 1989). Kane et al. (2000) found that variations in culvert design and placement influenced juvenile salmonids' ability to ascend a stream. Fish passage effects may be reduced by integrating proper engineering techniques with biological and ecological requirements of aquatic organisms.

Numerous low order tributary streams (Strahler 1957) that drain into the upper portion of the Nenana River are crossed by the Denali Highway using a variety of structures such as bridges and culverts. The Alaska Department of Fish and Game's (ADFG) Fish Passage Improvement Program (Program) assesses the degree of adequacy of juvenile salmonid passage at existing stream crossings throughout the state (O'Doherty 2010). The Program's culvert assessment measurements center on physical attributes of culverts and adjoining stream channel(s). Assessed culverts each receive a unique site identification number. The Program's fish passage criterion is based on a juvenile (55 mm) coho salmon's ability to pass through a variety of culvert types as classified by O'Doherty (2010). Culverts are classified as Green–indicating adequate, Gray–may be adequate, or Red–assumed inadequate for fish passage. The classifications may be used for planning and to prioritize maintenance and repairs of culverts by the Alaska Department of Transportation and Public Facilities (ADOTPF). The Program's typical culvert assessment does not include fish species presence information except for comments noting fish observations and opportunistic short-term minnow trapping efforts near culverts (O'Doherty 2010). However, fish presence data associated with culvert assessments may enhance ADOPTF's planning and prioritization process for maintenance and repairs.

To address the lack of fish presence data, this study was conducted to identify fish species upstream and downstream of culverts in July and August 2010. Ten tributary streams that drain into the upper portion of the Nenana River and are crossed by the Denali Highway were selected based on a culvert assessment classification of Red, the lack of fish data associated with the culverts, and feasibility of sampling. The objectives of this project were to: 1) document the presence of fish species in selected tributaries to the Nenana River upstream and downstream of culverts on the Denali Highway; 2) describe the life history stages of fish species captured in the selected tributaries; and 3) submit fish species and life stage information to ADFG for inclusion to the Alaska Freshwater Fish Inventory (AFFI) database. Completion of these objectives will provide a tool to land managers and transportation planners to facilitate aquatic organism passage when planning road construction and maintenance.

Study Area

The Denali Highway region of Interior Alaska spans an area between Cantwell and Paxson, Alaska (Figure 1). The Denali Highway is a 217 km mostly gravel road that is open from mid-May to October 1 and impassable to standard vehicle traffic in winter months. The Denali Highway corridor runs east to west and partially bisects the southern foothills of the Alaska Range mountains. Road surface elevations range from approximately 640 to 915 m above sea level. Much of the area is underlain by discontinuous and sporadic permafrost (Jorgenson et al. 2008). The dominant vegetation structure is tundra and alpine tundra that occur in the higher elevations along the road corridor (Sparrow et al. 1978). The adjacent mountain areas are dominated by glaciated valleys that feed large braided rivers such as the Nenana River (Figure 1). The western portion (68 km) of the Denali Highway lies within the upper one-third of the Nenana River drainage and follows a route completely south of the main-stem Nenana River.

The Nenana River flows westward out of the Alaska Range foothills then northward emptying into the Tanana River at Nenana, Alaska. Tributaries to the Nenana River crossed by the Denali Highway are clear-water streams fed by rain runoff and snowmelt.

Methods

Study Design and Stream Selection

In 2010, a temporal and spatial sampling approach was used to document fish species present during the open water season in the selected tributaries along the western portion of the Denali Highway (Program site ID numbers: 40501371 (Jack River), 40501368 (Edmonds Creek), 40501367 (unnamed stream), 40501366 (unnamed stream), 40501365 (West Fork Lily Creek), 40501364 (East Fork Lily Creek), 40500290 (West Fork Stickwan Creek), 40500291 (East Fork Stickwan Creek), 40500273 (unnamed stream), 40500292 (unnamed stream), and 40500274 (Monahan Creek); Figure 1). All sample stream culverts were classified as Red, i.e., inadequate for fish passage (O'Doherty 2010) and recommended as focus sample sites. Sample streams were chosen by consultation with the Program and the U.S. Fish and Wildlife Service's National Fish Passage Program. Stream names were acquired from U.S. Geological Survey 1:63,360 scale topographic maps. Site 40500292 was dry during both sampling trips and is excluded from this report.

A three-person team accessed the Denali Highway sampling sites by passenger vehicle. Three sampling sessions were chosen to increase the opportunity of encountering the maximum number of fish species with diverse migratory timing (Barton 1992; Finn et al. 1998). The first session was abandoned because of the inability to secure timely land access permission from the land owner. The second sampling session was 7–12 July and the third was 8–11 August. The sample sites established during 7–12 July were re-sampled in 8–11 August. The sample site boundaries, upstream and downstream from a culvert, were temporarily marked with surveyor's tape to enable repetitive sampling during the third session.

Fish Sampling

A backpack electrofisher, baited minnow traps, a beach seine, and observation were the sampling methods used during the project. Electrofishing was the principal fish collection method used in wadeable water because it was recognized as the most comprehensive and effective method for collecting fish in lotic systems (Reynolds 1996; Barbour et al. 1999; Simon and Sanders 1999; Flotemersch and Blocksom 2005). To reduce spinal and associated electrofishing-induced injuries (Dalbey et al. 1996), electrofishing was not conducted in the vicinity of observed fish >200 mm fork length (FL). Variable combinations of fishing gear were used within and among streams, contingent upon stream morphology, to maximize fish capture probability. Capture results were compared across gear types to assess fish presence.

Captured fish were identified to species and life stage and tallied. Fish lengths were obtained for at least the first 10 fish of a species for each sampled stream regardless of capture location either upstream or downstream of a culvert. Fish length was measured to the nearest 1 mm using FL or total length (TL) depending on the species. For instance, Dolly Varden *Salvelinus malma* were measured using FL and slimy sculpin *Cottus cognatus* were measured using TL. After recuperation in still water, fish were released back into the stream.

Fish life stage was determined through comparison of meristics from published literature. All fish were externally examined for secondary sex and life stage characteristics. Specimens requiring laboratory techniques to determine species or life stage were dispatched and brought to the U.S. Fish and Wildlife Service (USFWS) laboratory in Fairbanks for processing. Pyloric caeca and gill rakers were counted to verify species (Strauss and Bond 1990) for Dolly Varden because their external meristics may overlap with juvenile coho or Chinook salmon and cause misidentification in a field setting. Dolly Varden pyloric caeca counts range from 13–47, Chinook salmon range from 90–240 and coho salmon range from 45–114 (McPhail and Lindsey 1970; Trautman 1973). Dolly Varden gill raker counts range from 3–10 on the upper limb, and 8–14 on the lower limb of the first gill arch (denoted as 3–10 + 8–14; McPhail and Lindsey 1970), Chinook salmon counts range from 6–10 + 10–16, and coho salmon counts range from 6–9 + 12–16 (McPhail and Lindsey 1970; Trautman 1973). Fish processed for pyloric caeca and gill raker counts were examined twice for quality control. Dolly Varden greater than 91 mm FL were considered adults (Savviatova and Romanov 1969; Blackett 1973; Armstrong and Morrow 1980). Slimy sculpin greater than 74 mm TL were considered adults (Craig and Wells 1976). All captured Arctic grayling were <200 mm FL (Clark 1992) and burbot were <452 mm TL (Evenson 1990) and were considered juveniles.

Wadeable site fishing protocols.—An attempt was made to sample a minimum distance of 150–300 m upstream and downstream from a culvert (Lyons 1992; Patton et al. 2000; Reynolds et al. 2003). This range of sample reach lengths is consistent with the National Water-Quality Assessment Program stream habitat characterization protocols (Fitzpatrick et al. 1998) and with recommendations developed for small stream sampling (Patton et al. 2000). Fish were collected in a single upstream pass with a Smith-Root Model LR-24 backpack electrofisher. Electrofisher power settings were made according to stream specific conductivity calculated by the electrofisher and adjusted based on fish catches and observed fish response. Fishing time, species, and number of fish caught per species was recorded for each electrofishing event. Electrofishing catch per unit effort (CPUE) was calculated as the number of fish per second. Beach seines (9.0 x 1.2 m with 0.64 cm ace mesh) and minnow traps (23 x 45 cm, 0.6 cm wire mesh, with 2.5 cm diameter openings) baited with salmon roe and set overnight were used to augment electrofishing as a means of encountering as many fish species and life stages as possible. The CPUE for beach seines was calculated as fish per haul and minnow traps as fish per trap hour.

Aquatic Habitat Measurements

At each sample site water quality measurements, including specific conductivity (µS/cm) and pH, were measured using a Hach HQ40d portable water meter. Water temperature was taken using a handheld, pocket case thermometer and read to the nearest 0.5°C while submerged. Aquatic habitat conditions were qualitatively characterized at each sample site. Stream gradient (%) of study streams was determined using U.S. Geological Survey 1:63,360 scale topographic maps (McMahon et al. 1996). Stream order was assigned based on Strahler (1957), and major stream type classification followed Rosgen (1996). Geospatial coordinates of sample sites were recorded in decimal degrees (to the 5th decimal) with handheld global positioning system (GPS) units (Garmin GPSMAP 76S) set for the WGS84 datum.

Results

Fish Sampling

Approximately 0.8 river kilometers (rkm) of stream 40501371 (Jack River) was sampled on 12 July and 11 August (Table 1; Figure 2) using minnow traps, a beach seine, and observation (Table 2). Burbot (*n* = 2 juveniles) and slimy sculpin (*n* = 4 adults; 2 juveniles) were captured downstream and slimy sculpin were captured upstream (*n* = 1 adult) of the culvert (Table 2). Three Arctic grayling were observed upstream of the culvert. The length range for burbot from both sampling sessions was 149–165 mm TL (Table 2).

Approximately 0.4 rkm of stream 40501368 (Edmonds Creek) was sampled on 11 July and 11 August (Table 1; Figure 2) using a backpack electrofisher (Table 3). Dolly Varden were captured upstream (*n* = 2 adults; 1 juvenile) and downstream (*n* = 6 adults; 5 juveniles), and Arctic grayling were captured upstream (*n* = 3 juveniles) and downstream (*n* = 2 juveniles) of the culvert (Table 3). The length range for all Dolly Varden from both sampling sessions was 34–138 mm FL and 114–129 mm FL for Arctic grayling (Table 3).

Approximately 0.3 rkm of stream 40501367 was sampled on 10 July and 11 August (Table 1; Figure 2) using a backpack electrofisher (Table 4). Dolly Varden were captured upstream (*n* = 3 adults; 8 juveniles) and downstream (*n* = 1 adult), and slimy sculpin were captured downstream (*n* = 2 adults; 6 juveniles) of the culvert (Table 4). The length range for all Dolly Varden from both sampling sessions was 66–126 mm FL and 64–81 mm TL for slimy sculpin (Table 4).

Approximately 0.4 rkm of stream 40501366 was sampled on 9 July and 11 August (Table 1; Figure 2) using a backpack electrofisher (Table 5). Dolly Varden were captured upstream (*n* = 1 adult) and downstream (*n* = 1 adult), and Arctic grayling were captured downstream (*n* = 2 juveniles) of the culvert (Table 5). The length range for all Dolly Varden from both sampling sessions was 130–177 mm FL and 112–118 mm FL for Arctic grayling (Table 5).

Approximately 0.3 rkm of stream 40501365 (West Fork Lily Creek) was sampled on 9 July and 9 August (Table 1; Figure 2) using minnow traps (Table 6). Dolly Varden were captured upstream (*n* = 1 adult; 1 juvenile) and downstream (*n* = 1 adult; 9 juveniles) of the culvert (Table 6). Data from 9 August for this stream were inadvertently not recorded. The length range for all Dolly Varden from 9 July was 82–154 mm FL (Table 6).

Approximately 0.5 rkm of stream 40501364 (East Fork Lily Creek) was sampled on 10 July and 10 August (Table 1; Figure 2) using a backpack electrofisher (Table 7). Dolly Varden were captured upstream (*n* = 6 adults; 7 juveniles) and downstream (*n* = 26; 15 were measured; 8 adults and 7 juveniles) of the culvert (Table 7). The length range for all measured Dolly Varden from both sampling sessions was 33–218 mm FL (Table 7).

Approximately 0.4 rkm of stream 40500290 (West Fork Stickwan Creek) was sampled on 8 July and 9 August (Table 1; Figure 2) using minnow traps (Table 8). Dolly Varden were captured upstream (*n* = 1 adult), Arctic grayling were captured upstream (*n* = 9 juveniles) and downstream (*n* = 3 juveniles), and slimy sculpin were captured downstream (*n* = 1 juvenile) of the culvert (Table 8). The length of the Dolly Varden from 8 July was 128 mm FL and the slimy sculpin was 65 mm TL. The length range for all Arctic grayling from both sampling sessions was 87–119 mm FL (Table 8).

Approximately 0.6 rkm of stream 40500291 (East Fork Stickwan Creek) was sampled on 9 July and 9 August (Table 1; Figure 2) using a backpack electrofisher (Table 9). A Dolly Varden was captured downstream (*n* = 1 adult) of the culvert and was 145 mm FL (Table 9).

Approximately 0.7 rkm of stream 40500273 was sampled on 7 July and 8 August (Table 1; Figure 2) using minnow traps (Table 10). Slimy sculpin were captured upstream (*n* = 23; 22 were measured; 13 adults and 9 juveniles) and downstream (*n* = 19; none were measured) of the culvert (Table 10). The length range for all measured slimy sculpin from both sampling sessions was 56–100 mm TL (Table 10).

Approximately 0.4 rkm of stream 40500274 (Monahan Creek) was sampled on 8 July and 9 August (Table 1; Figure 2) using minnow traps (Table 11). No fish were captured.

Gill raker and pyloric caeca counts were conducted for seven Dolly Varden (Table 12). For all seven Dolly Varden, counts of both structures fell within the ranges reported by McPhail and Lindsey (1970) and McPhail (1961).

Aquatic Habitat Assessment

Each creek was sampled one time during 8–11 July for water temperature, specific conductivity (µS/cm), and pH (Table 13). Water temperature among streams ranged from 4.5–12.0°C. Specific conductivity among streams ranged from 49.0–214.1 µS/cm. The pH among streams ranged from 7.2–7.7. All sampled streams were either first or second-order streams. Stream gradient (%) ranged from 0.5–11.9. Rosgen (1996) stream type classifications ranged from B4–A3, i.e., low gradient and moderately sinuous to steep single channel streams.

Habitat descriptions, including photographs, associated with Program culvert assessments may be accessed at the internet address:
http://www.adfg.alaska.gov/index.cfm?adfg=fishpassage.main (ADFG 2012a).

Alaska Freshwater Fish Inventory Database Submission

Fish species information was submitted to ADFG for addition to the AFFI database via the required completion of the 2010 ADFG Fish Resource Permit Report. The AFFI may be accessed at the internet address: http://www.adfg.alaska.gov/index.cfm?adfg=ffinventory.main (ADFG 2012b).

Discussion

Sampling identified four fish species within the sampled sections of select tributaries to the Nenana River that are crossed by the Denali Highway. All the tributaries had culverts classified as inadequate for fish passage (Red) based on the ability of juvenile (55 mm) coho salmon to swim through a variety of culvert types. Individual fish species have different size thresholds that may determine their ability to move through a culvert. Larinier (2002) suggested the use of a “reference fish” (species and size) that possesses the least swimming ability needed to pass through the culvert. It may be prudent to base culvert designs on fish species present to accommodate the varying abilities of these species to navigate through culverts. Adequate migration timing to desired habitats may be restricted to only those species and sizes of fish that are able overcome conditions found at poorly performing culverts.

The greatest diversity of fish species was found in streams 40501371 (Jack River) and 40500290 (West Fork Stickwan Creek) (Table 14). No fish were found in stream 40500274. Dolly Varden was the most common and widely distributed fish (7 of 10 streams), and juvenile and adult life stages were present upstream and downstream of culverts. Stream resident Dolly Varden inhabiting the headwaters of the Tanana River drainage are considered isolated and non-anadromous, i.e., make limited migrations for wintering, feeding, and reproduction (McPhail and Lindsey 1970; Armstrong and Morrow 1980). Dolly Varden migrate from tributaries to winter refuge in deeper water and return to tributaries for feeding and spawning (Armstrong and Morrow 1980). Dolly Varden require the use of headwater tributaries for portions of their life cycle. Therefore, it is important to provide unimpeded access to and from those habitats.

Juvenile Arctic grayling were also found upstream and downstream of culverts in three of the sampled streams. Similar to Dolly Varden, Arctic grayling make limited migrations, must seek winter refuge in deeper water, and migrate back to tributaries for feeding and spawning (Gryska 2006). No adult Arctic grayling were captured but observations of larger fish, relative to captured juveniles, were made in stream 40501371 (Jack River). Stream 40501371 (Jack River) was the largest stream sampled and considered the most likely to contain habitat for larger Arctic grayling.

Slimy sculpin were captured mostly downstream of culverts except for streams 40501371 (Jack River) and 40050273. Slimy sculpin are bottom dwellers common to streams with fairly fast current and rocky bottoms (Morrow 1980). Both juvenile and adult life stages of slimy sculpin were present. Slimy sculpin are not considered to be migratory (Morrow 1980) but may be forced to seek refuge away from frozen creeks during winter. Slimy sculpin are likely restricted to areas below poorly designed culverts except during intermittent flow events that may facilitate passage to areas upstream of culverts.

Adult and juvenile Dolly Varden and slimy sculpin were captured upstream and downstream of culverts in several of the sampled streams. Juvenile Arctic grayling were also captured upstream and downstream of culverts. However, Dolly Varden <60 mm FL (Figure 3), Arctic grayling <101 mm FL (Figure 4), and slimy sculpin <56 mm TL (Figure 5) were not captured upstream of the culverts suggesting a length threshold analogous to the 55 mm coho salmon criteria used by the Program for fish passage. Thus, juvenile Dolly Varden, slimy sculpin, and Arctic grayling may be restricted from migration past culverts with insurmountable physical barriers. These examples indicate that fish life stage and culvert performance elements that differed among the 10 culvert sites likely influenced these fishes ability to pass upstream (ADFG 2012a).

Fish Sampling for Stream Crossing Structures

Fish surveys that identify species and life stages at or near stream crossings in transportation corridors could greatly assist in evaluating and designing fish passage structures and in prioritizing their maintenance and repairs. Further, development of a standardized method of strategically integrating fish presence, life stage, habitat requirements, and distribution data into stream crossing assessments would be beneficial for the local fish and aquatic resources and also increase the efficiency in planning and directing repair efforts (Kemp and O'Hanley 2010). However, the effort put toward focused fish surveys to describe the effects of culverts on fish passage will require a balance of funding, time allotted to employ an adequate survey method, and the availability of existing information about fish species that inhabit the stream or drainage of concern.

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Table 1. Sample streams, site coordinates (upstream (U) and downstream (D) sample site boundaries), sample dates, and river kilometer (rkm) distance between U and D in 2010, and culvert classification.

Stream[a]	Sample site boundary coordinates (datum WGS-84)	Sample dates	Stream distance (rkm) between upper and lower sample sites	Culvert classification[a]
40501371 Jack River	U 63.37966N 148.85713W D 63.38252N 148.87081W	7/12 and 8/11	0.8	red
40501368 Edmonds Creek	U 63.39125N 148.52595W D 63.39474N 148.52484W	7/11 and 8/11	0.4	red
40501367	U 63.38224N 148.43577W D 63.38469N 148.43377W	7/10 and 8/11	0.3	red
40501366	U 63.37900N 148.40952W D 63.38135N 148.43377W	7/9 and 8/11	0.4	red
40501365 Lily Creek, W. Fork	U 63.33453N 148.28031W D 63.33593N 148.27635W	7/9 and 8/9	0.3	red
20501364 Lily Creek, E. Fork	U 63.33247N 148.27232W D 63.33608N 148.27462W	7/10 and 8/10	0.5	red
40500290 Stickwan Creek, W. Fork	U 63.29728N 148.15063W D 63.30029N 148.14750W	7/8 and 8/9	0.4	red
40500291 Stickwan Creek, E. Fork	U 63.29897N 148.12990W D 63.30284N 148.13649W	7/9 and 8/9	0.6	red
40500273	U 63.27536N 148.05035W D 63.28032N 148.04995W	7/7 and 8/8	0.7	red
40500274 Monahan Creek	U 63.22557N 147.73060W D 63.22832N 147.72840W	7/8 and 8/9	0.4	red

[a] Stream numbers and passage structure classifications were derived from Alaska Department of Fish and Game Fish Passage Inventory Program survey reports.

Table 2. Sample date, sample location, effort, species, number of fish (*n*), length range (mm), and catch-per-unit-effort (CPUE) of all fish species captured at sample site 40501371 (Jack River).

Sample date	Location	Effort	Species[a]	*n*	Length range (mm)	CPUE
			Minnow Trap			
7/12	UOC	117.5 h	--	0		0 /h
7/12	DOC	94.0 h	SLSC	1	86	0.01 /h
7/12	DOC		BURB	1	165	0.01 /h
8/11	UOC	100.0 h	SLSC	1	87	0.01 /h
8/11	DOC	100.0 h	BURB	1	149	0.01 /h
Total	UOC	217.5 h	SLSC	1		0.00 /h
	DOC	194.0 h	SLSC	1		0.01 /h
	DOC		BURB	2		0.02 /h
			Seine			
7/12	DOC	4 hauls	--	0		0 /haul
8/11	DOC	5 hauls	SLSC	5	14–95	1.00 /haul
Total	DOC	9 hauls	SLSC	5		0.56 /haul
			Observation			
7/12	UOC	---	ARGR	3		---

[a] Abbreviations - Upstream of Culvert (UOC), Downstream of Culvert (DOC), burbot (BURB), slimy sculpin (SLSC).

Table 3. Sample date, sample location, effort, species, number of fish (*n*), length range (mm), and catch-per-unit-effort (CPUE) of all fish species captured at sample site 40501368 (Edmonds Creek).

Sample date	Location	Effort	Species[a]	*n*	Length range (mm)	CPUE
			Electrofish			
7/11	UOC	492 s	ARGR	1	129	0.00 /s
7/11	UOC		DVAR	1	69	0.00 /s
7/11	DOC	308 s	DVAR	5	51–138	0.02 /s
8/11	UOC	501 s	DVAR	2	108–110	0.00 /s
8/11	UOC		ARGR	2	114–123	0.00 /s
8/11	DOC	269 s	DVAR	6	34–133	0.02 /s
8/11	DOC		ARGR	2	120–129	0.01 /s
Total	UOC	993 s	ARGR	3		0.00 /s
			DVAR	3		0.00 /s
	DOC	577 s	DVAR	11		0.02 /s
			ARGR	2		0.00 /s

[a] Abbreviations - Upstream of Culvert (UOC), Downstream of Culvert (DOC), Dolly Varden (DVAR), and Arctic grayling (ARGR).

Table 4. Sample date, sample location, effort, species, number of fish (*n*), length range (mm), and catch-per-unit-effort (CPUE) of all fish species captured at sample site 40501367.

Sample date	Location	Effort	Species[a]	*n*	Length range (mm)	CPUE
			Electrofish			
7/10	UOC	185 s	DVAR	3	74–99	0.02 /s
7/10	DOC	218 s	SLSC	4	64–81	0.02 /s
8/11	UOC	387 s	DVAR	8	66–119	0.02 /s
8/11	DOC	277 s	DVAR	1	126	0.00 /s
8/11	DOC		SLSC	4	66–76	0.01 /s
Total	UOC	572 s	DVAR	11		0.02 /s
	DOC	495 s	DVAR	1		0.00 /s
			SLSC	8		0.02 /s

[a] Abbreviations - Upstream of Culvert (UOC), Downstream of Culvert (DOC), Dolly Varden (DVAR), and slimy sculpin (SLSC).

Table 5. Sample date, sample location, effort, species, number of fish (*n*), length range (mm), and catch-per-unit-effort (CPUE) of all fish species captured at sample site 40501366.

Sample date	Location	Effort	Species[a]	*n*	Length range (mm)	CPUE
			Electrofish			
7/9	UOC	176 s	DVAR	1	177	0.01 /s
7/9	DOC	170 s	DVAR	1	130	0.01 /s
8/11	UOC	205 s	--	0		0 /s
8/11	DOC	215 s	ARGR	2	112–118	0.01 /s
Total	UOC	381 s	DVAR	1		0.00 /s
	DOC	385 s	DVAR	1		0.00 /s
			ARGR	2		0.01 /s

[a] Abbreviations - Upstream of Culvert (UOC), Downstream of Culvert (DOC), Dolly Varden (DVAR), and Arctic grayling (ARGR).

Table 6. Sample date, sample location, effort, species, number of fish (*n*), length range (mm), and catch-per-unit-effort (CPUE) of all fish species captured at sample site 40501365 (West Fork Lily Creek). The * for sample date 8/9 indicates that data was inadvertently not recorded.

Sample date	Location	Effort	Species[a]	*n*	Length range (mm)	CPUE
			Minnow Trap			
7/9	UOC	110.0 h	DVAR	2	90–99	0.02 /h
7/9	DOC	110.0 h	DVAR	10	82–154	0.09 /h
8/9	UOC	110.0 h	*	*		*
8/9	DOC	110.0 h	*	*		*
Total	UOC	110.0 h	DVAR	2		0.02 /h
	DOC	110.0 h	DVAR	10		0.09 /h

[a] Abbreviations - Upstream of Culvert (UOC), Downstream of Culvert (DOC), and Dolly Varden (DVAR).

Table 7. Sample date, sample location, effort, species, number of fish (*n*) with bracketed number equaling fish with length not taken, length range (mm), and catch-per-unit-effort (CPUE) of all fish species captured at sample site 40501364 (East Fork Lily Creek).

Sample date	Location	Effort	Species[a]	*n*	Length range (mm)	CPUE
			Electrofish			
7/10	UOC	398 s	DVAR	6	60–218	0.02 /s
7/10	DOC	297 s	DVAR	10 [4]	34–195	0.05 /s
8/10	UOC	199 s	DVAR	7	69–127	0.04 /s
8/10	DOC	253 s	DVAR	5 [7]	33–143	0.05 /s
Total	UOC	597 s	DVAR	13		0.02 /s
	DOC	550 s	DVAR	26		0.05 /s

[a] Abbreviations - Upstream of Culvert (UOC), Downstream of Culvert (DOC), and Dolly Varden (DVAR).

Table 8. Sample date, sample location, effort, species, number of fish (*n*), length range (mm), and catch-per-unit-effort (CPUE) of all fish species captured at sample site 40500290 (West Fork Stickwan Creek).

Sample date	Location	Effort	Species[a]	*n*	Length range (mm)	CPUE
			Minnow Trap			
7/8	UOC	97.5 h	ARGR	2	103–108	0.02 /h
7/8	UOC		DVAR	1	128	0.01 /h
7/8	DOC	97.5 h	ARGR	3	87–119	0.03 /h
7/8	DOC		SLSC	1	65	0.01 /h
8/9	UOC	90.0 h	ARGR	7	101–116	0.08 /h
8/9	DOC	90.0 h	---	0		0 /h
Total	UOC	187.5 h	ARGR	9		0.05 /h
	UOC		DVAR	1		0.01 /h
	DOC	187.5 h	ARGR	3		0.02 /h
	DOC		SLSC	1		0.01 /h

[a] Abbreviations - Upstream of Culvert (UOC), Downstream of Culvert (DOC), Dolly Varden (DVAR), Arctic grayling (ARGR), and slimy sculpin (SLSC).

Table 9. Sample date, sample location, effort, species, number of fish (*n*), length range (mm), and catch-per-unit-effort (CPUE) of all fish species captured at sample site 40500291 (East Fork Stickwan Creek).

Sample date	Location	Effort	Species[a]	*n*	Length range (mm)	CPUE
			Electrofish			
7/9	UOC	1,042 s	--	0		0 /s
7/9	DOC	1,370 s	DVAR	1	145	0.00 /s
8/9	UOC	793 s	--	0		0 /s
8/9	DOC	867 s	--	0		0 /s
Total	UOC	1,835 s	--	0		0 /s
	DOC	2,237 s	DVAR	1		0.00 /s

[a] Abbreviations - Upstream of Culvert (UOC), Downstream of Culvert (DOC), and Dolly Varden (DVAR).

Table 10. Sample date, sample location, effort, species, number of fish (*n*) with bracketed number equaling fish with length not taken, length range (mm), and catch-per-unit-effort (CPUE) of all fish species captured at sample site 40500273.

Sample date	Location	Effort	Species[a]	*n*	Length range (mm)	CPUE
			Minnow Trap			
7/7	UOC	98.8 h	SLSC	12	56–100	0.12 /h
7/7	DOC	98.8 h	SLSC	[14]		0.14 /h
8/8	UOC	92.5 h	SLSC	10 [1]	60–99	0.12 /h
8/8	DOC	92.5 h	SLSC	[5]		0.05 /h
Total	UOC	191.3 h	SLSC	23		0.12 /h
	DOC	191.3 h	SLSC	19		0.10 /h

[a] Abbreviations - Upstream of Culvert (UOC), Downstream of Culvert (DOC), and slimy sculpin (SLSC).

Table 11. Sample date, sample location, effort, species, number of fish (*n*), and catch-per-unit-effort (CPUE) of all fish species captured at sample site 40500274 (Monahan Creek).

Sample date	Location	Effort	Species[a]	*n*	CPUE
			Electrofish		
7/8	UOC	401 s	--	0	0 /s
7/8	DOC	560 s	--	0	0 /s
8/9	UOC	243 s	--	0	0 /s
8/9	DOC	365 s	--	0	0 /s
Total	UOC	644 s	--	0	0 /s
	DOC	925 s	--	0	0 /s

[a] Abbreviations - Upstream of Culvert (UOC), Downstream of Culvert (DOC).

Table 12. Gill raker and pyloric caeca counts for seven Dolly Varden captured from tributaries to the Nenana River along the western Denali Highway, 2010.

			Gill rakers			
Date	Stream	Length (mm)	Upper	Lower	Total	Pyloric caeca
7/10	40501364	34[a]	---	---	---	28
7/10	40501364	60	8	11	19	23
7/10	40501364	61	9	11	20	20
7/10	40501364	72	9	12	21	20
7/10	40501364	93	8	13	21	27
7/11	40501368	80	9	13	22	27
8/11	40501368	34[a]	---	---	---	31

[a] Gill rakers not developed enough for accurate counts.

Table 13. Aquatic habitat characteristics included water temperature, conductivity, and pH measurements and stream morphology characteristics included steam order, gradient and Rosgen stream type from sample streams on the western Denali Highway, 2010.

Date	Stream	Water temperature (°C)	Conductivity (µS/cm)	pH	Stream order	Gradient (%)	Rosgen stream type
7/11	40501371	8.0	169.6	7.2	2	0.7	B4
7/11	40501368	4.5	214.1	7.4	2	7.6	A3
7/10	40501367	6.5	204.0	7.4	2	10.0	A3
7/10	40501366	5.0	66.7	7.4	1	11.9	A3
7/10	40501365	5.0	77.7	7.3	1	11.9	A3
7/10	40501364	5.0	49.0	7.3	2	3.2	A4
7/10	40500290	11.0	102.0	7.3	2	0.7	G3
7/9	40500291	11.0	91.9	7.2	1	0.5	G4
7/8	40500273	12.0	167.8	7.7	1	2.1	A4
7/8	40500274	9.5	117.1	7.5	1	6.6	A3

Table 14. Family, scientific, and common names of fish species captured in tributary streams to the Nenana River on the western Denali Highway in 2010.

	Salmonidae		Gadidae	Cottidae
	Salvelinus malma	*Thymallus arcticus*	*Lota lota*	*Cottus cognatus*
Stream number	Dolly Varden	Arctic grayling	burbot	slimy sculpin
40501371		X[a]	X[c]	X[bc]
40501368	X[bc]	X[c]		
40501367	X[bc]			X[bc]
40501366	X[b]	X[c]		
40501365	X[bc]			
40501364	X[bc]			
40500290	X[b]	X[c]		X[c]
40500291	X[b]			
40500273				X[bc]

[a] Observation.
[b] Adult life stage.
[c] Juvenile life stage.

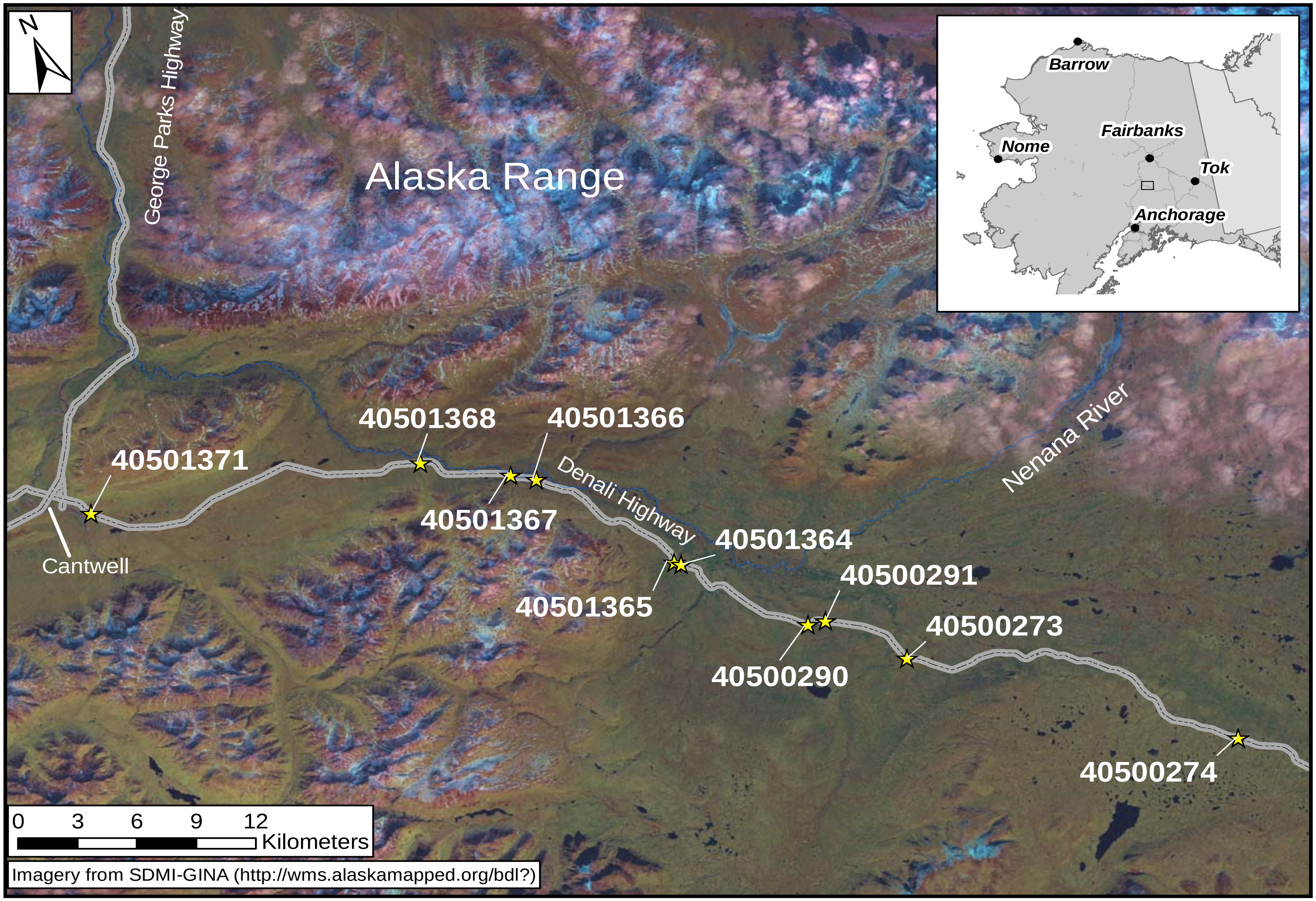

Figure 1. Nenana River tributary streams noted with stars and Program identification numbers for sites sampled during 2010 along the western Denali Highway.

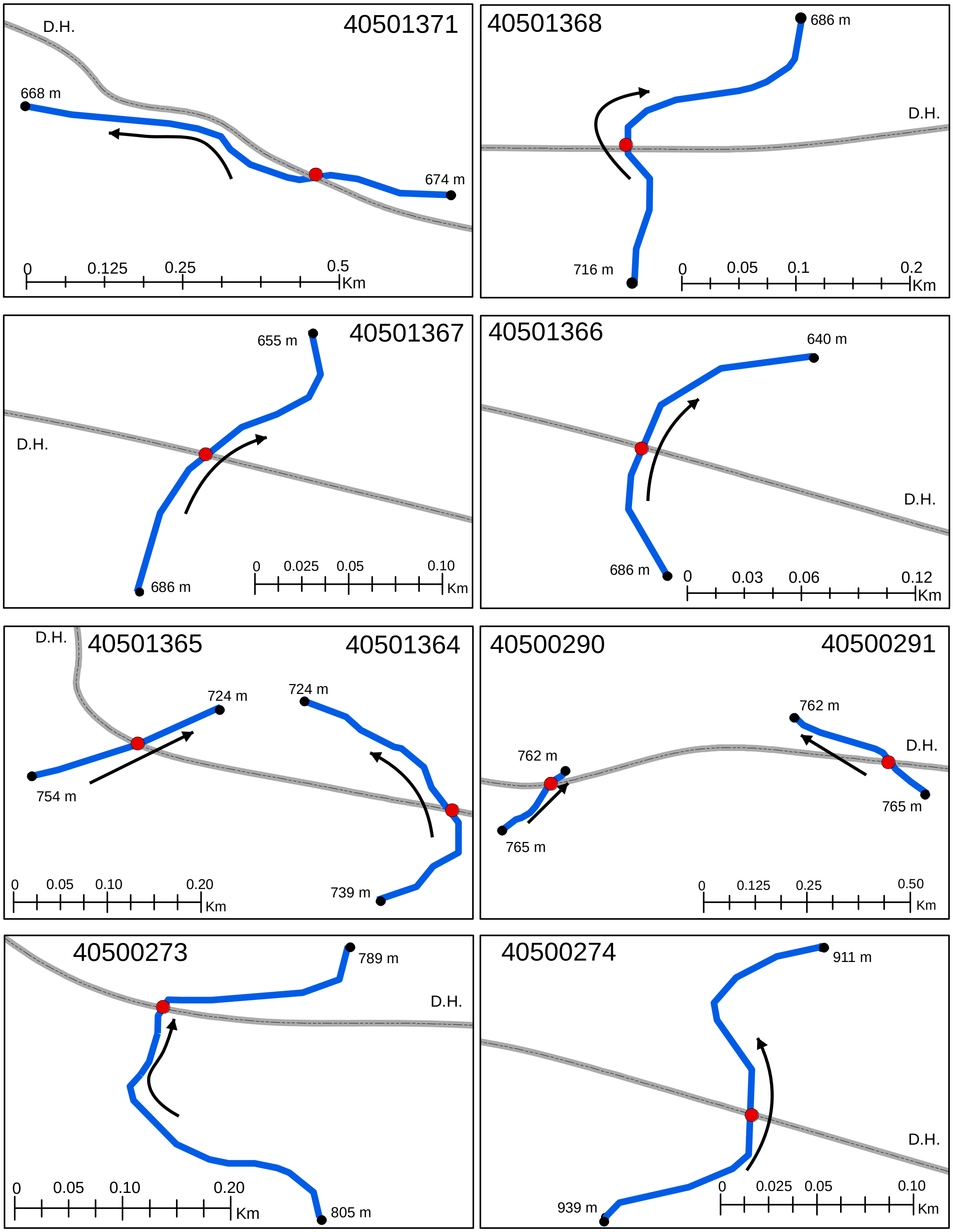

Figure 2. Denali Highway (D.H.) stream sections sampled upstream and downstream of culverts (red dots). Black arrows indicate direction of stream flow. Elevations (m) of the terminus of sampled stream sections are shown for each stream.

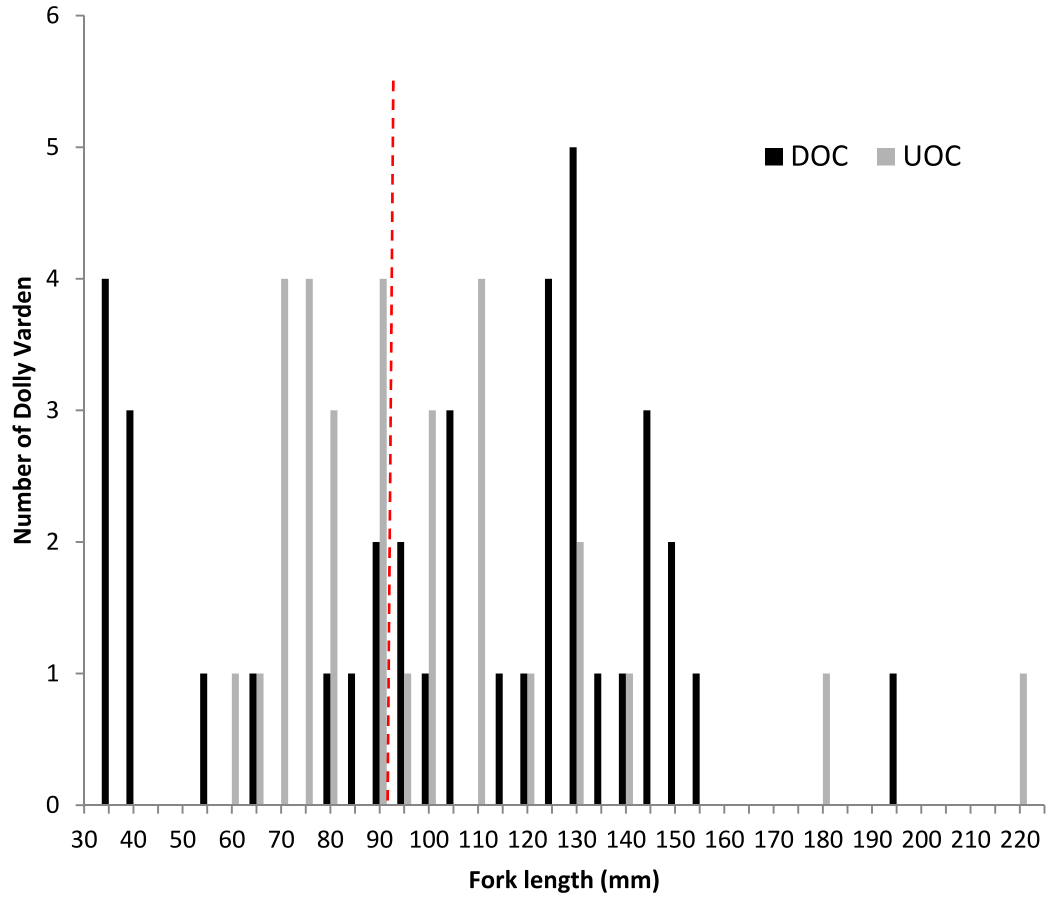

Figure 3. Length-frequency histogram of all measured Dolly Varden (*n* = 70) captured downstream (DOC) and upstream (UOC) of culverts for all fishing gear types and streams sampled along the western Denali Highway. The vertical red dashed line indicates the approximate minimum length (91mm) at maturity.

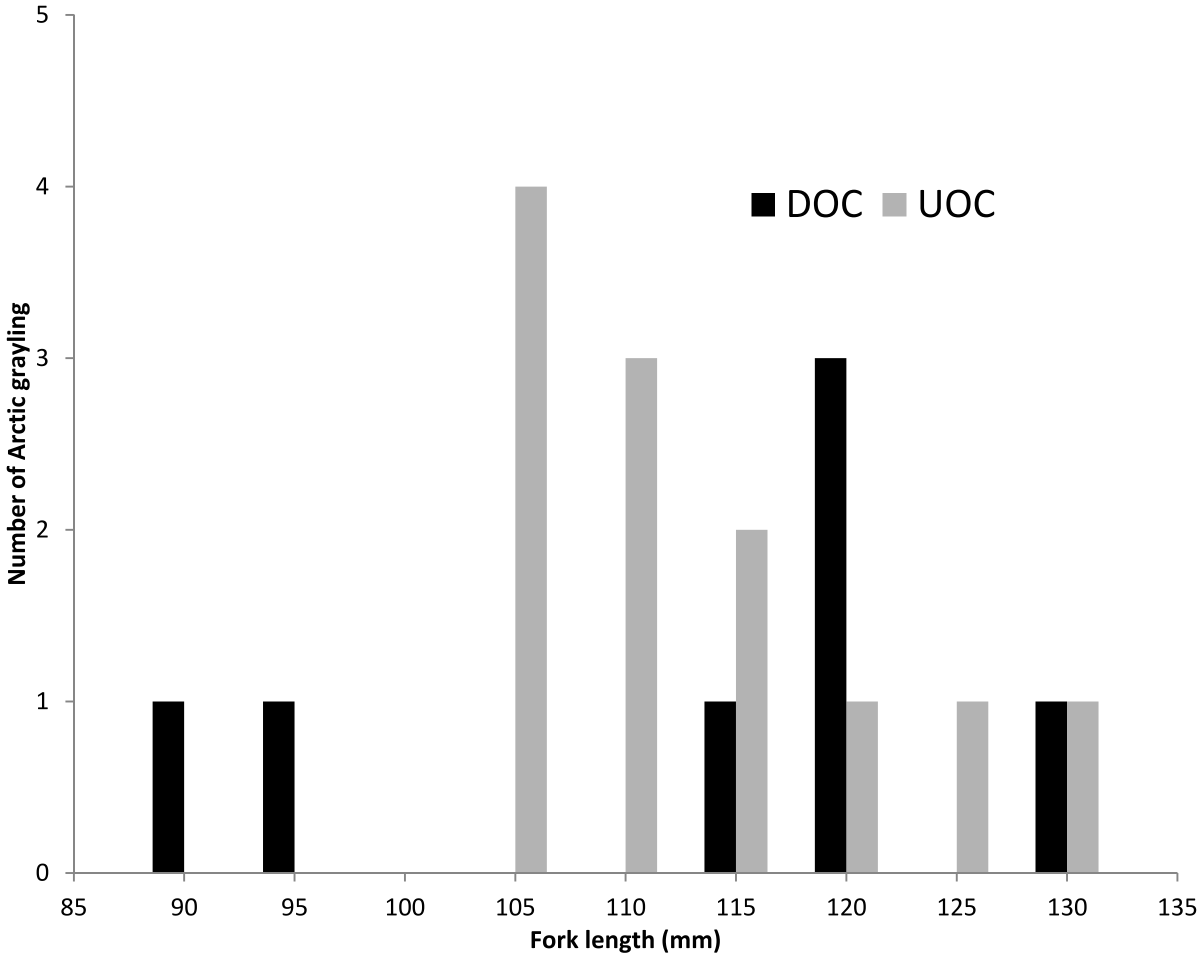

Figure 4. Length-frequency histogram of all measured Arctic grayling (*n* = 19) captured downstream (DOC) and upstream (UOC) of culverts for all fishing gear types and streams sampled along the western Denali Highway. All captured Arctic grayling were juveniles.

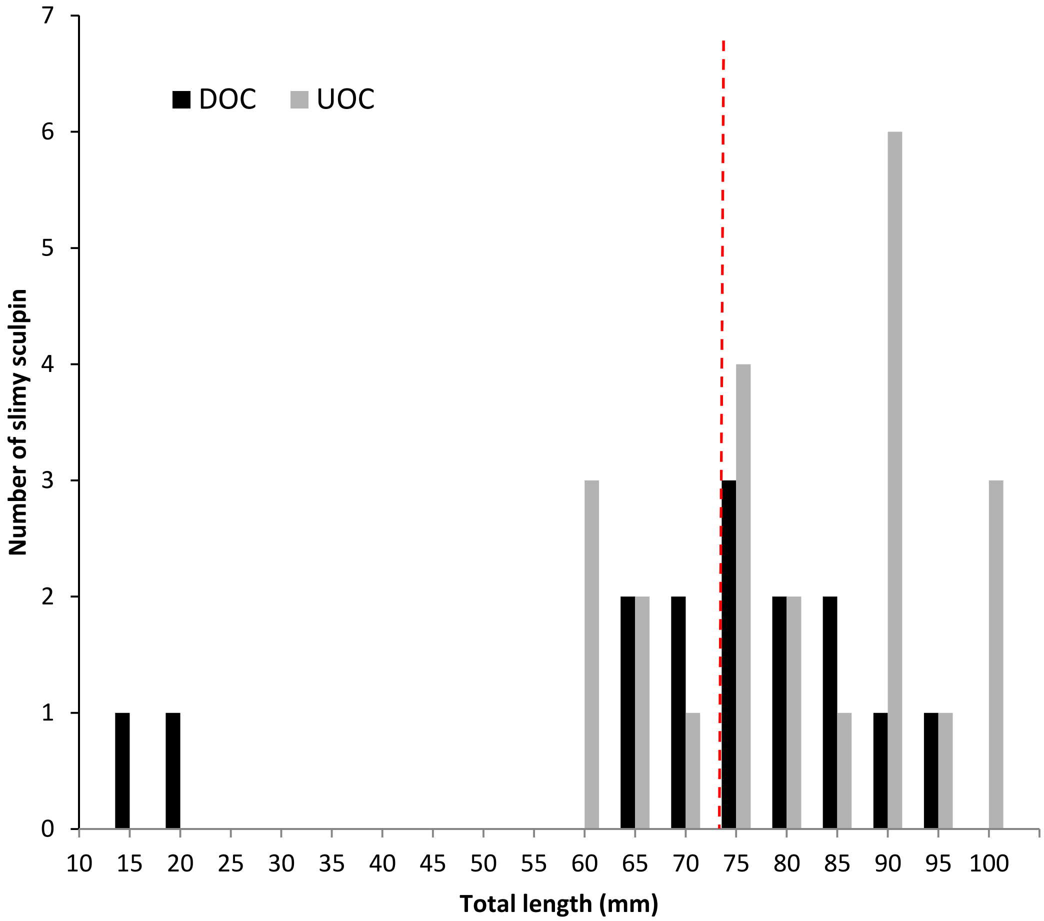

Figure 5. Length-frequency histogram of all measured slimy sculpin (*n* = 38) captured downstream (DOC) and upstream (UOC) of culverts for all fishing gear types and streams sampled along the western Denali Highway. The vertical red dashed line indicates the approximate minimum length (74 mm) at maturity.