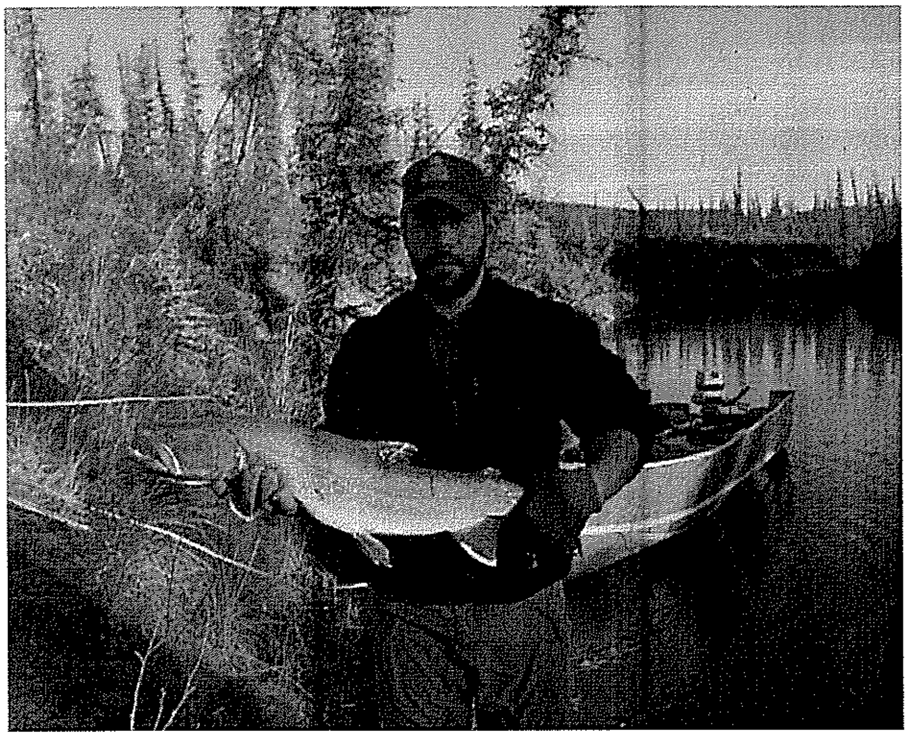
Bull trout distribution, life history, and habitat requirements in the southern and central Mackenzie River Valley, Northwest Territories



A report submitted to the Government of Canada Habitat Stewardship Program for Species at Risk

by

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INTRODUCTION

The bull trout, *Salvelinus confluentus*, is a native char from western North American (McPhail and Baxter 1996), which occurs in several inland tributaries throughout the Northwest Territories (Rescan Environmental 1994; Reist et al. 2002, Fig. 1). Bull trout are generally found in headwaters of relatively pristine, cold, high-gradient mountain streams (Goetz 1989; McCart 1997). In watersheds where the species occurs, populations are typically small and widespread. Bull trout are slow-growing fish that mature late and generally spawn in non-consecutive years, which is likely an adaptation to the extreme environments in which they live (McPhail and Baxter 1996). These traits increase their susceptibility to perturbation.

Bull trout exhibit a high degree of life history variation within the species, which include anadromous, stream-resident, adfluvial (lacustrine), and fluvial types. Adfluvial (lake-dwelling) and fluvial (stream-dwelling) life history types, which are considered migratory, occur most frequently throughout the range. The stream-resident life history, which is non-migratory, is not as widespread throughout the species range. Each life history type exhibits different population dynamics and possesses unique habitat requirements (Goetz 1989; McPhail and Baxter 1996).

During the last 30 years bull trout populations have experienced drastic declines in local areas throughout the northwestern United States and southern Alberta. Peripheral populations from the southwestern United States have been extirpated from the McCloud River, California and from three major tributaries in the Willamette system, Oregon (Goetz 1989; McPhail and Baxter 1996). Impacts demonstrated as contributing to the decline of southern bull trout populations include fragmentation and isolation of populations by man-made structures; over-fishing; habitat disturbance from industrial activities such as seismic, pipeline, forestry and mining work; interaction with exotic species and the cumulative effects of these activities (McCart 1997; Baxter et al. 1999). In response to population declines in the south, the species was formally listed as "threatened" within the coterminous United States and "sensitive" in Alberta, British Columbia, and the Yukon Territory (U.S. Fish and Wildlife Service 1999; Canadian Endangered Species Conservation Council 2001). The species is listed as "May Be At

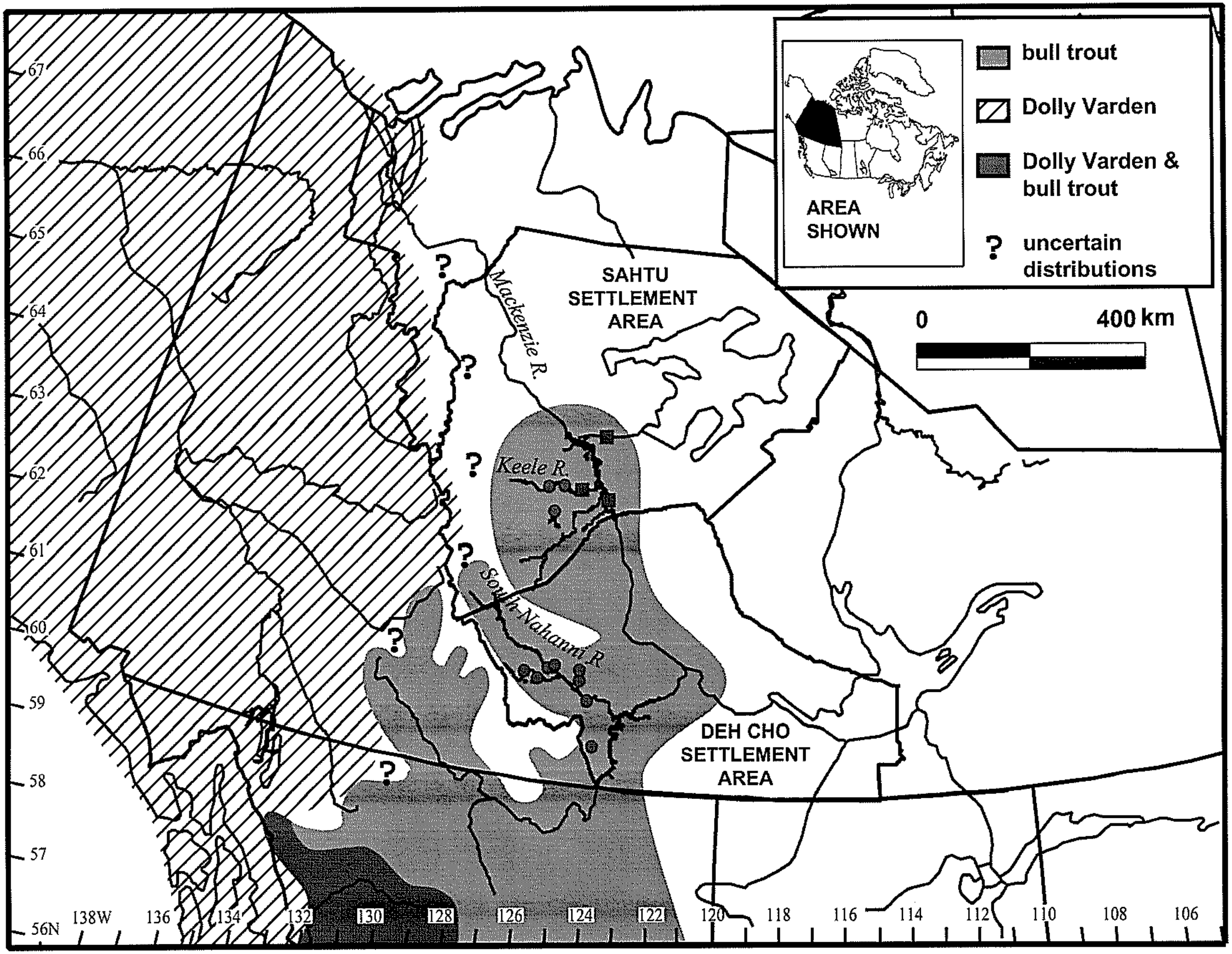


Figure 1. Distribution of bull trout and the related char, Dolly Varden, in Northwestern Canada showing locations of confirmed bull trout captures (● this study; ■ Reist et al. 2002) in the Northwest Territories.

Risk" in the Northwest Territories (NWT) and is a candidate for a detailed risk assessment in this region (Government of the Northwest Territories, Department of Resources, Wildlife and Economic Development 2000).

In areas such as Alberta, where populations have experienced significant declines, managers have implemented sport-fishing regulations (i.e., zero-bag-limit), monitoring programs, non-native fish removal programs, and habitat use studies to reverse declining population trends (Post and Johnston 2002). Understanding and documenting the distribution, life history, and habitat requirements of bull trout populations throughout the range is critical for successful development of effective management strategies. However, little ecological information is available for bull trout from remote areas throughout the Northwest Territories (Reist et al. 2002). Furthermore, resource development is evolving at a rapid pace throughout the region which, based on inadequate information available, requires fish habitat managers to make poorly informed decisions. Given the current and anticipated level of resource activity throughout the region it is critical to acquire ecological information regarding habitat use for this species to establish baseline data that can be used to implement appropriate management programs.

The objectives of this study were to document the distribution, identify the different life history types, and determine the habitat requirements of bull trout populations throughout as large a geographic area in the NWT as possible. This report will 1) describe the distribution, life history, and habitat use of bull trout found in the NWT, 2) compare bull trout populations and habitat found in the NWT to those found in the south, and 3) discuss management issues as they pertain to bull trout in the NWT.

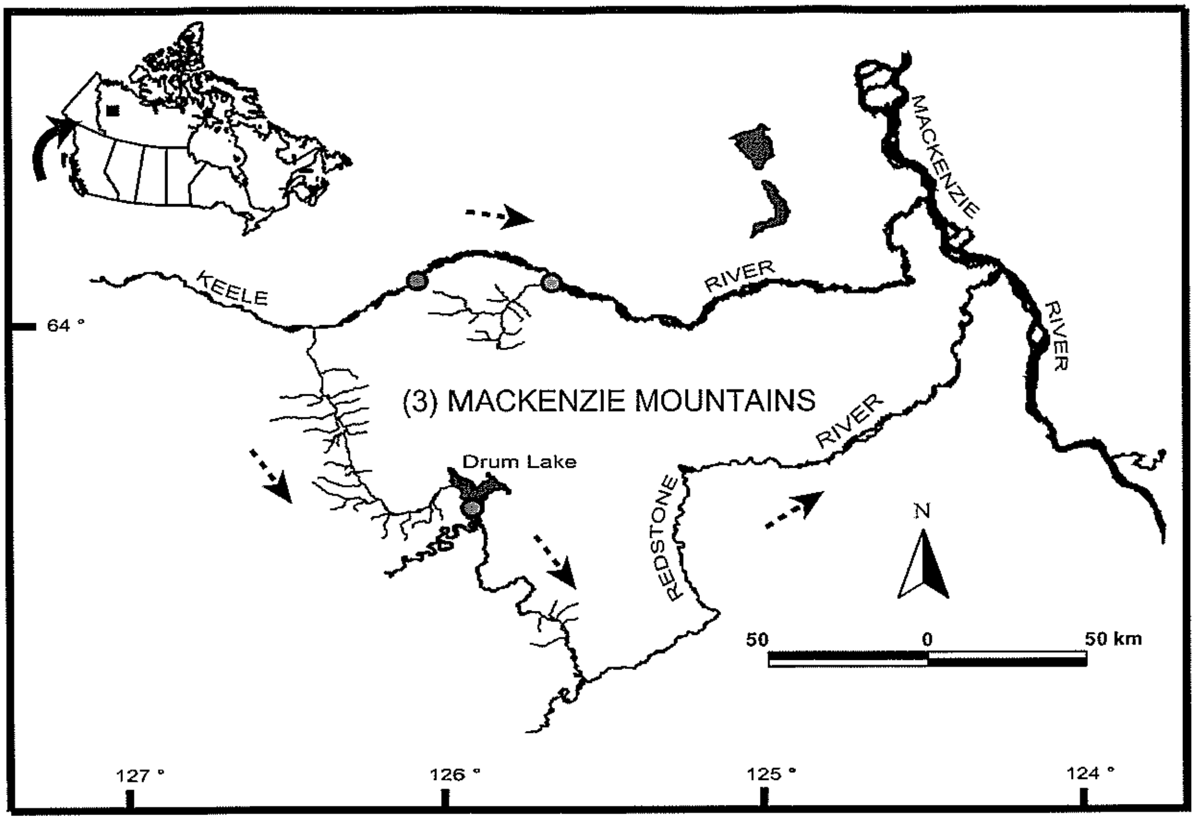
METHODS

Study Sites

In order to obtain baseline data on bull trout distribution, life history, and habitat use in the NWT, twelve streams were selected in the Keele, South Nahanni, and Liard River watersheds (Locations 1, 2, and 3 on Fig. 2) that were reported to contain bull trout based on previous capture records. The twelve study streams were sampled to confirm the presence of bull trout in the summer and fall of 2000 and 2001. Habitat measurements were then completed at the following sites: Fast, Funeral, Jorgenson, Marengo, and three unnamed streams located in the Keele, South Nahanni and Liard River watersheds (Locations 1, 2, and 3 on Fig. 2). Habitat data were acquired from an unnamed stream located in the southwestern corner of the NWT (60° 36' N, 124° 02' W). This stream's headwaters originate in the Franklin Range at an approximate elevation of 1500 m. The unnamed stream is a 2nd order stream, based on the classification system of Strahler (see Gallager 1999) that flows east into the Kotaneelee River (Location 1 on Fig. 2). Habitat was documented in the Nahanni Butte area at three sites: Funeral (60°36'N, 124°48'W), Jorgenson (61°31'N, 126°05'W), and Marengo (60° 36' N, 124° 48' W) creeks (Location 2 on Fig. 2). Funeral Creek is a 1st order stream and Jorgenson and Marengo are 2nd order streams. All of the streams surveyed in the Nahanni Butte area have headwater's that originate in the Nahanni Range at an elevation of approximately 2000 – 3000 m and flow into the South Nahanni River (Fig. 2). In the Mackenzie Mountains habitat was documented at an unnamed creek (60°14'N, 125°59'W), which is a major tributary of the Keele River and in two tributaries from the Drum Lake system (63°48'N, 126°09'W, Location 3 on Fig. 2). Tributaries flowing into Drum Lake and the Keele River originate in the Mackenzie Mountains at an elevation of approximately 1500 – 2000 m. The streams surveyed throughout the region are medium to high-gradient mountain streams with headwaters that originate from snowmelt and underground upwellings. Extreme barriers to fish migration occur in the South Nahanni Watershed at Virginia falls (~90 m), and Jorgenson and Marengo falls (~15 m) (Fig. 2).

Fish sampling

Fish sampling was conducted in the Keele, South Nahanni, and Liard River watersheds (Locations 1, 2, and 3 on Fig. 2) in the summer and fall of 2000 and 2001. These three watersheds are found throughout the southwestern and central Mackenzie Valley, NWT. Large rivers (Keele, South Nahanni, Flat) and associated tributaries were sampled at various locations accessible only by boat or helicopter. Tributaries flowing into mainstem rivers and lakes were stratified into lower, middle, and upper sections. In each section randomly selected reaches (200 – 500 m) were electrofished in an upstream fashion using a Smith Root, gas-powered backpack electroshocker. Unwadable areas



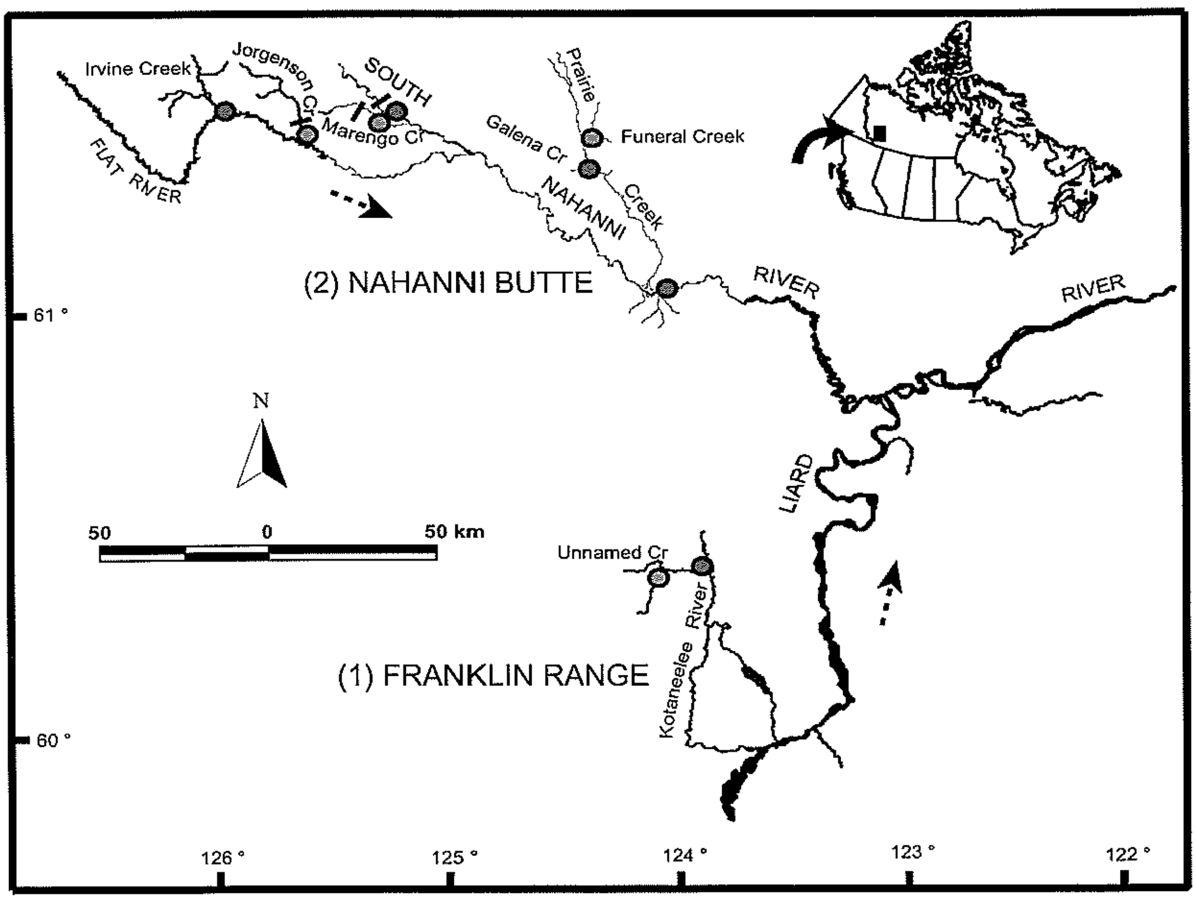


Figure 2. Study sites showing habitat (◉) and fish sampling locations (● & ◉) in the central (top) and southern (bottom) NorthwestTerritories. Note that dashed arrows show flow direction, "/" represent impassable falls, and only partial drainages are shown for clarity.

were angled using barbless hooks. Population estimates were completed at four randomly selected reaches (~200 m) in Funeral Creek (61° 36' N, 124° 48'W) using the Zippin three-removal method (see Zippin 1958). Population estimates were only completed in Funeral Creek because it was the only site where bull trout were caught consistently and was safely wadable during the sampling period. The number of bull trout captured during each pass was entered into the "Microfish" program (see Van Deventer and Platts 1989) to calculate the estimated population size and 95% confidence intervals. The program calculates maximum-likelihood population estimates based on the number of fish captured on each electrofishing pass (Van Deventer and Platts 1989).

At each sampling location char captured were identified to species prior to release. Fork length (nearest mm) and weight (nearest g) were measured, and sex and maturity were documented where possible. All bull trout > 200 mm were fitted with an individually numbered Floy-tag inserted at the base of the dorsal fin and a portion of the adipose fin was removed for genetic work and to evaluate tag loss. The first fin ray was removed from the left pelvic fin for non-lethal ageing.

Voucher specimens were kept from each sampling area for confirmation of species' identity. Char retained from field sampling were compared to known bull trout at the Department of Fisheries and Oceans, Freshwater Institute in Winnipeg. A linear discriminant function shown to be 100% effective in distinguishing Dolly Varden from bull trout (see Haas and McPhail 1991) was used to confirm species identity for all sexually mature individuals. Biological processing, which included meristic and morphometric measurements, age determination from whole and sectioned otoliths, as well as sex and maturity determination, was completed for all voucher specimens (see Reist 1997). Char were examined internally to determine sex (1 = male, 2 = female) and were assigned the following maturity codes based on gonad development: 0 = unknown (virgin fish), 01 = immature female, 02 = mature female, 03 = ripe female, 04 = spent female, 05 = resting female, 06 = immature male, 07 = mature male, 08 = ripe male, 09 = spent male, 10 = resting male, and 11 = unknown (non virgin fish).

Habitat surveys

During the summer and fall of 2001, habitat surveys were conducted in six streams (Fig. 2) to describe bull trout habitat use in the region. The objective was to describe stream features in tributaries where bull trout have been captured and determine specific habitat use at the habitat unit level (pool, run, riffle) where possible.

Habitat use was quantified at the macrohabitat level for all streams and the microhabitat level for one stream during the study. Macrohabitat represents general physical features (e.g., depth, velocity, substrate, wetted width) of a stream. Microhabitat represents the physical features of the stream at the habitat unit level (pool, run, riffle) where fish are captured. For the purpose of this study microhabitat was quantified at the habitat unit level where bull trout were observed or captured rather than at fish positions (focal point) in the stream.

Microhabitat

Microhabitat data were collected from Funeral Creek in September 2001. A two-person crew electrofished two randomly selected reaches (200-300 m) using a Smith Root, gas-powered backpack electroshocker. The reaches were blocked at the upper and lower ends by seine nets and three consecutive electrofishing passes were completed at each reach. After each pass, all bull trout captured were removed from the reach and held in a fish holding bag downstream of the sampling reach. Each time a bull trout was captured a metal washer with yellow or orange flagging tape, representing either juvenile (i.e., < 200 mm) or adult (i.e., > 200 mm) fish, was placed in the habitat unit for later identification. Lengths (nearest mm) and weights (nearest g) were recorded for all bull trout captured in the field and Floy-tags were attached to all individuals greater than 200 mm that were released live after sampling. All bull trout larger than 200 mm were considered adults and all less than 200 m were juveniles. The size criteria for juveniles and adults were based on size-at-age data determined by whole and sectioned otoliths from sacrificed individuals from the stream.

To determine physical features of each habitat type where bull trout were captured, three equidistant transects were placed parallel and perpendicular to water flow within each habitat unit. At each of the habitat units depth, velocity, substrate, and cover were measured at points where transects crossed giving nine measurements for each variable. Depth was measured with a meter stick, bottom velocity was measured (~ 5 cm above the bottom) using a Marsh-McBirney flow meter accurate to 0.01 m/s, dominant substrate was estimated visually in the surrounding 5 cm for each point using a modified Wentworth scale (see Table 1), and cover was estimated visually at each point according to a ranked classification scale (see Table 2). The wetted width of the stream was randomly measured at 50 m intervals throughout all sampling reaches in each stream.

The mean depth and velocity were determined for each habitat unit. Mean depth was calculated by dividing the sum of all nine measurements by 12 to account for 0 depth (cm) at the bank (Platts et al. 1983). The mode was determined for substrate and cover at each habitat unit and frequency histograms were developed to determine dominant substrate and cover across and within streams.

Macrohabitat

Habitat data were obtained from 81 pools, 55 runs, and 61 riffles that were randomly sampled from 22 reaches in six streams throughout the NWT. Habitat surveys were conducted during August and September of 2001 in streams where bull trout had been captured during stream inventory surveys in 2000 and 2001. Reaches that were 200 to 400 m were selected in the lower, middle, and upper sections of each stream for sampling. Habitat typing followed the technique of Bisson et al. (1988) based on hydraulic characteristics of each stream, however habitat was not classified at a scale finer than the pool, run, and riffle level. To determine physical features of the stream three transects parallel and perpendicular to flow were placed in each randomly selected habitat unit and depth, velocity, dominant substrate and cover were recorded at nine points as described above.

Boxplots and frequency histograms of macro and microhabitat use and availability were constructed in order to provide a visual representation of the data. Comparisons of macrohabitat between streams were made using descriptive statistics.

Table 1. Codes used to define substrate composition for stream surveys in the Northwest Territories (after Sexauer and James 1997).

Code	Particle size range (mm)	Substrate definition
6	> 256	Boulder
5	126 - 255	Large Cobble
4	64 - 125	Small Cobble
3	16 - 63	Pebble
2	2 - 15	Gravel
1	0.06 - 1	Sand
0	< 0.059	Silt

Table 2. Codes used to classify habitat cover types for stream surveys in the Northwest Territories (after Sexauer and James 1997).

Code	Type or size range	Cover definition
1	Aquatic vegetation	Submerged vegetation
2	Riparian vegetation	Overhanging vegetation
3	water column depth	Depth
4	water turbulence	Turbulence
5	65 - 255 mm	Cobble
6	256+ mm	Boulder
7	> 30 cm diameter	Large wood
8	< 30 cm diameter	Small wood
9	stable bank, undercut	Undercut bank
10	none of the above are applicable	No cover

RESULTS

Distribution

Bull trout populations were captured in twelve tributaries throughout the Deh Cho (south) and Sahtu (north) settlement areas in 1) the Franklin Mountains centered at approximately 60° 36' N, 124° 02' W; 2) Nahanni Butte centered at approximately 61° 22' N, 124° 48' W; and, 3) the Mackenzie Mountains centered at approximately 64° 15' N, 126° 00' W (Fig. 1 and Locations 1, 2, and 3 on Fig. 2). All three areas are characterized by clear, cold, high-gradient streams, which originate in the mountains and drain into larger more turbid mainstem tributaries. Bull trout are known to use clear, cold streams for spawning but their use of turbid mainstem rivers is unclear in most systems.

In the Franklin Mountains, bull trout were found at several sites over consecutive years from an unnamed creek (60° 36' N, 124° 02' W) flowing east into the Kotaneelee River system. Bull trout were captured approximately 14 km upstream near the headwaters of this unnamed creek and also at its confluence with the Kotaneelee River (Location 1 on Fig. 2). In the Nahanni Butte area bull trout were captured from seven different locations in the summer and fall, 2001 (Location 2 on Fig. 2). The largest number of bull trout (n = 78) captured in this area was from Funeral Creek (60° 36' N, 124° 48' W). In the Mackenzie Mountains, bull trout were captured at the outlet of Drum Lake over successive years and juveniles were captured in a tributary stream flowing into the lake outlet. Bull trout were also captured from two locations in the Keele River (Location 3 on Fig. 2). The furthest west that bull trout occurred in the Keele River was approximately 110 river kilometers from the confluence of the Mackenzie River as sites further west of this location were sampled but no bull trout were captured. Three char with unknown identities were captured from Funeral Creek and study streams in the Liard and Keele River drainages. Preliminary results indicate that these fish could be Dolly Varden and bull trout hybrids or backcrosses. Further tests must be completed to confirm the identity of these fish.

Biology

Size-at-age data from bull trout populations captured throughout the NWT show two types of growth patterns. Individuals are either small, slow growing, and rarely exceed fork lengths greater than 400 mm at sexual maturity or they are large, fast growing, and attain large sizes (500 – 700 mm) once sexual maturity is reached. Such growth patterns are well represented by large mature fish that range in size from 423 mm to 661 mm and smaller mature bull trout that range in size from 236 mm to 355 mm (Fig. 3, Table 3). The two growth patterns displayed by bull trout caught in the NWT correspond with size ranges for various life history types from other areas across the species range (Table 4). Most mature bull trout from Funeral Creek and an unnamed tributary in the Fort Liard region were relatively small compared to bull trout caught in the Keele River and Drum Lake (Figs. 3 & 4). Resting males and females were observed in all locations, which indicate that bull trout populations do not spawn in consecutive years in this region.

The diet of adults from all populations consisted primarily of aquatic and terrestrial insects as well as other fish (Table 3). Fish eaten by bull trout that were identifiable during stomach content analysis included Arctic grayling (*Thymallus arcticus*), lake chub (*Couesius plumbeus*), sculpin (*Cottus* sp.), and sucker (*Catostomus* sp.). Stomach analysis also revealed that an adult bull trout had consumed a juvenile bull trout (Table 3). Juveniles (age 0 – 6) captured from all locations consumed only aquatic and terrestrial insects (Table 3).

Bull trout captured from the Drum Lake outlet ranged in size from 420 mm to 680 mm with the majority of these individuals in the 540 mm to 670 mm size range (A on Fig. 4). Two juvenile bull trout, which were determined to be one-year-old fish, were caught in an unnamed tributary flowing into the Drum Lake outlet (A on Fig. 4). The tributary on which these fish were captured appeared to possess suitable spawning and rearing habitat; however, extremely low flows likely prevented successful passage for large adults to spawn at this site during the fall in 2001. Bull trout from the outlet displayed aggressive behavior to one another, as large lesions were observed on several bull trout during sampling. The male/female sex ratio was 1:1 (females = 7, males = 7).

Bull trout captured in the Keele River ranged in size from 430 mm to 640 mm (B on Fig. 4). Length frequency data show that juvenile bull trout were not captured in this river, as typical size ranges for juveniles are 0 to 400 mm (B on Fig. 4). However, fish were observed throughout the summer and fall just below a tributary that appeared to have a large proportion of suitable spawning habitat. These fish appeared to be staging below this tributary in the late summer and early fall and people from Fort Norman, a local community in the area, have reported ripe char which resembled bull trout in similar tributaries of the Keele River in late fall.

Bull trout captured from Funeral Creek ranged in size from 30 mm to 430 mm, although the majority of individual fish represented juvenile age classes in the 30 mm to 180 mm size range (C on Fig. 4). The estimated average annual growth of juveniles (age 0 – 5) is marginal (27.9 mm/yr, 14.2 g/yr), however after age five the average annual weight gain increases substantially (~ 60 g/yr). The Funeral Creek population was relatively small as population estimates yielded 25 (+/- 4.2) for adults and 24 (+/- 4.02) for juveniles. The average fish/100 m^2 was 3.4 for adults and 6.1 for juveniles. Evidence of cannibalism was documented in the Funeral Creek bull trout population (Table 3).

Bull trout captured from an unnamed tributary in the Kotaneelee River system ranged in size from 200 mm to 400 mm with the majority of the individuals in the 200 mm to 350 mm range (D on Fig. 4). No juveniles were captured in this stream, however juvenile salmonids were observed in the stream. Mature bull trout from this stream appear to be small compared to those found in Drum Lake, and the Keele, South Nahanni and Flat rivers.

Although the majority of bull trout were captured at Funeral Creek, individuals were also captured from six other locations throughout the lower South Nahanni River watershed. Bull trout no. 47057 (FL = 321, WT = 350 g) was caught at the confluence of Galena and Prairie creeks (Fig. 2). Three bull trout (no. 47325, 47058, 47059), which ranged in size from 236 mm to 400 mm, were captured from the South Nahanni River just below the confluence of Prairie Creek (Fig. 2, Table 3). Bull trout no. 47063 (FL = 510 mm, WT = 1250 g) was captured near the base of Virginia Falls (~90 m). Bull trout no. 47064 (FL = 359 mm, WT = 475 g) was captured in a large pool at the base of a small

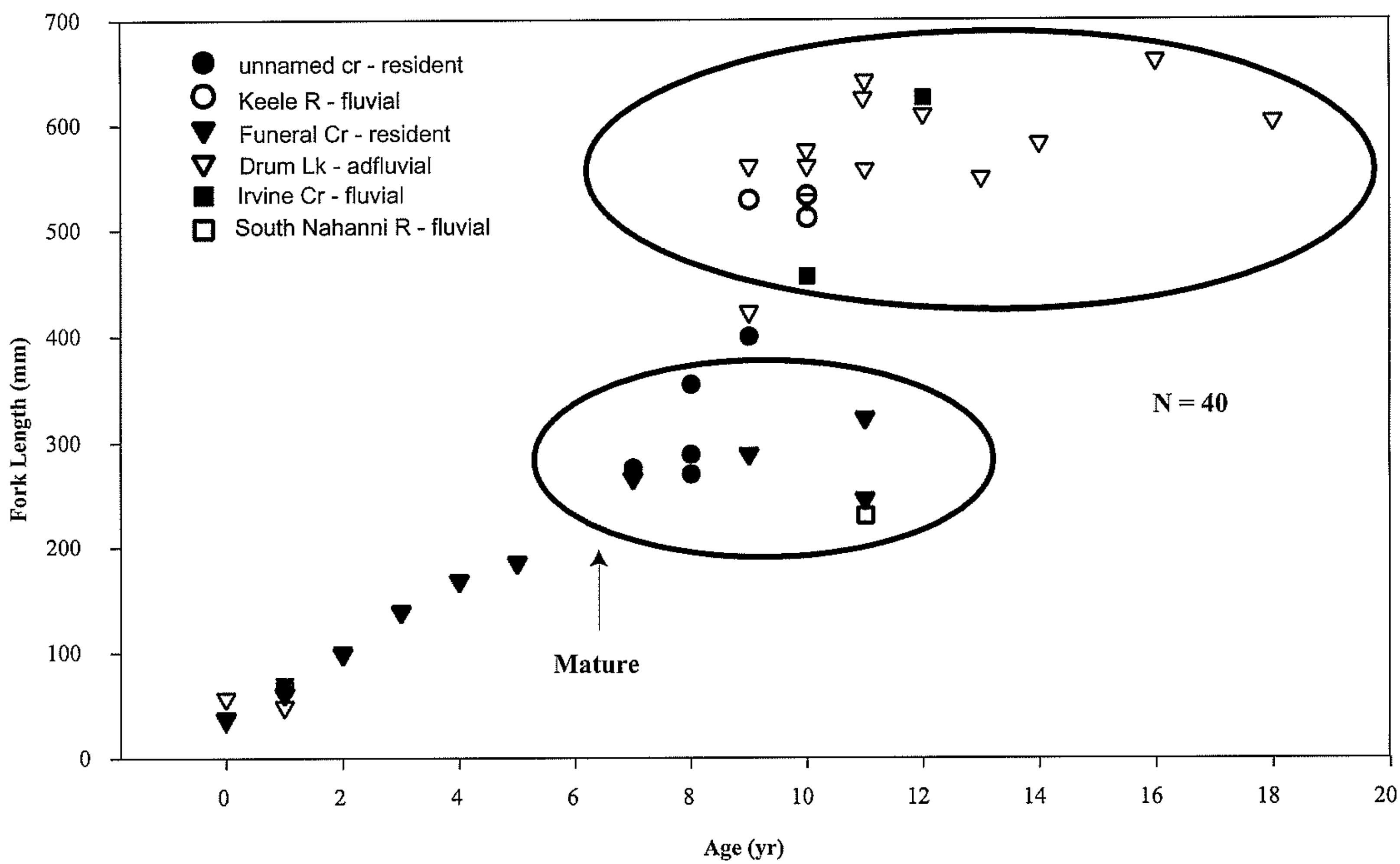


Figure 3. Size-at-age relationship of bull trout captured at six locations in the NWT from 2000 to 2001. Note that all points to the right of arrow are mature fish and hypothesized life history types for corresponding tributaries are outlined in legend. The points within the ellipses represent the two size ranges for mature fish, which correspond to migratory (top) and non-migratory (bottom) life history types.

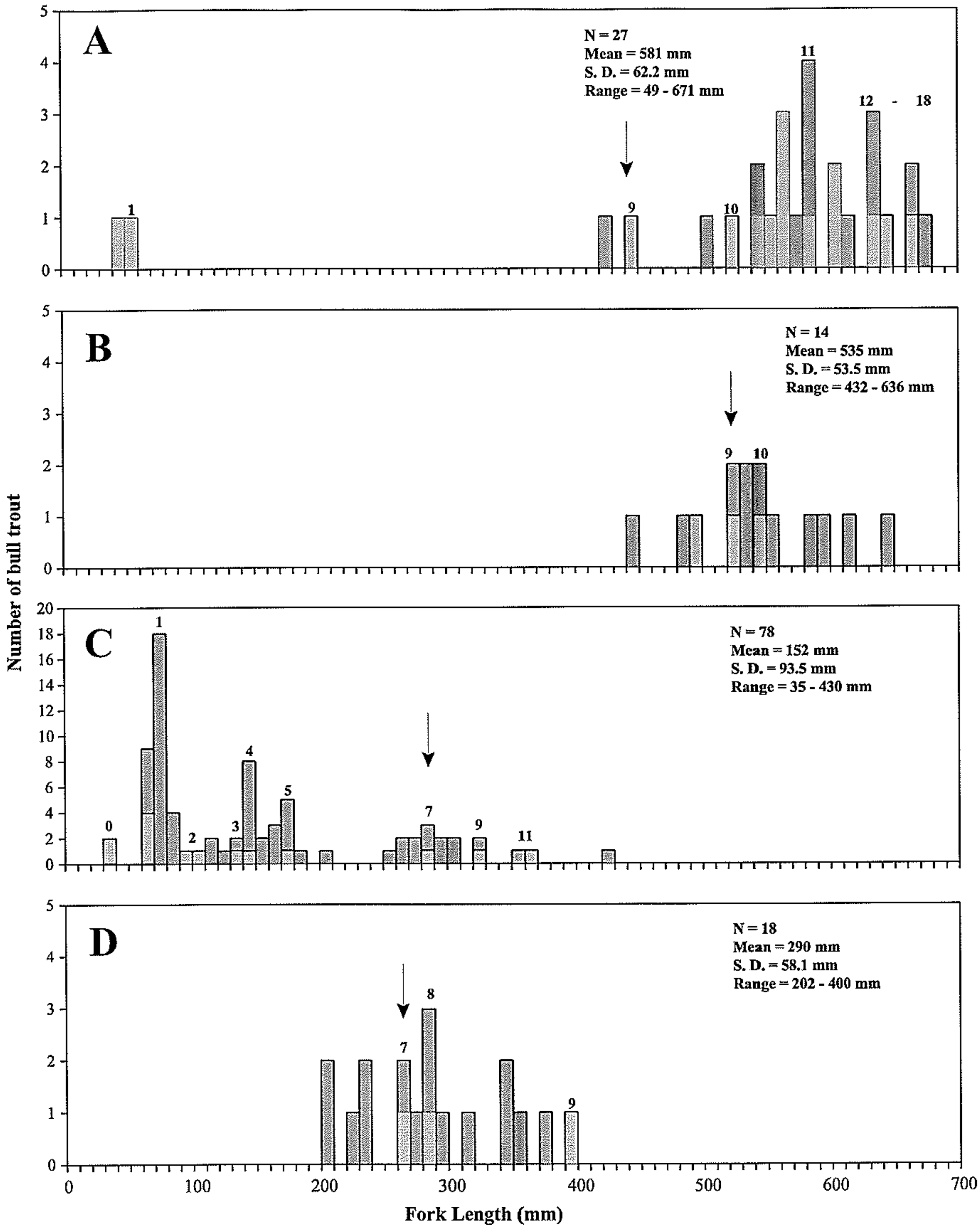


Figure 4. Length-frequency distributions of bull trout captured in Drum Lake (A), Keele River (B), Funeral Creek (C),and an unnamed stream in the Kotaneelee River System (D) in 2000 and 2001. Note lighter shaded bars represent dead-sampled individuals with corresponding ages in bold above bars. Mature fish are below and to the right of arrows.

Table 3. Biological data collected from dead-sampled bull trout captured in streams and rivers from the Northwest Territories in 2000 and 2001.

Fish ID	Date M/D/Y	Location[1]	FL (mm)	Wt (g)	Sex	Mat.[2]	Gonad Wt (g)	Age	Life[3] history	Life[4] stage
47257	07/24/00	unnamed cr.[A]	289	235	2	01	1.0	8	SR	A
47258	07/24/00	unnamed cr.[A]	355	479	.	.	.	8	SR	A
47259	08/05/00	Keele R.	512	1435	1	10	1.0	10	F	A
47260	08/05/00	Keele R.	533	1341	1	10	4.3	10	F	A
47261	09/13/00	Drum L.	561	1806	2	05	9.3	9	AF	A
47262	09/13/00	Drum L.	583	2161	2	05	9.8	14	AF	A
47326	08/10/01	unnamed cr.[A]	270	200	2	05	0.8	8	SR	A
47327	08/10/01	unnamed cr.[A]	276	253	1	06	1.5	7	SR	A
47328	08/10/01	unnamed cr.[A]	400	736	1	10	8.9	9	SR	A
47267	08/13/01	Funeral Cr.	168	53	1	06	.	4	SR	J
47268	08/13/01	Funeral Cr.	266	204	2	02	0.7	7	SR	A
47269	08/13/01	Funeral Cr.	354	495	2	05	8.0		SR	A
47270	08/13/01	Funeral Cr.	185	72	1	06	.	5	SR	J
47263	08/14/01	Funeral Cr.	71	2.8	.	.	.	1	SR	J
47264	08/14/01	Funeral Cr.	64	2.3	.	.	.	1	SR	J
47265	08/14/01	Funeral Cr.	323	387	1	07	5.2	11	SR	J
47266	08/14/01	Funeral Cr.	289	281	1	07	3.8	9	SR	J
47325	08/15/01	South Nahanni R.	281	236	1	10	.	11	SR	A
47330	09/11/01	Funeral Cr.	272	246	2	02	1.5	11	SR	A
47331	09/11/01	Funeral Cr.	101	10	.	00	.	2	SR	J
47332	09/11/01	Funeral Cr.	67	3		00	.	1	SR	J
47333	09/11/01	Funeral Cr.	61	2	2	01	.	1	SR	J
47334	09/11/01	Funeral Cr.	35	1	2	01	.	0	SR	YOY
47335	09/11/01	Funeral Cr.	38	1	.	00	.	0	SR	YOY
47336	09/11/01	Funeral Cr.	99	14	2	01	0.1	2	SR	J
47337	09/11/01	Funeral Cr.	139	28	2	01	1.0	3	SR	J
47596	09/15/01	Irvine Cr.	626	2870	2	05	17.2	12	F	A
47338	09/15/01	Irvine Cr.	934	456	2	05	4.6	10	F	A
47329	09/20/01	Keele R.	529	1268	2	05	.	9	F	A
47339	09/25/01	Drum L. outlet	711	423	1	10	0.3	9	AF	A
47340	09/25/01	Drum L. outlet	604	1917	1	09	3.9	18	AF	A
47341	09/25/01	Drum L. outlet	568	1823	1	10	1.1	10	AF	A
47342	09/25/01	Drum L. outlet	528	1561	1	09	3.0	10	AF	A
47343	09/25/01	Drum L. outlet	639	2771	2	05	23.3	99	AF	A
47344	09/25/01	Drum L. outlet	661	3379	2	05	20.2	16	AF	A
47345	09/25/01	Drum L. outlet	642	3144	1	09	1.6	11	AF	A
47346	09/25/01	Drum L. outlet	561	1875	1	10	1.0	10	AF	A
47347	09/25/01	Drum L. outlet	550	1735	1	10	0.9	13	AF	A
47348	09/25/01	Drum L. outlet	558	1954	2	05	8.8	11	AF	A
47349	09/25/01	Drum L. outlet	635	2480	2	05	15.3	11	AF	A
47119	09/27/01	Drum L. outlet	610	2360	2	05	.	12	AF	A
47350	09/27/01	unnamed cr.[B]	49	0.9	.	06	.	1	AF	J
47351	09/27/01	unnamed cr.[B]	57	1.8	1	00	.	0	AF	J

Key

1. A - Unnamed Creek flowing into Kotaneelee River system, B - Unnamed Creek flowing into Drum Lake outlet
2. Maturity (see methods for codes)
3. AF = adfluvial, F = fluvial, SR = stream-resident
4. A = adult, J = juvenile, YOY = young-of-the-year

Table 4. Length range of various life history types for bull trout populations from drainages throughout the southern range and for populations from the Northwest Territories.

Location	**Life History**	**Length distribution of mature fish (mm)**
Various systems throughout the range (latitude ~49 - 56° N)[A]	Stream-resident	140 - 410
	Fluvial	410 - 730
	Adfluvial	508 - 824
Northwest Territories (this study)		
Unnamed Creek (Kotaneelee River system)	Stream-resident	270 - 400
Funeral Creek	Stream-resident	246 - 323
South Nahanni River	Stream-resident	236
Keele River	Fluvial	512 - 533
Flat River	Fluvial	456 - 626
Drum Lake	Adfluvial	423 - 661

[A] Values are ranges for sites summarized from the available literature falls (~ 10 m) in Marengo creek (Fig. 2). Three bull trout (no. 47060, 47061, and 47062), which ranged in size from 245 mm to 336 mm, were captured in a large pool at the base of a falls (~ 15 m) in Jorgenson Creek (Fig. 2). Bull trout no. 47338 (FL = 934 mm, WT = 456 g) and no. 47596 (FL = 626 mm, WT = 2870 g) were captured in a large pool just below the confluence of Irvine Creek and the Flat River (Fig. 2, Table 3).

Microhabitat

In the summer (August 13 – 15) and fall (September 11 – 13) of 2001 a total of 59 juvenile and 18 adult bull trout were captured from Funeral Creek. Juveniles occupied pools, runs and riffles, however the majority of fish were found in riffles (Table 5). Adults occupied pools and riffles but were captured in pools most frequently (Table 5). Juveniles generally used shallow (0 – 15 cm), high velocity (0.2 – 0.4 m/s) sections of stream with an abundance of small cobble to boulder type substrate (Table 6, Figs. 5 and 6). Mean water depth used by juveniles was 14.68 cm and mean water velocity was 0.38 m/s (Table 6). Most juveniles were captured in fast water areas (i.e., riffles) but were either near or at the bottom using small cobble to boulder type substrate (Figs. 5 and 6). Juveniles were commonly found in pocket pools created by boulder and large cobble in these fast water areas. Adults used deeper (20 – 40 cm), low velocity (0.1 – 0.3 m/s) sections of stream with an abundance of cobble to boulder type substrate (Table 6, Figs. 5 and 6). Mean water depth used by adults was 29.31 cm and mean water velocity was 0.38 m/s (Table 6). Adults were typically captured in pools and deeper riffles, which were comprised of small cobble and boulder type substrate (Figs. 5 and 6).

Macrohabitat

Water temperatures for the six streams surveyed during August and September ranged from 3.6 to 12.7° C (Table 7). The elevation for the six streams ranged from 400 to 2000 m and all streams surveyed were 1st to 3rd order (Table 7). The streams sampled represented small to intermediate size streams (1st to 3rd order) with the smallest stream (Funeral Creek) having an average wetted width of 2.33 m and the largest (unnamed creek, Keele drainage) with an average of 9.94 m (Table 7). Bull trout were found in six streams, however the number of individuals captured was extremely low (i.e., < 30) in all streams except Funeral Creek (n = 75). Given the low densities observed, assessment of

Table 5. Number of juvenile and adult bull trout using different microhabitats in Funeral Creek during the fall and summer 2001. Note proportion of total fish caught using each habitat type is reported in parentheses.

Life stage	Pools	Runs	Riffles
Juvenile	19 (32)	1 (2)	39 (66)
Adult	12 (67)	0	6 (33)

Table 6. Microhabitat use by juvenile and adult bull trout during the summer and fall 2001 in Funeral Creek. Values are means for water depth and velocity with standard deviations in parentheses and mode for substrate and cover.

Life stage	Water depth (cm)	Bottom velocity (m/s)	Substrate	Cover
Juvenile	14.68 (5.50)	0.38 (0.17)	Small cobble	Boulder
Adult	29.31 (15.70)	0.25 (0.16)	Small cobble	Boulder

Table 7. Physical habitat characteristics of study locations where habitat use by bull trout was measured in the Northwest Territories. Depth and velocities are mean values with ranges in parentheses. Note substrate and cover categories are described in Tables 1 and 2.

Location	Site	Stream order (map scale 1:50, 000)	Mean wetted width (m)	Mean temp (°C)	Elevation (m) (map scale 1:50, 000)	Depth (cm)	Velocity (m/s)	Dominant substrate	Dominant cover
				Drum Lake (63° 48' N, 126° 09' W)					
Drum Lake outlet	1	1	4.10	4.0 (Sept)	800	20.4(4-60)	0.21(0.01-0.81)	Pebble	Overhead veg.
	2	1	4.45	4.0 (Sept)	800	19.1(3-66)	0.18(0.01-0.70)	Pebble	Cobble
	3	2	16.4	6.4 (Sept)	800	149(54-282)	0.32(0.12-0.49)	Silt	Depth
				Funeral Creek (61° 36' N, 124° 44' W)					
Funeral Creek	1	1	3.36	7.8 (Aug)	1000	28.0(9-89)	0.39(0.0-1.13)	Small cobble	Boulder
	2	1	2.56	7.5 (Aug)	1100	29.5(9-93)	0.26(0.0-0.93)	Small cobble	Boulder
	3	1	1.72	4.6 (Sept)	1100	22.2(9-80)	0.30(0.1-1.33)	Small cobble	Boulder
	4	1	1.70	4.1 (Sept)	1100	29.1(7-90)	0.22(0.01-0.91)	Small cobble	Boulder
				Jorgenson Creek (61° 31' N, 126° 05' W)					
Jorgenson Creek	1	2	6.26	7.9 (Sept)	600	53.1(12-140)	0.37(0.01-1.20)	Small cobble	Boulder
	2	2	4.86	7.8 (Sept)	600	31.8(10-72)	0.68(0.01-1.46)	Small cobble	Boulder
				Marengo Creek (61° 35' N, 125° 48' W)					
Marengo Creek	1	2	4.96	.	600	40.9(12-85)	0.41(0.01-1.40)	Boulder	Boulder
	2	2	2.82	.	600	31.5(12-88)	0.37(0.01-1.72)	Large cobble	Boulder
				Keele River (64° 14'N, 125° 59' W)					
Unnamed Creek	1	3	10.7	4.1 (Sept)	400	38.2(12-114)	0.55(0.01-1.46)	Small cobble	Boulder
	2	3	13.8	5.6 (Sept)	400	46.8(12-122)	0.41(0.0-1.25)	Small cobble	Boulder
	3	2	5.17	3.6 (Sept)	600	35.9(12-66)	0.35(0.01-1.02)	Small cobble	Boulder
	4	2	10.1	4.0 (Sept)	600	45.0(12-130)	0.42(0.0-1.46)	Small cobble	Boulder
				Kotaneelee River (60° 36' N, 124° 01' W)					
Unnamed Creek	1	2	4.95	12.7 (Aug)	1500	50.2(15-110)	0.29(0.0-1.00)	Sand	Overhead veg.
	2	1	6.90	10.3 (Aug)	2000	55.3(8-135)	0.47(0.0-1.21)	Small cobble	Large wood
	3	1	5.80	7.8 (Aug)	2000	49.1 (8-140)	0.51(0.0-1.40)	Small cobble	turbulence
	4	1	7.20	8.5 (Aug)	2000	52.5 (18-104)	0.48(0.0-1.55)	Large cobble	turbulence

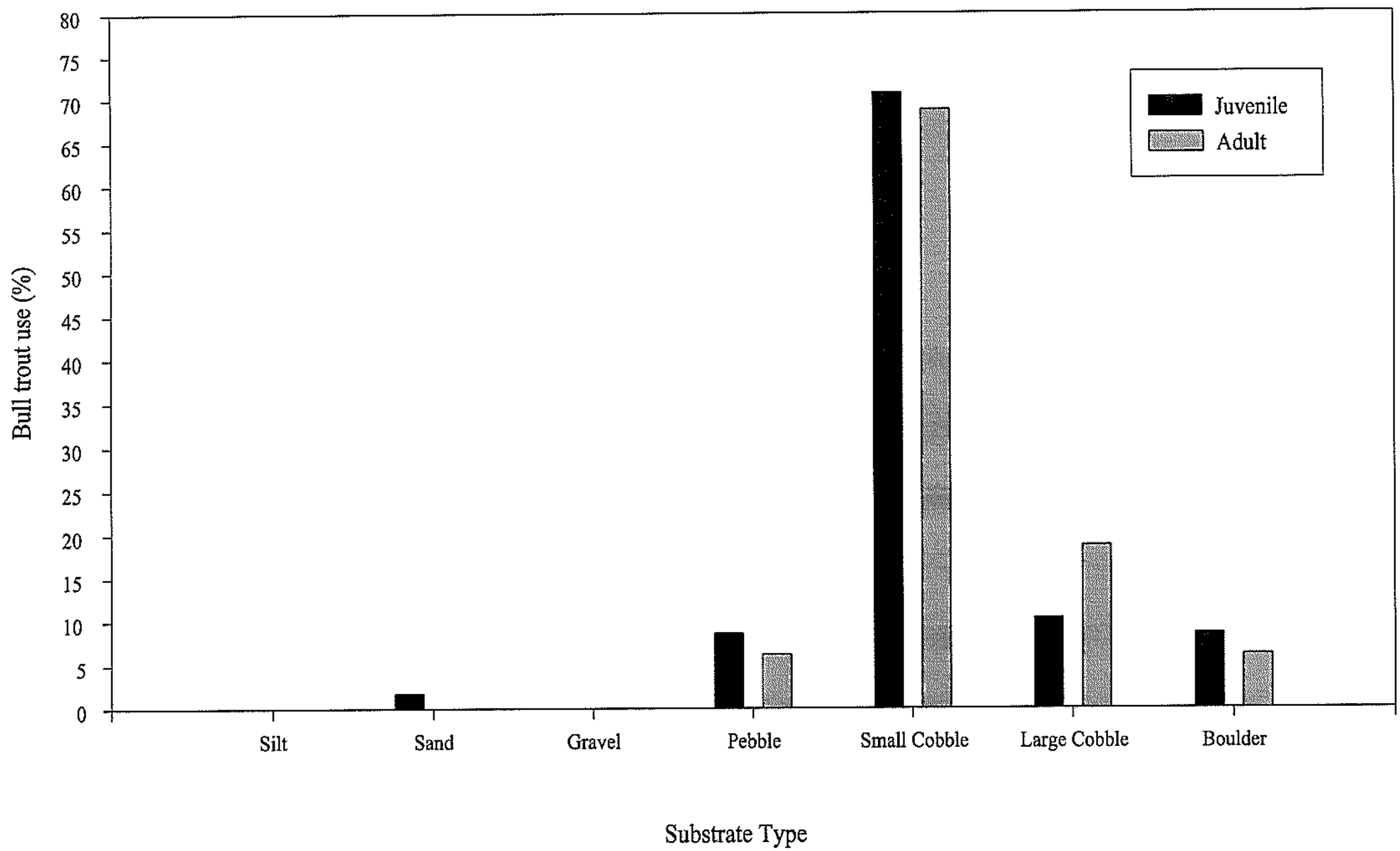


Figure 5. Substrate use by bull trout juveniles and adults in Funeral Creek during the summer and fall 2001.

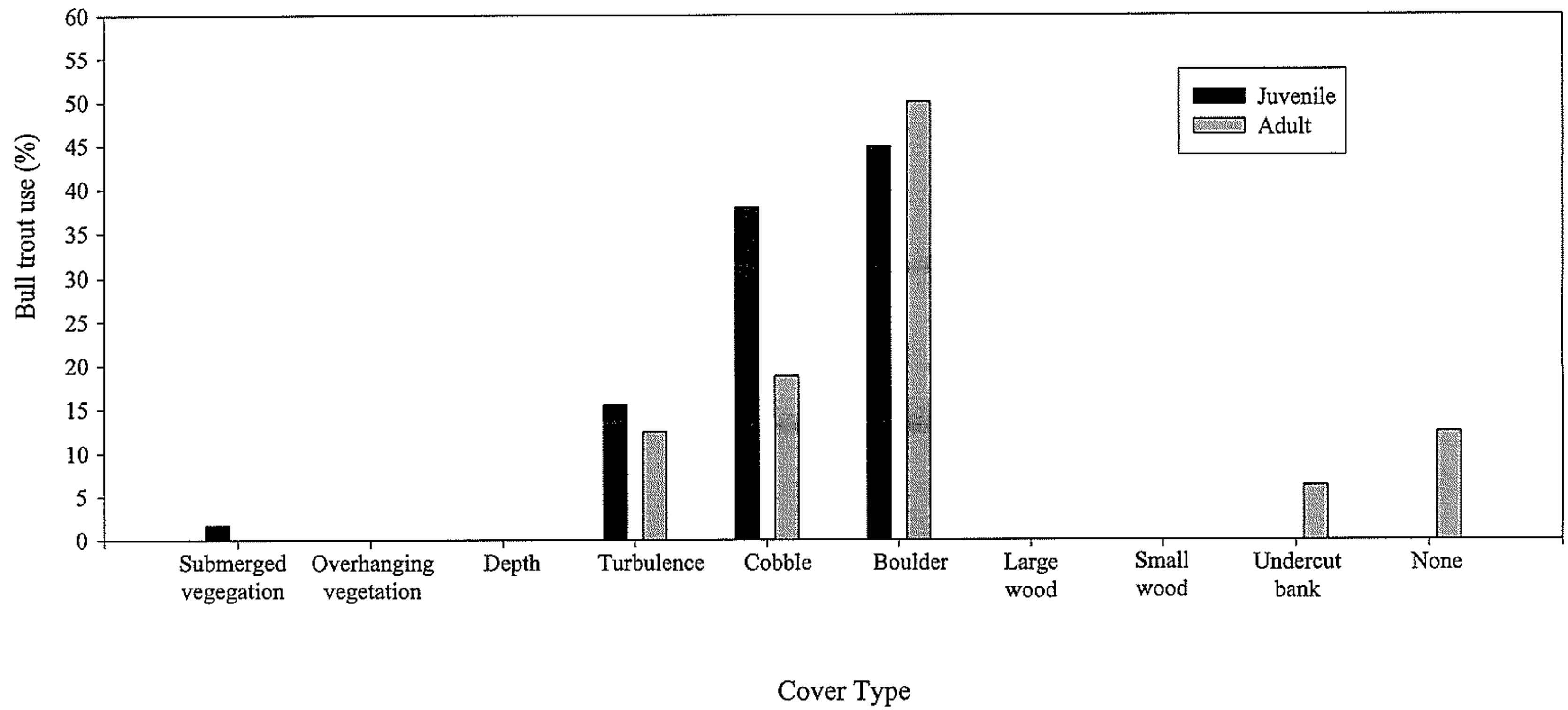


Figure 6. Cover use by bull trout juveniles and adults in Funeral Creek during the summer and fall 2001.

specific microhabitat use of adults and juveniles was only possible in Funeral Creek. Macrohabitat data were obtained from all other locations as these sites were considered to be bull trout habitat based on presence of the species during previous inventory sampling.

Habitat data from the six streams show that different habitat units (pool, riffle, and run) provide unique habitat for bull trout throughout the region. Pools found across the six streams were the deepest, followed by runs and riffles (Fig. 7). Mean water velocity values across the streams showed that pools had the lowest velocities and riffles had the highest (Fig. 7). Comparisons between the three habitat types indicate that pools represent deep, slow-water habitat, riffles are shallow fast-water habitat, and runs have intermediate water depths and velocities compared to pool and riffle habitats (Fig. 7). Habitat availability histograms show that pools possess the most diverse array of substrate, followed by runs and riffles which have larger proportions of pebble to cobble type substrate (Fig. 8). Small cobble is the dominant substrate found in all three habitats throughout the six streams (Table 7, Fig. 8). Cover data for pool, run and riffle habitats across the six sites indicate that boulder (substrate) is the most common type of cover available followed by turbulence, large wood and depth (Fig. 9). Pools have the most diverse cover available followed by runs, and riffles (Fig. 9).

Depth availability data show that most streams have a large proportion of habitat in the 0 to 60 cm range (Fig. 10). Funeral Creek and an unnamed tributary from Drum Lake possess a large proportion of shallow water habitat (0 – 20 cm), whereas Jorgenson, Marengo, and unnamed tributaries in the Liard and Keele drainages have a greater proportion of deep-water habitat (20 – 60 cm) (Fig. 10). Funeral Creek and the Drum Lake tributaries have lower mean velocities than Jorgenson, Marengo, and the Liard and Keele tributaries (Table 8, Fig. 11). Small cobble was the dominant substrate found throughout five of the streams (Fig. 12). The stream surveyed in the Liard drainage showed the most types of substrate available and the Drum Lake tributary has the largest proportion of silt and sand which is not typical substrate used by bull trout (Fig. 12). Funeral, Jorgenson, and Marengo creeks, as well as an unnamed tributary from the Keele drainage have predominantly large substrate, which is also the main source of cover available in these streams (Figs. 12 and 13). The Liard tributary has the largest proportion

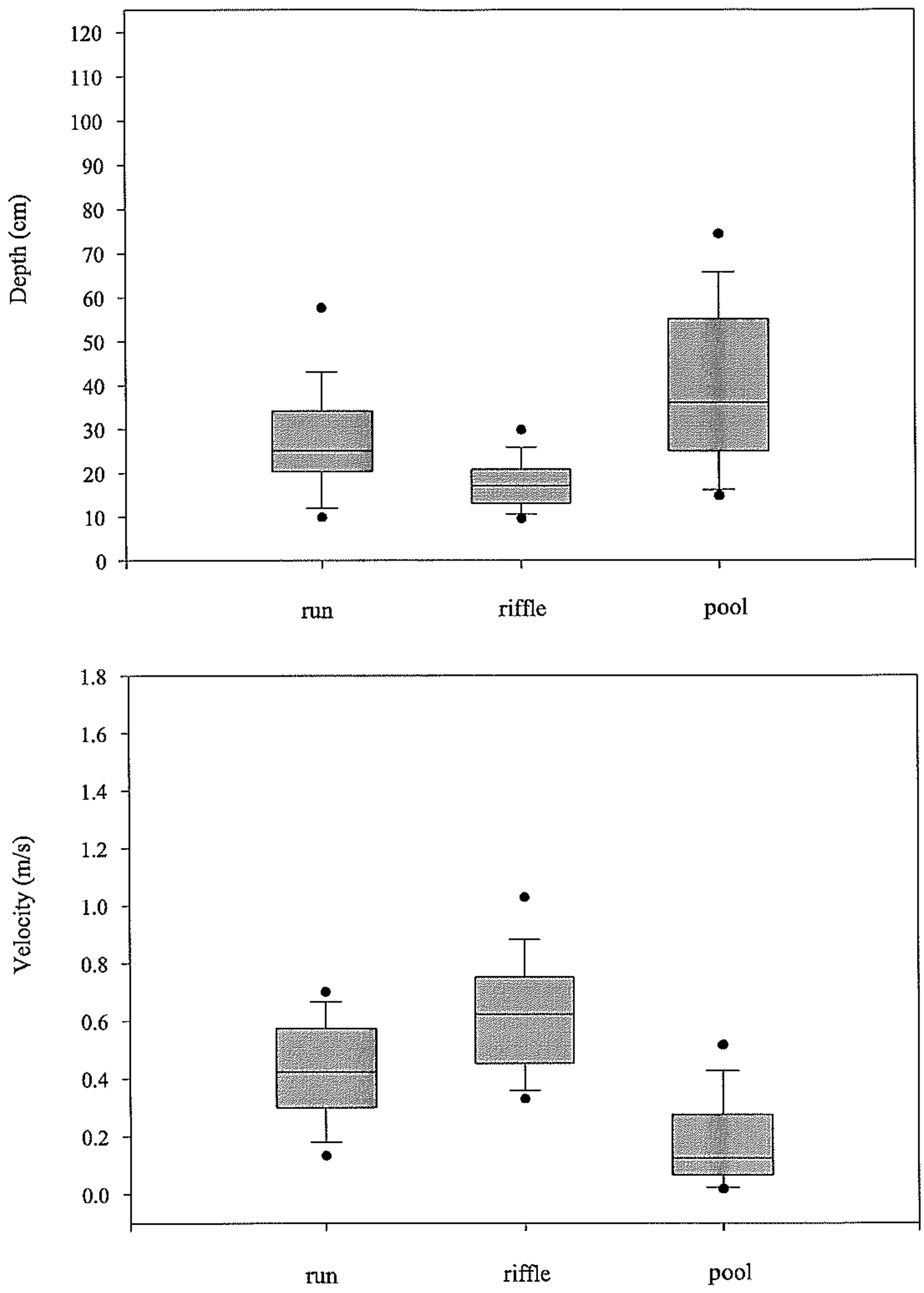


Figure 7. Box plots showing 5th (lower dot), 10th, 25th, 50th, 75th, 90th (horizontal lines), and 95th (upper dot) percentiles respectively, for mean depth (top) and velocity (bottom) of pool, riffle, and run habitat units measured from six streams throughout the southern and central Northwest Territories.

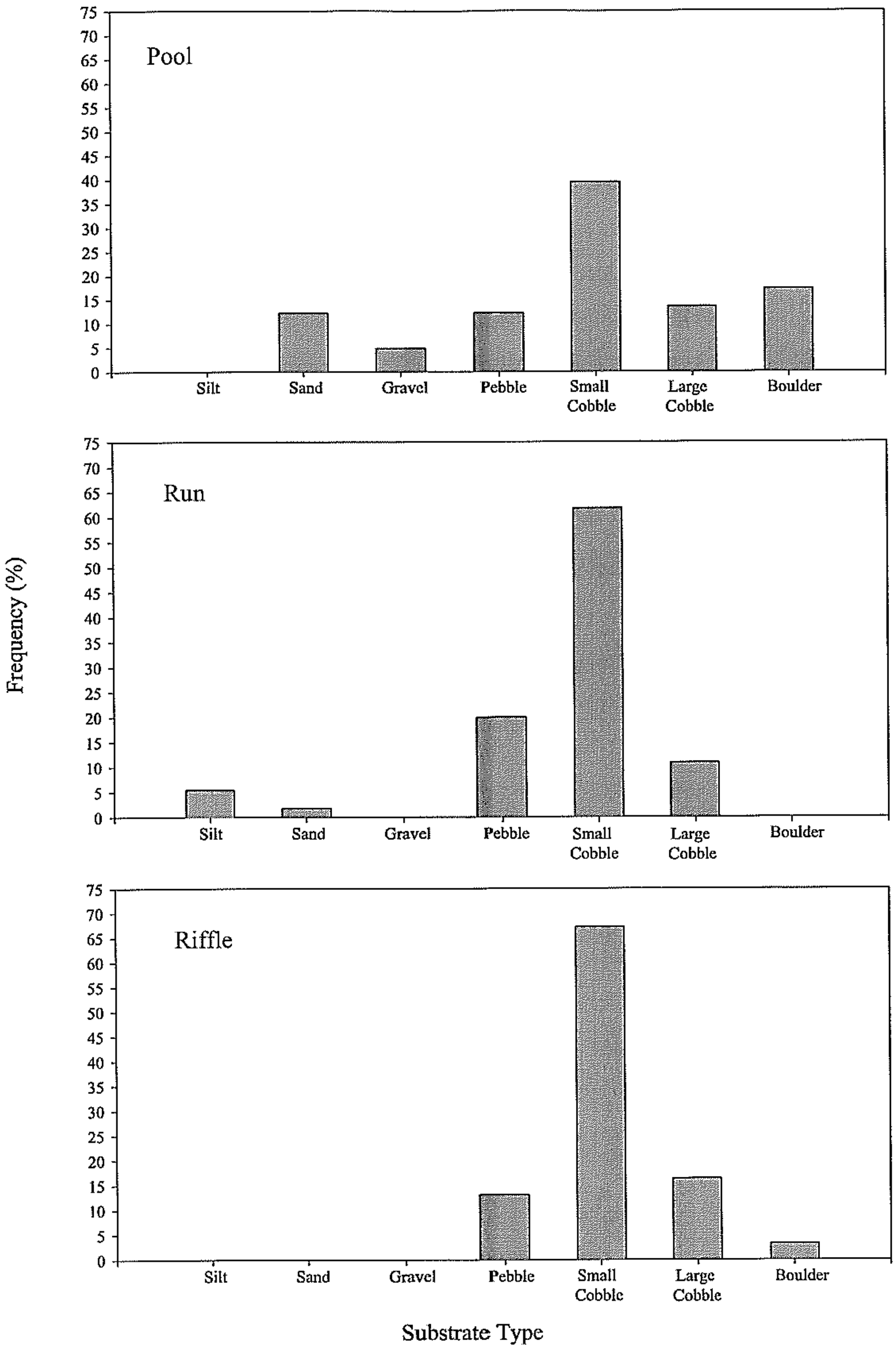


Figure 8. Habitat availability data for substrate in pool, run, and riffle habitats from six streams in the Northwest Territories.

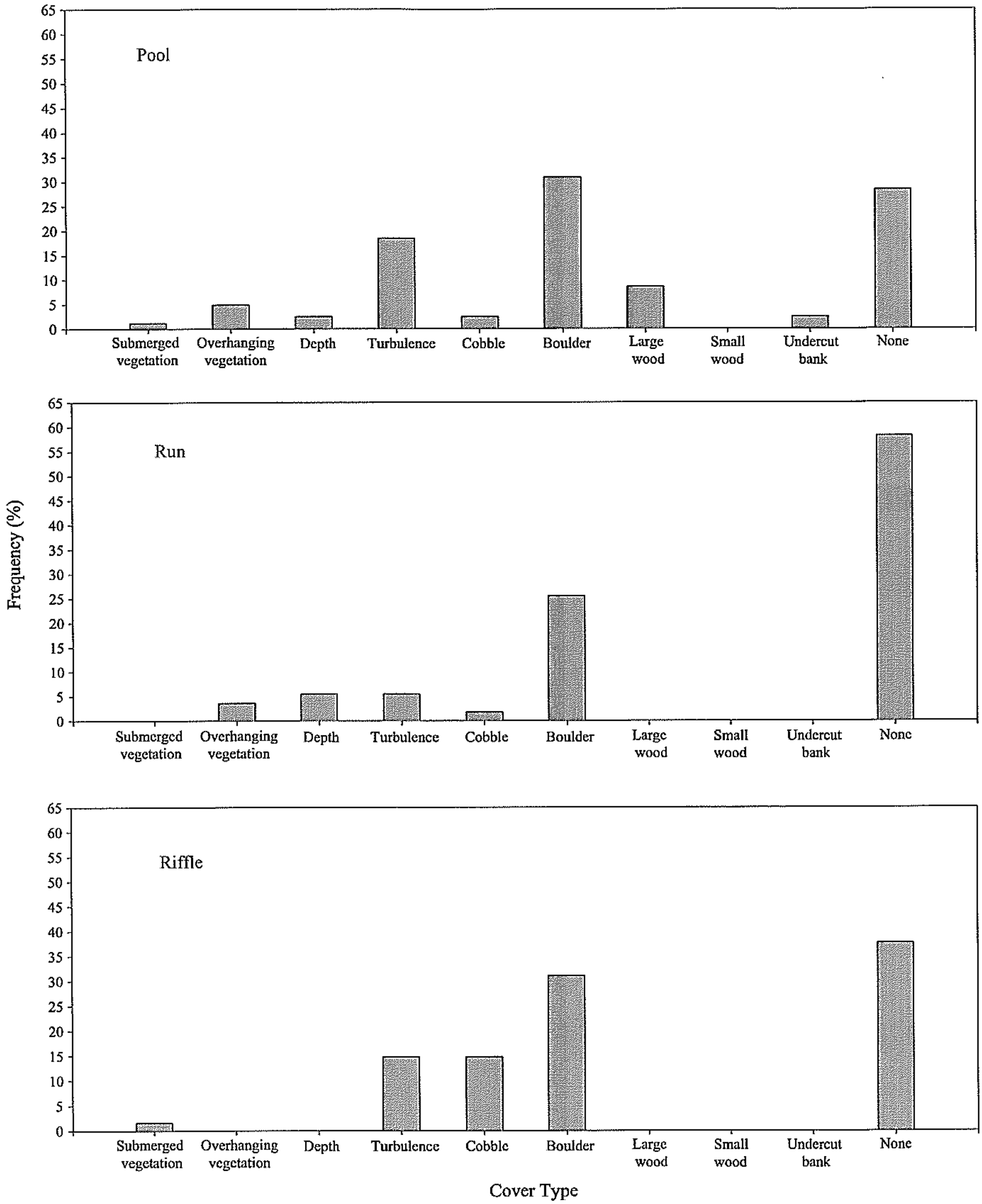


Figure 9. Habitat availability data for cover in pool, run and riffle habitats from six streams in the Northwest Territories.

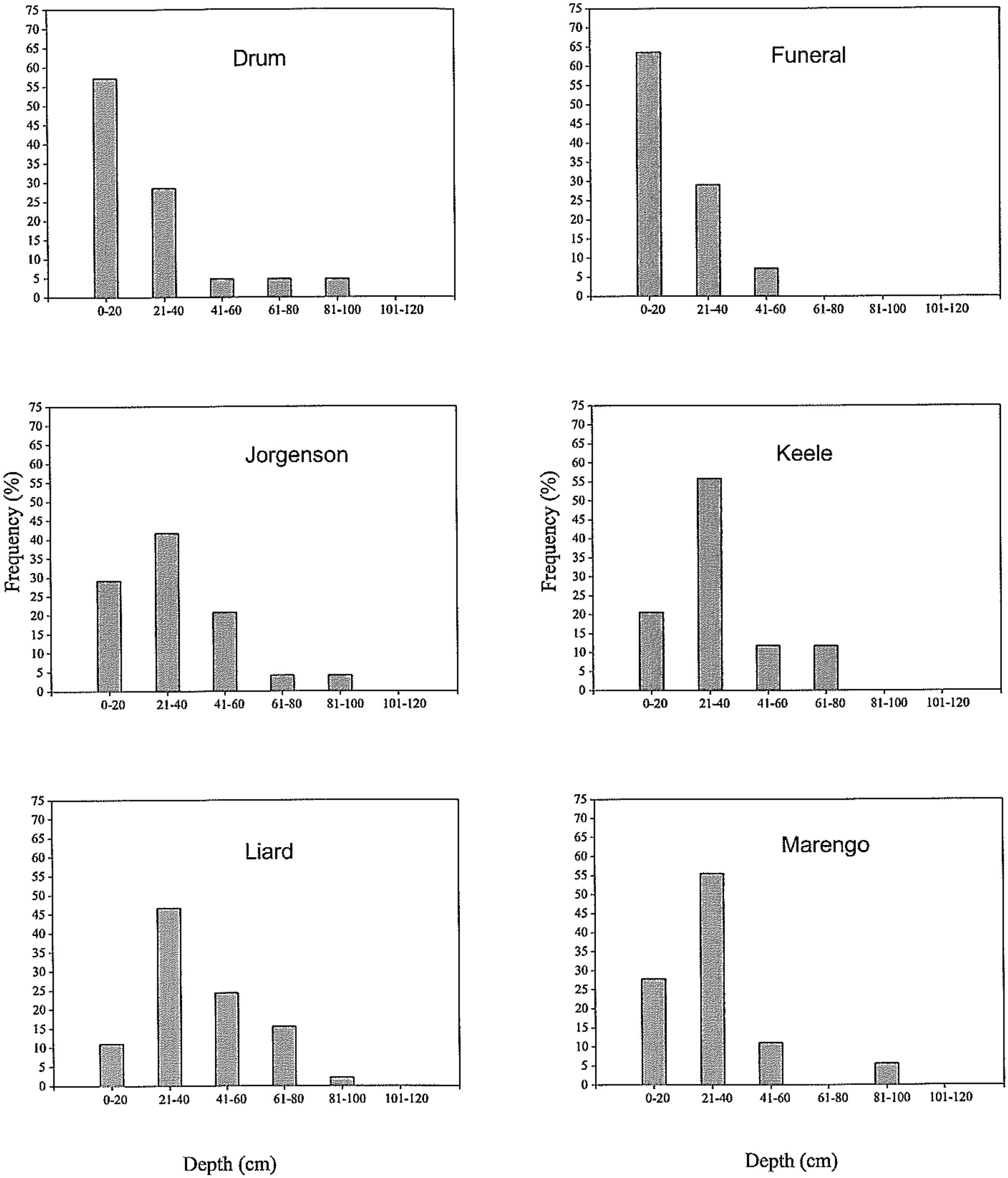


Figure 10. Frequency histograms of depth availability for pool, run and riffle habitats from six streams surveyed in the summer and fall 2001.

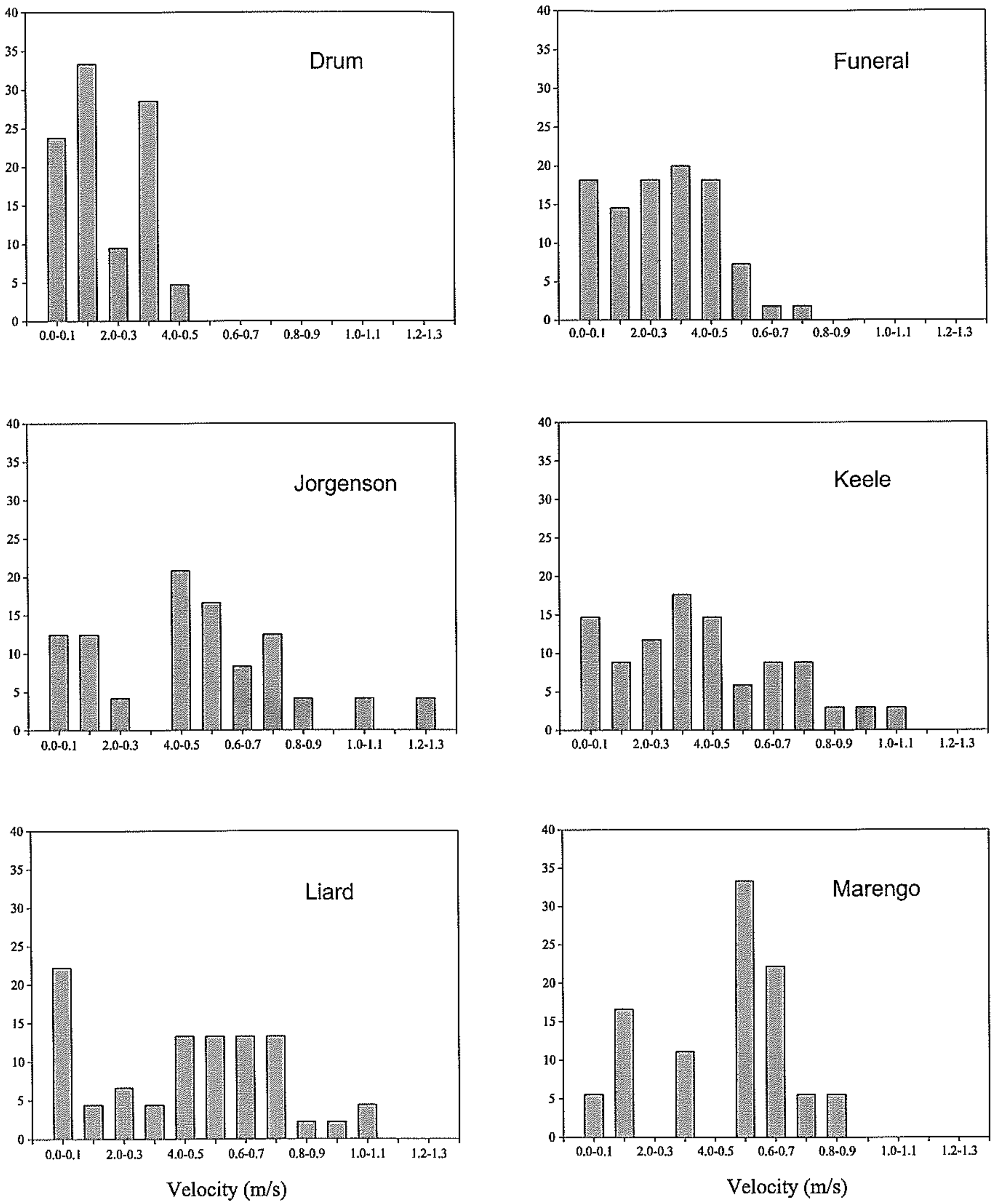


Figure 11. Frequency histograms of velocity for pool, run, and riffle habitats from six streams surveyed in the summer and fall 2001.

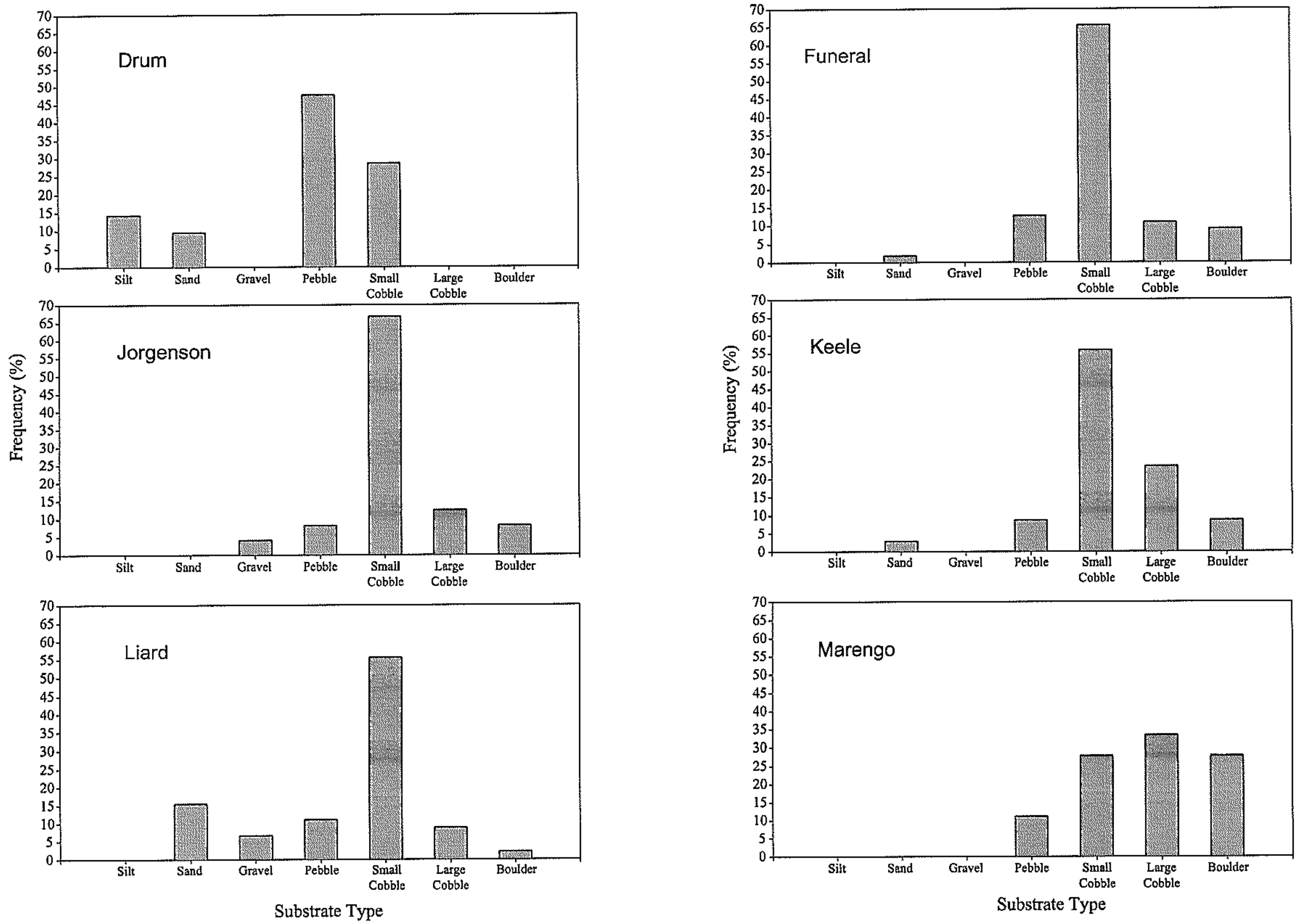


Figure 12. Frequency histograms of substrate availability for pool, run, and riffle habitats from six streams surveyed in the summer and fall 2001.

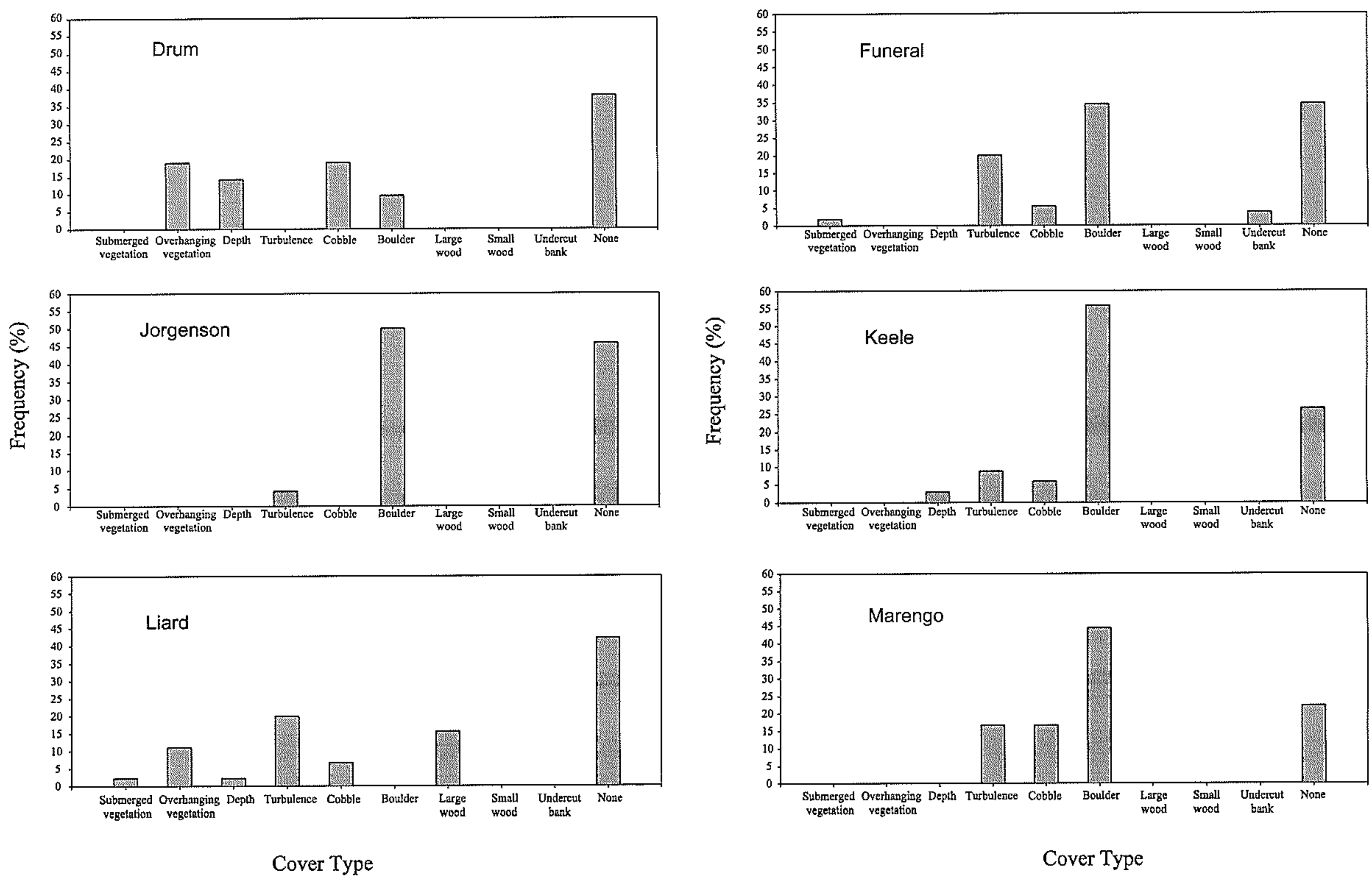


Figure 13. Frequency histograms of cover availability for pool, run, and riffle habitats from six streams surveyed during the summer and fall 2001.

Table 8. Macrohabitat characteristics summarized for bull trout across the range and measurements taken from six streams in the Northwest Territories during this study.

Location	Life Stage	Water depth (cm)	Water velocity (m/s)	Substrate size (mm)	Dominant Cover
Various systems throughout the range	Spawn/egg	20 - 60	0.1 - 0.4	20 - 130	wood, cavity
(latitude 49 - 56° N)[1]	Young of the year	0 - 20	0.0 - 0.3	6 - 250	substrate (turbulence)
	Juveniles	20 - 60	0.0 - 0.3	20 - 250	wood, substrate, cavity
	Adults	20 - 200	0.0 - 0.6	0.059 - 250	wood, substrate, cavity
Northwest Territories (this study)[2]					
Unnamed Creek, Liard River		37.91+2.61 (9.6-84.5)	0.45+0.04 (0.007-01.09)	0.06 - 256	turbulence, large wood
Unnamed Creek, Keele River		33.7+2.9 (15.5-76.0)	0.41+0.05 (0.01-1.06)	0.06 - 256	Substrate
Unnamed Creek, Drum Lake		24.9+5.0 (5.1-88.2)	0.21+0.03 (.049-.424)	0.059 - 256	substrate, overganging vegetation
Funeral Creek, South Nahanni River		21.1+1.61 (8.71-55.0)	0.29+0.02 (0.024-0.72)	16 - 256	substrate (turbulence)
Jorgenson Creek, South Nahanni River		32.5+3.6 (11.3-83.2)	0.51+0.07 (0.013-1.27)	2 - 256	Substrate
Marengo Creek, South Nahanni River		29.7+4.0 (13.0-83.3)	0.49+0.05 (0.062-0.87)	16 - 256	substrate (turbulence)

1. Values are ranges for sites summarized from the literature for all life history types and life stages.

2. Values for water depth and velocity are given as the mean + SE with ranges in parentheses, substrate is given as ranges, and cover as dominant types with less dominant types in parentheses.

of woody debris available for cover from all streams (Fig. 13). The Drum Lake and Liard tributaries have the most overhead vegetation available for all streams surveyed (Fig. 13).

The six streams surveyed throughout the southern and central NWT have habitat which is within the ranges described in the literature for water depth, velocity, substrate, and cover used by all life histories and stages of bull trout across the range (Table 8). Cobble to boulder substrate, which is used by adults for spawning and juveniles for cover (Baxter and McPhail 1996) is available in all streams (Figs. 12 and 13).

DISCUSSION

Distribution

Prior to investigations, which examined the range of bull trout in the Northwest Territories (see Reist et al. 2001) the previous northernmost confirmed locality for the species was at Prairie Creek (~ 61° N, 125° W), a tributary of the South Nahanni River in the southern Northwest Territories (Haas and McPhail 1991; Rescan 1994). Char captures have also been previously reported in this area (Ker, Priestman and Associates Ltd. 1980; Beak Consultants Ltd. 1981; Parks Canada 1984; Haas and McPhail 1991; Halliwell and Catto 1998) but only one report (Rescan Environmental 1994) identifies these char specifically as bull trout. Results from this study confirm that bull trout populations occur throughout several tributaries in the Liard, lower South Nahanni and Keele River watersheds. Repeated capture of bull trout over subsequent sampling trips, combined with literature records, and local reports confirm that several self-sustaining bull trout populations occur throughout the Sahtu and Deh Cho settlement areas. Although bull trout were located in many tributaries during the study it appears that most populations are relatively small and widespread, which is consistent for most populations found throughout the species' range (Goetz 1989; McPhail and Baxter 1996; Swanberg 1997; Baxter et al. 1999). Very few areas yielded large numbers of bull trout, however in local areas, such as Drum Lake, bull trout appear to be abundant as minimal sampling effort over a short period resulted in capture of many large adults. Local lodge owners and sport fishermen report that bull trout have been abundant in the lake in the past and continue to thrive (Fabien Wright, Drum Lake Lodge owner and guide, personal communication

2002). Furthermore, the presence of bull trout throughout several large watersheds, such as the Keele, South Nahanni, and Liard rivers does provide evidence that bull trout populations are more widespread than first thought in the NWT. Given that a large amount of suitable habitat appears to be available in this region, productivity is low in these systems, the growing season is short, and few impassable barriers exist in most watercourses, it is likely that most bull trout populations use large areas in these watersheds throughout their life history. This is especially true for migratory populations that use specific sites within a watershed, which also require that the various sites used be connected.

Biology

Growth, particularily for adult fish, reflects differences in life histories as individuals from stream-resident bull trout populations typically do not exceed 400 mm and individuals from adfluvial and fluvial bull trout populations are generally 400 mm to 700 mm (Baxter and McPhail 1996; McCart 1997). Given these size discrepancies it appears that three life history types occur in the NWT: 1) stream-resident, 2) fluvial, and 3) adfluvial. Bull trout captured from Funeral Creek and an unnamed creek in the Kotaneelee River system appear to be from stream-resident populations as most mature individuals are less than 400 mm. Bull trout from the Keele and Flat rivers appear to be from fluvial populations as these individuals are large compared to fish of similar age from Funeral Creek and the Kotaneelee River system. All mature fish captured from the Drum Lake outflow are large and are likely from an adfluvial population that uses the lake for feeding and over-wintering.

Bull trout captured in the South Nahanni River watershed appear to represent fluvial and stream-resident populations as several small mature fish were caught in smaller tributaries that flow into mainstem rivers (e.g., Jorgenson) and several large mature fish were captured in mainstem tributaries (e.g., Flat River). Since no impassable barriers occur downstream of Virginia Falls, a meta-population structure and genetic exchange between wandering individuals from both life histories is possible and likely. Furthermore, small apparently isolated populations, such as the Funeral Creek population, may actually be connected to larger spawning populations by genetic exchange between wandering fish which exhibit different life histories. Bull trout populations in watersheds across the species range have demonstrated evidence of meta-population structure (Fitch 1997; Rude and Stelfox 1997; Wissmar and Craig 1997; Hvenegaard and Thera 2001). Meta-populations are a product of incomplete isolation and local adaptation and maintain genetic variability through straying from other breeding populations. Wandering fish strengthen regional populations by refounding and protecting the genetic diversity that is necessary for survival under constantly changing environments, thus it facilitates the replenishment and long-term persistence of such populations (Quinn *et al.* 1991; NRC 1996; Policansky and Magnuson 1998). Given that meta-populations could occupy the lower South Nahanni watershed it will be critical to maintain migratory pathways to facilitate genetic exchange between individuals as fragmentation of migratory corridors could create a group of increasingly isolated and dwindling populations that are more vulnerable to biotic and abiotic perturbations.

Bull trout are typically slow growing fish that mature late (Goetz 1989; Ford et al. 1995; Baxter and McPhail 1996; McCart 1997), however growth differs between life history types within the species (Stelfox 1997; McCart 1997). Stream-resident populations typically occur in small, high-gradient mountain streams where cold water and velocity barriers are common (Goetz 1989; McPhail and Baxter 1996). Consequently, productivity in these streams is far lower than streams and lakes that fluvial and adfluvial populations occupy. Stream-resident fish are slow growing, mature early, and have low fecundity (Goetz 1989; McPhail and Baxter 1996). Most stream-resident fish are small (dwarfed) and sexually mature adults from populations throughout the species' range do not typically exceed 400 mm (Adams 1994; Boag and Hvenegaard 1997; Spangler 1997). Fluvial populations are found in larger, more productive mainstem streams and rivers for much of their lives. Compared to stream-resident types, fluvial bull trout are fast growing, mature late, and adults are typically large, attaining lengths of 500 to 700 mm (Goetz 1989; McPhail and Baxter 1996; Hvenegaard and Thera 2001). Similarly, adfluvial bull trout are fast growing, mature late, and reach lengths of 500 to 700 mm once sexually mature (McPhail and Murray 1979; Fraley and Shepard 1989; Stelfox and Egan 1995; Ratliff et al. 1996). Average growth reported for adfluvial juveniles from Lower Kananaskis Lake was 100-113 mm/yr (Stelfox and Egan 1995).

Other adfluvial populations exhibit growth rates within this range as Ratliff et al. (1996) reported average growth of 167 mm/year for juveniles in Lake Billy Chinook, Oregon, and Fraley and Shepard (1989) determined that average annual growth rates from age 3 to 8 ranged from 88 to 95 mm/year in Flathead Lake, Montana. Growth rates for fluvial populations reported in the literature are similar (i.e., 90 – 150 mm/yr) to those seen in adfluvial populations (Ratliff et al. 1996; Swanbereg 1997; Hvenegaard unpublished data). Average growth for resident bull trout from Moores Creek, Idaho was 33 mm/yr (Spangler 1997), which is considerable less than observed values for fluvial and adfluvial types.

The Funeral Creek stream-resident population is an example of an extremely small, slow growing, isolated population that inhabits a relatively low productivity stream. Average growth from age 3 until age 5 for Funeral Creek fish is about 35 to 40 mm/yr. Marginal growth during the first five years of life can hamper the ability of juveniles to contribute to the adult cohort. Growth exhibited by the Funeral Creek population, appears to be relatively slow, especially during juvenile life stages (0 to 5 years). The low productivity combined with few forage fish available for this population probably explains the cannibalistic behavior observed. Given that growth rates are significantly different between stream-resident, adfuvial, and fluvial life history types, it is critical for managers to document and understand the life history of bull trout populations in the north since each will differ in their susceptibility to disturbances (e.g., fishing, habitat disturbances). Furthermore, as latitude increases productivity generally deceases due to colder temperature and shorter growing seasons. Populations that occupy drainages further north will likely be more susceptible to perturbations than those found further south. The Funeral Creek population should be monitored carefully as subtle anthropogenic perturbations could significantly impact the success of this population.

Spawning in non-consecutive years is common for bull trout populations throughout the range (Goetz 1989; McPhail and Baxter 1996 and references therein; McCart 1997) and is probably an adaptation to marginal productivity throughout the year. Bull trout captured from all three watersheds provided evidence of alternate-year (or less often) spawning behavior as resting females and males were found from all life history types. Since both resting males and females were observed it is likely that alternate year spawning is the norm in this region in response to low productivity which is typical of drainages north of 60°. Furthermore, bull trout in the NWT may spawn every 2 – 3 years as a further adaptation to low productivity, which is common for other char species at higher latitudes (Jim Johnson, Fisheries Research Biologist Arctic Fish Ecology and Assessment Research Section, Fisheries and Oceans Canada, personal communication 2002). Evidence of consecutive-year spawning at lower latitudes (see Baxter 1995; Stelfox and Egan 1995; Ratliff et al. 1996) supports this argument and suggests that northern bull trout populations may not be as resilient to disturbances as their southern counterparts.

Microhabitat

Bull trout captured in Funeral Creek showed distinct preferences for specific types of microhabitats. Differences in habitat use were detected between juveniles and adults. Adults were generally found in deep, slow-water areas staying relatively close to cover, whereas juveniles were typically found in shallow, fast-water areas at or near the bottom in and around cover. Although juveniles were frequently found in fast-water habitat, such as riffles, most fish were occupying pocket pools or channel margins that allowed them to avoid being swept downstream and provided concealment from predators. Saffel and Scarneccia (1995) reported that juvenile abundance increased as the number of pocket pools increased throughout four streams in Idaho. In most situations juveniles were not observed until electronarcosis (i.e., fish temporarily paralyzed) had occurred during electrofishing. Remaining at or near the bottom near cover is common behaviour for juveniles, especially young-of-the-year, and is reported in other systems (Saffel and Scarneccia 1995; Baxter 1997; Goetz 1997; Sexauer and James 1997). Adults typically remained in deeper, low velocity areas with sufficient cover provided by large boulders. The difference in habitat use seen for juveniles and adults is probably a result of size difference, which corresponds to different feeding habits, physical capabilities, and energy requirements by each life stage.

The depth and velocities that were used by juvenile bull trout in Funeral Creek are consistent with those reported in other studies. Baxter (1997) reported that bull trout fry and juveniles prefer depths between 10 and 40 cm and water velocities that are between

0.05 and 0.30 m/s. Sexauer and James (1997) described depth use by juvenile bull trout at night ranging between 10 and 30 cm and water velocities ranging between 0.05 and 0.25 m/s. The substrate and cover types used by bull trout in Funeral Creek consisted primarily of cobble to boulder substrates and boulder as the most preferred cover. Sexauer and James (1997) showed that juvenile bull trout used a combination of cobble to boulder type substrate and primarily boulder for cover. Baxter (1997) reports high preference by juveniles for rootwads as primary cover followed by cobble and boulder substrates. These studies are consistent with the data from this study and support the hypothesis that spawning and rearing habitat in the NWT is similar to spawning and rearing habitat found in southern areas. However, it is important to consider that although some habitat requirements (e.g., cobble to boulder substrate) may be consistent across the range, other habitat characteristics that could be integral for population success may be site specific. For example, several studies have shown that woody debris is an important type of cover for bull trout in specific areas throughout the range (see Goetz 1997; Baxter 1997) and may play a critical role in creating and maintaining stream habitat (Hauer et al. 1999). In most streams surveyed in this study woody debris was not abundant, which is likely a result of the environment and suggests that fish in the north use other types of habitat for cover. Furthermore, populations at the southern and northern extent of the species' range may have adapted to survive in extreme environments and use unique habitat making them genetically distinct from central populations. If these populations are genetically distinct from more central populations it will be critical to determine their habitat preferences to implement appropriate conservation strategies for these unique populations.

Macrohabitat

All study streams have a large proportion of cobble to boulder-type substrate, which is required for redd construction and is frequently used by juveniles as cover (Baxter and McPhail 1996; Baxter 1997; Reiser et al. 1997; Sexauer and James 1997). Populations that occupy streams found at higher latitudes in Nahanni Butte and the Mackenzie Mountains occupy a narrow range of habitat niches compared to those found at lower latitudes due to less diverse cover and substrate availability. The abundance of bull trout does not appear to be related to substrate and cover diversity between the study streams. However, distribution along the length of each study stream may be affected by substrate and cover diversity. For example the Liard study stream, which is the most southern site surveyed, has the most diverse substrate and cover habitat available and fish were distributed throughout large reaches (i.e., 2 – 4 km) at this site. Conversely, the Funeral Creek, Drum Lake, and Keele River sites are further north, possess less diverse habitat and bull trout were found at specific sites in fewer smaller reaches (100 – 200 m). Bull trout found in the six study streams use a number of different habitat types based on availability (e.g., Liard study stream) but appear to have very specific spawning and rearing habitat requirements within each (e.g., Funeral Creek).

All streams surveyed possess a large proportion of suitable habitat according to reported values for the species throughout the range (Goetz 1989; Baxter and McPhail 1996 and references therein). The six study streams provide some form of habitat for bull trout given the presence of the species at these sites. The type of habitat use (e.g., spawning, feeding) at a particular site is a method for determining habitat quality, especially since bull trout are known to select very specific habitat for some life history activities such as spawning and rearing. Across the species range bull trout frequently travel long distances to spawning streams (Baxter and McPhail 1999) where redd superimposition commonly occurs in areas that appear to have a large proportion of suitable spawning habitat (Baxter and McPhail 1996). From a management perspective spawning sites should be defined as high quality habitat and compared throughout streams to detect differences and understand preferences in each region. The Funeral Creek site is the first spawning and rearing stream documented in the NWT and should be monitored carefully to ensure spawning success continues. The only other location where evidence of spawning was documented was at the Drum Lake site where two juvenile (ages 1 and 2) bull trout were captured. The particular stream that these fish were captured in appeared to be experiencing a low-water year as the water depth was extremely low in many areas and the upper reaches were dry. Based on comparisons to documented spawning streams for bull trout in the south (see Fairless et al. 1994; Reiser et al. 1997) many of the tributaries flowing into Drum Lake have suitable substrate (cobble to boulder), water temperatures (6 – 9° C), and depth for successful spawning.

The Liard study stream appears to provide habitat for spawning, rearing and feeding purposes as adults and younger fish were located throughout most of this stream. Other locations, such as Marengo and Jorgenson creeks have a large proportion of suitable spawning and rearing habitat, however bull trout occurred in extremely low densities (i.e., < 10). Observing bull trout in low densities throughout these streams should not preclude their importance as spawning and rearing tributaries if suitable habitat exists. Furthermore, bull trout may use specific sites in these tributaries for spawning and rearing purposes and limited fish sampling efforts may have prevented capture of juvenile life history stages at such sites.

Bull trout occur in high gradient streams with low velocity areas (e.g., pocket pools) and a large proportion of cobble to boulder type substrate throughout the range (Goetz 1989; Baxter and McPhail 1996). Studies suggest that groundwater upwelling is a critical habitat characteristic that spawning bull trout seek as it provides a stable incubation environment for eggs throughout the developmental process and increases spawning success (Baxter and McPhail 1999). It is apparent that these types of streams with similar or nearly identical habitat characteristics occur throughout the southern and central NWT. Funeral Creek, which is a known spawning tributary, possesses all of the habitat characteristics necessary for successful spawning: groundwater upwellings, sufficient flow, and cobble to boulder substrate (Baxter and McPhail 1996; Baxter and McPhail 1999). Evidence of spawning was not detected in other streams, however most have a large proportion of suitable spawning substrate available.

Management

The presence of bull trout populations throughout large geographic areas in the southern and central NWT raises several management concerns. The suggested current distribution of bull trout in the region extends as far north as Great Bear River (64° 55'N, 125° 39'W) and self-sustaining populations have been documented in the Sahtu Settlement Area centered at approximately 64° 30'N and 125° 00'W (Figs. 1 and 2; Reist et al. 2002). Bull trout populations occurring in this area must be considered as peripheral populations, that is populations separated from more central ones by spatial distance (Lesica and Allendorf 1995) as no further evidence demonstrates that the species range continues further north of this central area. Until evidence is available to suggest that these are not peripheral populations, managers in the Sahtu region should raise awareness for this species, as peripheral populations are typically small and more susceptible to extirpation due to random biotic or abiotic events. Despite the small size and fragile nature of these populations, they are expected to be genetically distinct from more central populations. Such genetic variability is important for the species as it increases their ability to evolve new adaptations (Lesica and Allendorf 1995). Peripheral populations may also experience different environmental conditions than more central populations, such as truncated growing seasons and lower overall productivity, and thus may also be considered as ecologically marginal populations (Lesica and Allendorf 1995). Managers in the north should recognize the potential genetic value of peripheral bull trout populations, as these populations likely possess the genetic diversity that allows the species to survive in marginal and changing environments.

Taylor et al. (1999) documented a high degree of molecular substructure for local bull trout populations from northwestern North America, which suggests that substantial limits on gene flow exist between geographical regions across the range. It is also postulated that Wisconsinan-glaciated areas in the NWT were recolonized by bull trout from the Bering or Nahanni refugia and may represent genetically distinct populations from those that recolonized from portions of the Columbia refugium (Haas and McPhail 2001). Given that relatively small, and in some situations partially isolated (i.e., spatially) bull trout populations occur throughout large watersheds in the central and southwestern NWT, it is plausible that local adaptation to environmental conditions has already occurred and may continue to occur. Conservation of peripheral populations, especially small isolated populations, will be critical for long-term persistence of the species in this area. Managers in the north should implement research programs to acquire information on the distribution, life history, and biology of these populations. Basic monitoring programs should also be implemented, as they will be critical for conservation of these small populations. Genetic research to detect similarities and differences between peripheral and more central populations should also be a high priority.

In order to conserve bull trout populations at the northern extent of the distribution it will be critical to develop and understand the true range of this species in the NWT. In the past bull trout and Dolly Varden have been incorrectly identified (Reist et al. 2002), as the two species have similar morphological features and are difficult to distinguish in the field, especially for non-experts. Clear, easily applied identification criteria have been developed to facilitate accurate in-field identification (Haas and McPhail 1991; Reist et al. 2002). These must be made available to, and applied by local fishers, sport fishers, consultants, and biologists from government agencies. The NWT sport-fishing guide has been recently updated (March 2002) to reflect the current known bull trout range, highlight morphological features used to identify the species, and provide conservative catch limits. Similar actions must be put into place for other aspects of fishery management (e.g., co-management boards). Future studies must address areas further north of Great Bear River, where bull trout and Dolly Varden char could hybridize or live in sympatry, as all of these situations have been documented in British Columbia (Haas and McPhail 1991; Baxter et al. 1997). If such occur, hybridization and areas of sympatry will further complicate in-field identification for chars found in this area.

The anticipated impact of climate change must also be considered for bull trout populations that occupy watersheds in the NWT. Given the predicted temperature changes associated with climate change and the narrow temperature preferences that bull trout exhibit (i.e., < 13 ° C for most of their lives), northern bull trout populations could be affected in three ways: 1) a change in availability of suitable thermal habitat, 2) northward colonization into rivers and lakes where Dolly Varden also occur with subsequent sympatry and hybridization, or 3) competition or predation from other freshwater species that may colonize northern freshwater systems (Reist 1994). Any of these events has the potential to negatively impact bull trout populations in the NWT. Preliminary habitat work shows that much suitable habitat is available for bull trout in the NWT, however, very few areas are used for spawning which implies that bull trout have very specific spawning and rearing habitat requirements. Bull trout spawning habitat requirements encompass a relatively narrow range of physical parameters, one being stable water temperatures usually associated with groundwater flow (Goetz 1989; McPhail and Baxter 1996; Baxter 1997; Baxter and McPhail 1999). Climate change could eliminate thermal refuges available to spawning bull trout forcing them into less desirable habitat where spawning success could be marginal. Northward movements by bull trout could create areas of sympatry (if they do not already occur) and hybridization with Dolly Varden. Competition between these two species could result in displacement by either species over time. Furthermore, competition, predation or a combination of both between bull trout and other freshwater fish species migrating north could change the fish fauna in the area by eliminating small, isolated bull trout populations that are unable to compete with other high level trophic predators.

The size and structure of bull trout populations in the NWT must also be considered in view of anticipated and existing industrial development that could affect populations in the NWT. Bull trout populations in the south have demonstrated an inherent vulnerability to a number of anthropogenic impacts that include fragmentation and isolation of populations as well as previously contiguous habitat by man-made barriers (e.g., dams, diversions); interaction with exotic species; habitat disturbance from industrial activities such as pipeline exploration and development, forestry, and mining; and overharvesting (McCart 1997; Baxter et al. 1999). Managers must understand and recognize that population size and structure typically coincide with different life history types, and each life history type has unique requirements. Furthermore, vulnerability to anthropogenic impacts and stochastic events will be significantly different between life history types.

Small isolated populations from headwater streams should be monitored carefully as these populations are likely at greatest risk of being imperiled and may be genetically distinct from larger central populations residing in mainstem rivers. The isolation of small resident populations (i.e., those with < 100 spawning adults), such as the one found in Funeral Creek, may lead to local extirpation as these populations rely on genetic exchange from larger regional populations to persist. Reiman and Allendorf (2001) suggest that approximately 100 spawning adults each year are required to minimize inbreeding in any population. Given that small apparently isolated bull trout populations are common throughout the species' range (see Adams 1994; Spangler 1997), it is probable that other factors are working to prevent inbreeding. Dunham and Rieman (1999) propose that bull trout found in most large watersheds are comprised of a number of small local populations or subpopulations, defined as meta-populations, that are connected to regional populations by migration and exchange of genetic material. Such meta-populations are a product of incomplete isolation and local adaptation and maintain genetic variability through straying from regional breeding populations. Straying strengthens local populations by refounding and maintaining levels of genetic diversity that are necessary for survival under constantly changing environments. This facilitates the replenishment and long-term persistence of such populations (Quinn et al. 1991; NRC 1996; Policansky and Magnuson 1998). The structure of bull trout populations found during this study (e.g., South Nahanni Watershed) and throughout the species' range is consistent with the meta-population concept (see Reiman and McIntyre 1993; Reiman and McIntyre 1995; McCart 1997; Rude and Stelfox 1997; Wissmar and Craig 1997; Baxter et al. 1999; Hvenegaard and Thera 2001).

Most streams surveyed are in remote locations and have not been disturbed by resource development. However, existing and anticipated resource development activities such as oil and gas, mining, and forestry could significantly impact bull trout habitat. Furthermore, it has been demonstrated in the south that different life history types and life stages within each type have different thresholds to habitat disturbances (McCart 1997; Wissmar and Craig 1997; Baxter et al. 1999). Bull trout populations that occupy streams in northern Canada could have a significantly lower tolerance to activities, which disturb habitat making them more vulnerable to subtle impacts on habitat. Until managers have a better understanding of distribution and abundance for bull trout populations in the NWT, all bull trout habitat should be monitored carefully to prevent unnecessary disturbances to potentially critical habitat. Once managers have a better understanding of the ecology of this species in the region, appropriate resources can be allocated to protecting those populations (i.e., small isolated populations) that are most susceptible to perturbations (e.g., overfishing, habitat disturbance).

One of the fundamental motives for initiating this study was to determine if northern bull trout populations and their habitat were similar to populations found in central and southern regions across the species' range. Preliminary results show that bull trout populations in the NWT use similar habitat as those found in the south. Given these findings, managers in the north could implement management plans designed around concepts developed for bull trout in the south. However, managers must be cautious using these extrapolation techniques because it is clear that bull trout populations found in the NWT appear to have very specific habitat requirements. Despite many studies on bull trout habitat use in the south, few managers have been able to detect subtle habitat requirements, especially in spawning life stages, for this species (McPhail and Baxter 1996). As was seen in Funeral Creek spawning habitat is selected based on several unknown habitat preferences as specific areas are used despite having access to other suitable spawning habitats. Managers must use a conservative approach when using information from the south to develop management plans for the species in the NWT and pay close attention to subtle differences that may be present for northern populations.

MANAGEMENT RECOMMENDATIONS

One of the objectives of this study was to develop guidelines to protect bull trout and their associated habitat to minimize future risks to this species. The main concern in this region is habitat disturbance caused by existing and anticipated resource development. However, partners who implemented this study do not feel that sufficient data, particularly habitat data, were obtained to develop specific guidelines to protect bull trout populations. Thus, general recommendations will be made that can be used by habitat managers for development proposals in and around bull trout habitat. The following factors should be considered upon review of development proposals planned within the NWT:

1) any streams that have suitable bull trout habitat should be non-destructively surveyed before development occurs to determine if bull trout occupy the stream. Suitable bull trout habitat will have the following characteristics: a) cobble to boulder-type substrate, b) summer water temperatures that do not exceed 15° C, c) minimum depth of 20 cm, and d) an abundance of pool and riffle habitat;
2) development plans be designed to avoid all streams that are known to contain bull trout (see Figure 2), especially streams that have been identified as likely spawning and rearing sites (e.g., Funeral Creek);
3) any development that must continue in areas where bull trout are known to occur should implement appropriate mitigation measures that will minimize sediment input into streams, maintain normal flow in the watercouse, minimize disturbance

to the streambed, and minimize thermal changes to the stream (i.e., avoid clear cutting to stream edge); and,

4) any development that must occur in and around bull trout habitat should not be conducted during the following periods a) spring (May 1 to June 31) because young-of-the year fish emerge from spawning redds and are susceptible to high mortality if disturbed, b) late summer (August 15 to 31) because adults begin movements into spawning streams, and, c) fall (September 1 to freeze up) because adults spawn during this period.

The factors above should be considered for any proposed resource development that will occur within the distribution of this species in the region. However, more specific guidelines must be developed as biological information becomes available for this species in the region. The purpose of guidelines is to prevent future declines for fish species, such as bull trout. However, few guidelines exist, especially for individual species that are found in the north. Furthermore, the use of one species as an environmental indicator species for ecosystem health is extremely valuable. Bull trout is an ideal candidate for this purpose because it has been demonstrated to be hypersensitive to environmental impacts. Since bull trout is known to be the most sensitive species to impacts in this region, I recommend that this species be used as an indicator for water quality and health of aquatic ecosystems is recommended. Managers could associate the presence of abundant, well-structured year classes from bull trout populations (i.e., healthy population) with excellent water quality and healthy aquatic systems. Conversely, year class losses, declines or a combination of both within populations would be an indication of marginal water quality reflecting an impact to the watershed. The use of bull trout in this capacity would allow managers to protect all aquatic organisms that co-exist with bull trout in the NWT. However, the use of bull trout as an indicator species would require a number of commitments from managers: 1) baseline data from unexploited populations, 2) sufficient resources (i.e., field staff, money), and, 3) consistent monitoring (e.g., annual population estimates). The foundation for the baseline data has been provided by this two-year study but future work is necessary to fill in data gaps. Much of the work during this study was done in co-operation with local co-management boards, consultants, and biologists from government agencies in the region. Similar strategies should be used to effectively implement future management and conservation programs for this species across the region.

SUMMARY

Since most bull trout populations found in the NWT occupy undisturbed streams in relatively pristine environments it will be critical to continue to acquire information pertaining to habitat use and distribution in the region. Spawning and rearing areas will be critical to identify in order to minimize impacts caused by resource development throughout the region. The unique opportunity to establish baseline data for undisturbed bull trout populations should not be squandered as such information will be the integral for sound management of this species in the region.

Future research on bull trout in the NWT should focus on population size and structure, specifically the conservation of genetic diversity at the population level and organization of populations (meta-populations) at various geographic scales. Considerable effort should be devoted to: 1) further documenting and understanding life history types and determining population sizes; 2) documenting habitat requirements for different life history types, life stages within each type, and understanding the relationships between them; and 3) determining the connectivity between different populations at genetic and spatial scales.

Future management initiatives should focus on the value of northern bull trout populations for the long-term persistence of the species. Managers must recognize that northern bull trout populations occupy many remote lakes and rivers and are likely the only ones that have not been exploited or impacted significantly by man throughout the range. Such environments likely allow populations to thrive, however without proper levels of conservation and protection these populations may be extirpated like many of those found at the southern extent of the distribution. Information on unexploited populations in the north can be used by managers in the south to design better recovery programs for populations that are at risk of extirpation. However, given the anticipated and existing level of resource development in the region, and the demonstrated hypersensitivity displayed by bull trout populations to disturbances, it will be critical to implement appropriate monitoring and protection programs. The development and design of effective management programs will be critical for appropriate protection of populations and their habitat during development in the region.

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