Distribution, Life History, and Habitat Use of Bull Trout (*Salvelinus confluentus*) in Mountain Streams of the Southern and Central Northwest Territories

By

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A Thesis Submitted
In Partial Fulfillment of the
Requirements of the Degree of

Master of Natural Resources Management

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DISTRIBUTION, LIFE HISTORY, AND HABITAT USE OF BULL TROUT *(Salvelinus confluentus)* IN MOUNTAIN STREAMS OF THE SOUTHERN AND CENTRAL NORTHWEST TERRITORIES

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ABSTRACT

During the past 30 years bull trout (*Salvelinus confluentus*) populations have declined in various watersheds across their range. The decline has been attributed to loss of habitat, over harvesting, habitat disturbance from resource development activities, and interaction with exotic species. The declining population trends observed over the past three decades suggest that this species is sensitive to impacts. In response to these declines, bull trout are listed as "Threatened" in the United States and "Sensitive" in Alberta, British Columbia, and the Yukon Territory. In the Northwest Territories bull trout are listed as "May Be at Risk" and are a candidate for a detailed risk assessment in the area.

The presence of bull trout has been confirmed in the Northwest Territories; however, the distribution and biology of populations in the region are poorly understood. In an effort to prevent declines seen in other areas, a research project was undertaken to determine the geographic distribution, life history (chapter 2), and habitat use (chapter 3) of bull trout in the southern and central Northwest Territories. Management recommendations were developed from this study (chapter 4) to guide management practices for populations in the region.

A total of 150 bull trout were captured from nine of the 18 tributaries surveyed in the Liard, South Nahanni, and Keele River drainages during the summer and fall of 2000 and 2001. The repeated capture of bull trout in tributaries of these drainages suggests that these fish are from self-sustaining populations rather than strays from watersheds south of the area. Growth patterns corresponding to adfluvial, fluvial, and stream-resident life histories were observed across the study area. Adults from all life history types spawned

in alternate years. In Funeral Creek, a tributary of the South Nahanni River, adults in spawning and post spawning condition as well as young-of-the-year and juvenile bull trout were captured. These findings indicate that this stream is used for spawning in the fall and provides rearing habitat for juveniles throughout the year. Although a total of 18 streams were surveyed across a large geographic area, bull trout were only caught in half of the tributaries and were far less abundant than other species such as Arctic grayling. These data imply that populations are probably small and widespread in the region, which is consistent for populations across the range.

Bull trout captured in the Northwest Territories preferred small, high-gradient streams with an abundance of cobble to boulder-type substrate. Water depths used by bull trout ranged from 24.9 cm to 37.9 cm and water velocities ranged from 0.21 m/s to 0.51 m/s. Small cobble was the dominant substrate and boulders were the dominant cover found in most streams across the study area. Habitat use differed for adults and juveniles in Funeral Creek. Juveniles preferred pocket pools in riffle type habitats and used small cobble and boulders for cover. Adults were found most frequently in pools and used large boulders for cover. Boulders were more abundant than small cobble in Funeral Creek.

The selection of small cobble rather than boulder-type substrate by juveniles in Funeral Creek suggests that habitat preferences are specific to different life stages and locations (i.e., streams). Although many of the habitat preferences found in the study area were similar to those seen in other areas, it is evident that bull trout in the north have specific habitat requirements that differ from other regions.

Research and monitoring programs must be implemented to learn more about this species in the area. Development activities can continue in the area if proper watershed

management practices are implemented. Recommendations for research and monitoring plans are outlined in the thesis. Mitigation strategies for activities that could compromise bull trout populations are also identified to guide habitat management in the future.

ACKNOWLEDGEMENTS

This thesis is dedicated to my niece Savannah Flynn, Kaeden Barbour-Pottie, and my beautiful wife Carly. Savannah and Kaeden continue to remind me how simple and special life is during challenging times which helps keep me grounded. Carly has provided extraordinary support and love throughout many challenging times. I have great admiration for her strength and determination, which continue to inspire me. Without her I would not be where I am today and I am forever grateful to her. I love them all very much.

Funding for this research was provided by Fisheries and Oceans Canada, Parks Canada Agency, the Habitat Stewardship Program for Species at Risk sponsored by the Government of Canada, Northern Scientific Training Program, Manitoba Wildlife Federation, and the University of Manitoba. In-kind support was provided by Parks Canada Agency, Government of the Northwest Territories, Department of Resources, Wildlife and Economic Development, Tulita Renewable Resource Council, Nahanni Butte Renewable Resource Council, Fort Liard Band, and the Natural Resources Institute.

I would like to begin by thanking my parents for always supporting me and encouraging me in all of my endeavors throughout my life. I would like to thank my mother for always being there to listen, understand, and provide advice when I needed it. I would like to thank my father for the countless hours of laughter, many great golf outings, and for always believing in me.

Thanks to my in-laws Rick and Cathy Sokolowski for always providing support, sharing their time at the cabin with me, and countless superb Sunday dinners.

I thank the following individuals for enduring many long hours of intense field work at times in less than hospitable conditions: L. Bataille, K. Bourassa, K. Cott, P. Cott, J. Demers, K. Ditz, K. Hickling, M. Low, A. Nande, G. Sibbeston, D. Tate, B. Vital, M. Vital, and S. Weaver.

Thanks to Pete Cott for providing valuable advice and assistance during my work. Thank you also for being a great friend, hunting companion, and the brother I never had.

Robert Bajno and Anna Elz are thanked for preparing and analyzing the samples for the genetic component of this project. Eric Taylor and Jim Reist are thanked for providing the resources to analyze the samples at the University of British Columbia and Freshwater Institute.

John Babaluk is thanked for providing the resources and lab space to age the fish. Thanks to Rick Wastle for ageing the fish and providing valuable technical advice and training on fish ageing.

Thanks to George Low for finding a way to get things done no matter how insurmountable the hurdles seemed. I will always be grateful for the support that you provided and for welcoming me into your home during long field seasons. We did find bull trout and I do have a thesis George!

Thanks to my advisor Jim Reist for convincing me to follow my dreams of becoming a fish biologist and the excellent advice and teaching along the way. Jim has always believed in me and challenged me throughout my thesis work. I will be a better biologist and person because of this.

Thank you to members of my academic committee: to Rick Baydack for his insight and expertise on field research; to Ken Stewart for his expertise and encyclopedia like knowledge on bull trout and fisheries research; and to Paul Blanchfield for his valuable comments on fish habitat research.

Finally, I would like to thank the Tulita Renewable Resource Council, Nahanni Butte Resource Council, and Fort Liard Band for allowing me to work on their sacred lands and experience God's country first hand. It is something that I will never forget.

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CHAPTER 1.

GENERAL INTRODUCTION

1.0 BACKGROUND

Chars (genus *Salvelinus*), trouts (genus *Salmo*), and salmon (genus *Oncoryhynchus*) belong to the family Salmonidae, which is the dominant family of fishes found in northern waters of North America, Europe, and Asia (Scott and Crossman 1973). The chars (*Salvelinus*) are a member of the Salmoninae sub-family, which is composed of freshwater and anadromous fishes. In North America five species of char are widely distributed: Arctic char (*Salvelinus alpinus*), brook trout (*S. fontinalis*), bull trout (*S. confluentus*), Dolly Varden (*S. malma*), and lake trout (*S. namayacush*). Brook trout is the only species not found in the northwestern portion of North America (Lee et al. 1980). Chars inhabit relatively cold rivers and lakes across their ranges. Although species co-occur in similar areas, each species has unique ecological preferences (Scott and Crossman 1973; Nelson and Paetz 1992).

The bull trout, *Salvelinus confluentus* (Suckley), is a native char from western North America (McPhail and Baxter 1996). Bull trout generally inhabit cold, clear, high-gradient mountain streams dominated by cobble to boulder-type substrate. However, some populations reside in lakes making only limited migrations to outlet streams to spawn in the fall (Goetz 1989; McPhail and Baxter 1996 and references therein). In watersheds across the range, bull trout do not typically occur in high densities (Ford et al. 1995; McPhail and Baxter 1996; Post and Johnston 2002). Bull trout are slow-growing fish that mature late and normally live to ten years but can reach ages in excess of 20 years (Bjornn 1961; Fraley and Shepard 1989). Adults are iteroparous and once sexual maturity is reached (age 5 to 6), spawn in the fall in consecutive (Baxter 1995; Stelfox and Egan 1995; Ratliff et al. 1996) or alternate years (Goetz 1989; McCart 1997). Alternate-year spawning is believed to be an adaptation to the low productivity environments in which some populations of these fish live. Young remain in natal streams for three to five years before they join adults in mainstem tributaries or lakes (Ford et al. 1995).

In the past bull trout populations occurred west of the continental divide throughout northern California (~ 41° N) and Nevada, central British Columbia, and north into the southern Yukon Territory (Fig. 1.1; Cavender 1978; Haas and McPhail 1991). East of the continental divide bull trout occurred throughout drainages in northern Montana and much of western Alberta (Fig. 1.1; Nelson and Paetz 1992; McPhail and Baxter 1996; Fitch 1997).

Over the past 30 years 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). A decline in local populations has also been observed in Alberta (McCart 1997) and several populations are at risk of being extirpated in Nevada, Washington, and British Columbia (Haas and McPhail 1991; McPhail and Baxter 1996). The current known distribution extends from the Oregon-California border (~ 42°N), throughout most of British Columbia, western Alberta, the southern Yukon Territory, and throughout interior drainages of the Northwest Territories (NWT) to about 64°N (Fig. 1.2; Haas and McPhail 1991; Reist et al. 2002).

Impacts identified as contributing to the decline of populations in the southern part of the range include fragmentation and isolation of populations and habitat by man-made structures; over-fishing; habitat disturbance from resource development activities such as mining, forestry; oil and gas development and exploration; interaction with exotic species; and, the cumulative effects of these activities (Ford 1995; McCart 1997; Baxter et al. 1999). Bull trout are considered to be hyper-sensitive to impacts and a good indicator of water quality and biotic integrity in aquatic ecosystems (Cross and Everest 1995; McPhail and Baxter 1996; McCart 1997).

Bull trout exhibit four different life history types: 1) fluvial, 2) adfluvial, 3) anadromous, and 4) stream-resident (Table 1.1). Fluvial, adfluvial, and anadromous life history types are considered migratory and the stream-resident type is considered to be non-migratory. The anadromous life history is the least studied and rarely found compared to fluvial and adfluvial populations (McPhail and Baxter 1996). The existence of the anadromous life history type within the species was uncertain until recent work in Washington confirmed the presence of several anadromous populations (Spalding 1997). Migratory bull trout spawn in headwater tributaries and juveniles remain in their natal streams for three to five years and then migrate, usually downstream, to larger mainstem rivers (fluvial) or lakes (adfluvial) to feed and overwinter (Fig. 1.3; McCart 1997). Migrations can be extensive and are known to exceed 300 km (Fraley and Shepard 1989; Burrows et al. 2001).

Figure. 1.1. Approximate historical distribution of bull trout (*Salvelinus confluentus*) in North America (after McPhail and Baxter 1996).

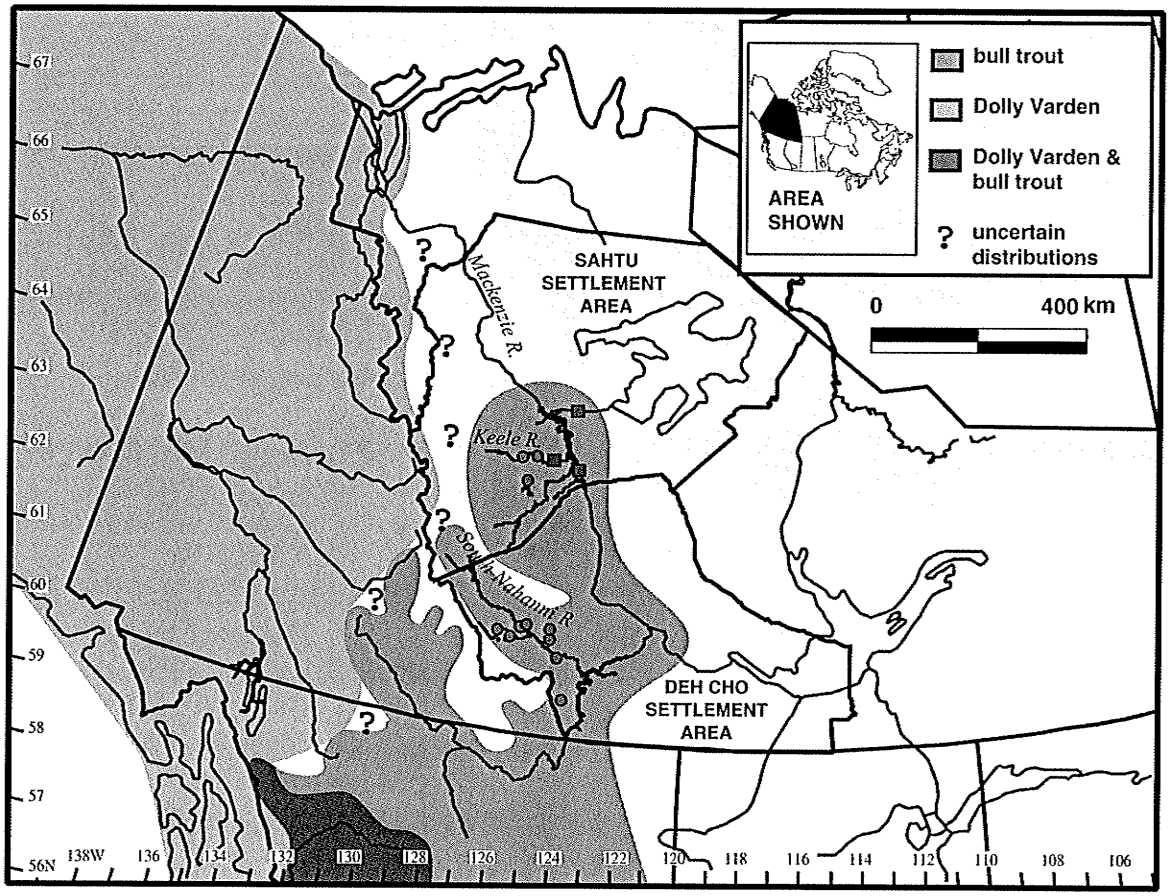

Figure 1.2. Distribution of bull trout and the related char, Dolly Varden, in Northwestern Canada showing locations of confirmed bull trout captures (● Mochnacz 2002; ■ Reist et al. 2002) in the Northwest Territories.

Non-migratory bull trout carry out their entire life cycle within one stream. Movements of non-migratory fish are limited (i.e., < 5 km) despite having access to larger more productive habitat (Fig. 1.3; McPhail and Baxter 1996; McCart 1997).

Fluvial bull trout carry out their entire life history in rivers and streams. Adults live in large rivers and major tributaries migrating to lower order (i.e., smaller) rivers and streams to spawn in the fall (Fig. 1.3). Juveniles usually live in small streams for the first three to five years of life before migrating to larger mainstream rivers and tributaries to feed (Fig. 1.4; Goetz 1989; Baxter and McPhail 1996). Adults typically live in deep pools with cover such as overhanging trees, woody debris, and large boulders. In drainages where fluvial populations occur, most fish occupy different habitats spread over large geographic areas. In northern drainages, such as the Liard and Peace River systems, fluvial adults are more widely dispersed than in the southern and central parts of the range. Northern populations do not appear to have a strong association with specific habitat types and are less constrained by temperature (Goetz 1989; Baxter and McPhail 1996). Fluvial bull trout are typically larger than non-migratory types and adults with fork lengths exceeding 900 mm have been caught in the Peace River system (R. L. & L. Environmental Services Ltd. 1994; Baxter 1995).

Adfluvial bull trout spawn either in tributary streams or inlets or outlets of lakes. Juveniles remain in spawning streams for three to five years and once they are sexually mature they move into lakes to join the adult population (Fig. 1.3). Adults forage in the littoral zone of lakes in the fall and spring, and move to deeper colder parts of lakes in the summer, probably to avoid warm surface water. Some adfluvial populations exhibit both diel and moon-phase patterns of vertical distribution associated with foraging (Baxter and McPhail 1996). Adfluvial bull trout often exhibit exceptional growth compared to stream-resident types. In large lakes and reservoirs in the upper Columbia, Fraser, and Peace systems it is not uncommon to observe adults exceeding 700 mm (fork length - FL) and weighing 9 kg (Bjornn 1961; Baxter and McPhail 1996). Adfluvial populations typically use small streams and rivers connected to lakes for spawning. Altering hydrological processes within these watersheds can impact the survival of such populations.

Table 1.1. Life history characteristics of bull trout populations found in watersheds across the range in North America.

Life history	Migratory/ non-migratory	Habitat			Adult size range (mm)
		Spawning	Rearing	Feeding	
Fluvial	Migratory	Lower order streams	Small streams	Large cold rivers and streams	400 - 900*
Adfluvial	Migratory	Inlets and outlets of lakes; small tributary streams	Lakes	Lakes	400 - 700*
Anadromous	Migratory	Lakes and rivers	Rivers and lakes	Ocean (summer), lakes and rivers	?
Stream-resident	Non-migratory	Small streams	Small cold headwater streams	Small cold headwater streams	200 - 400*

* May spawn in consecutive or alternate years.

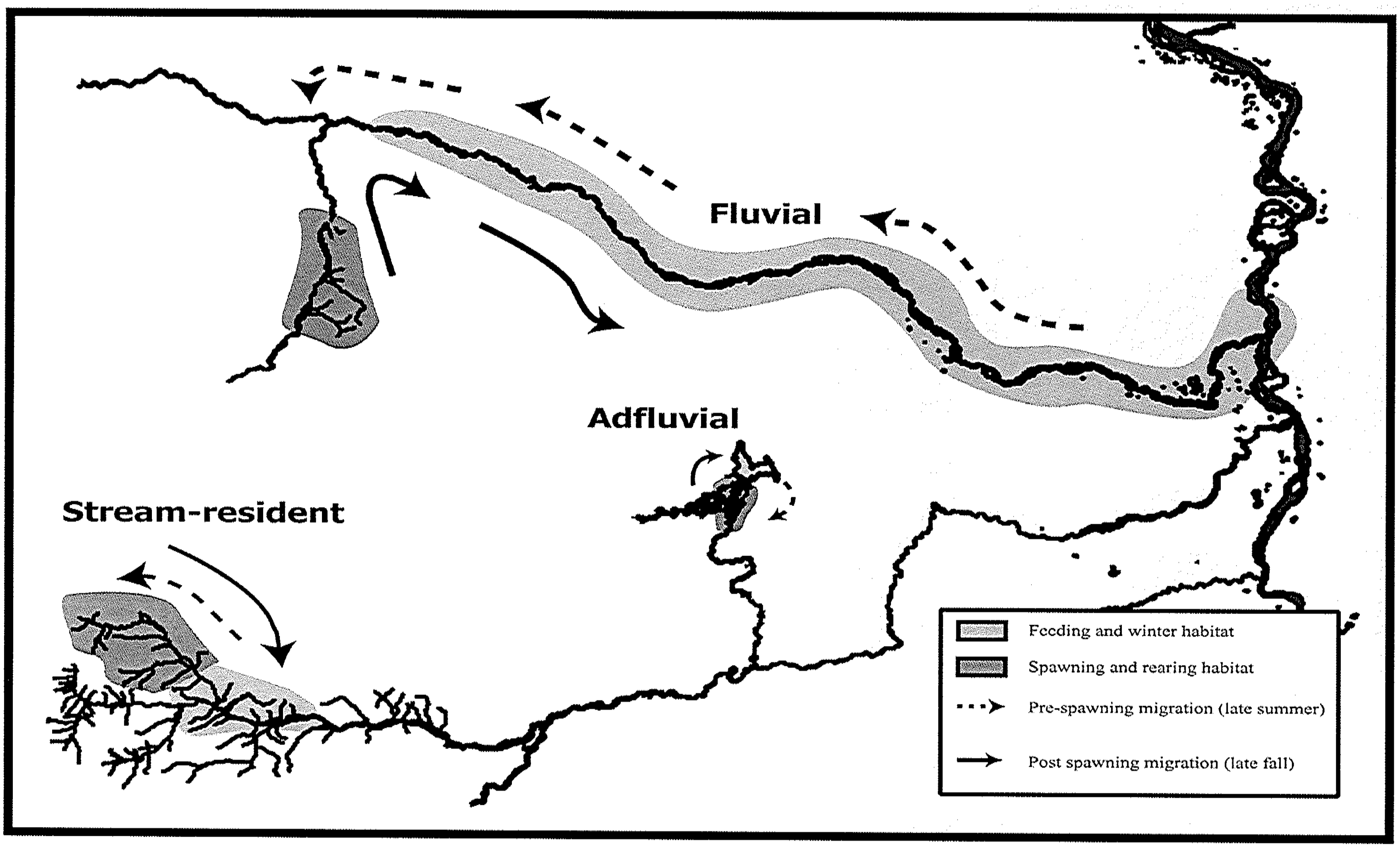

Figure 1.3. Generalized seasonal movements of adfluvial, fluvial, and stream-resident life history types for adult bull trout found in various drainages across the range.

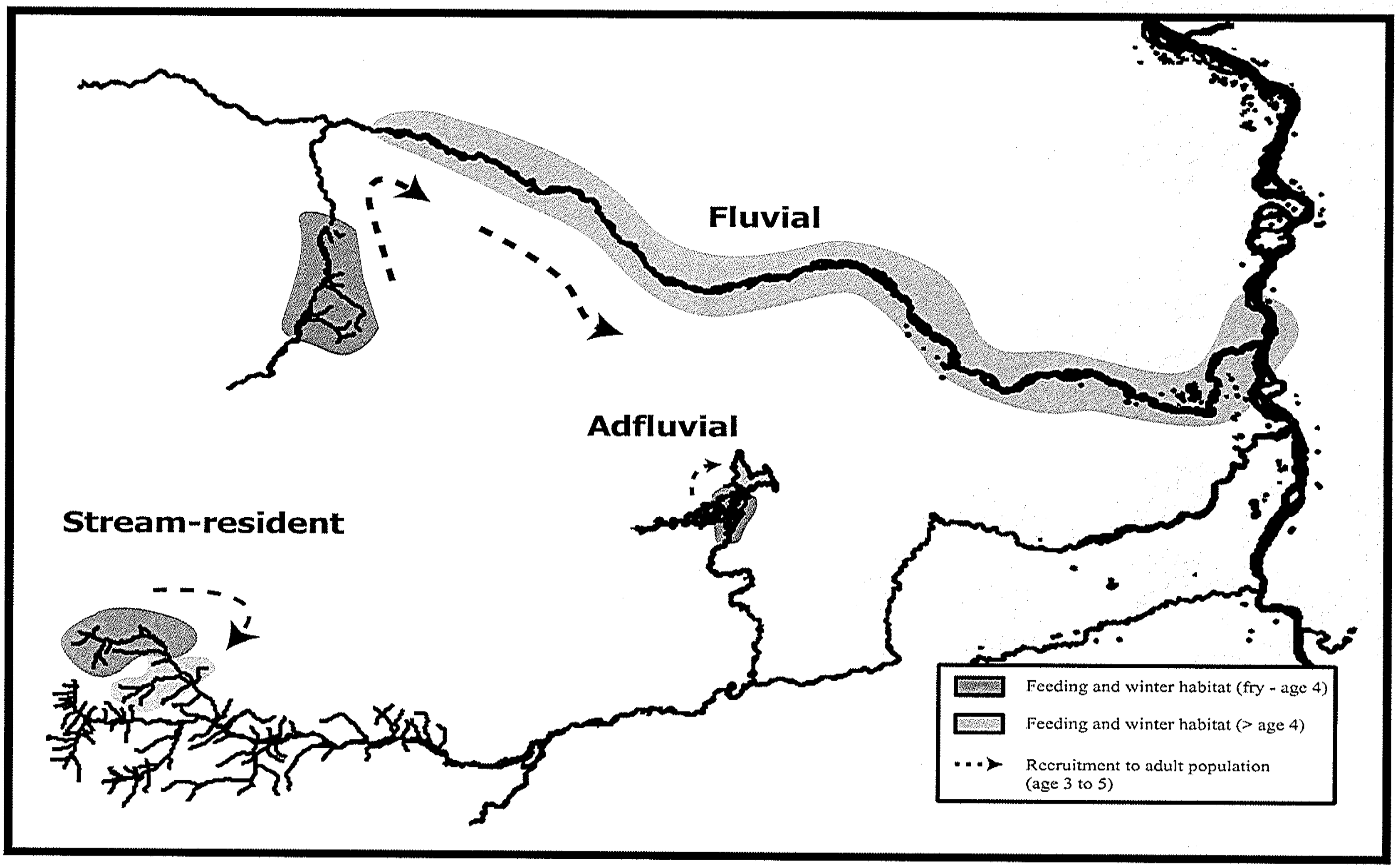

Figure 1.4. Generalized habitat use by young (fry to age 4) and juvenile (> age 4) bull trout for adfluvial, fluvial, and stream-resident life history types found in various systems across the range. Note that boundaries are not exact, and habitat use and movements may vary by age for different drainage systems.

Wissmar and Craig (1997) demonstrated that isolation of spawning bull trout populations in small mountain streams combined with channel de-watering decreased fish survival.

The non-migratory life history types can be further separated into resident and isolated types. Stream-resident bull trout spend most of their lives in localized regions of rivers and streams making limited migrations even if pathways are available to them (Fig. 1.3). Stream-resident populations are often associated with headwater streams in mountainous regions where cold water and velocity barriers are common. These streams are typically smaller and have higher gradients than those occupied by fluvial and adfluvial populations. (Baxter and McPhail 1996; McPhail and Baxter 1996; McCart 1997). Most fish from stream-resident populations exhibit slow growth rates and are small relative to other life history types. Stream-resident adults caught across the range rarely exceed fork lengths of 400 mm (Adams 1994; Boag and Hvenegaard 1997; Spangler 1997), which is small compared to adfluvial and fluvial adults which average fork lengths ranging from 400 to 600 mm, and often exceed 700 mm (Stelfox and Egan 1995; Swanberg 1997). Marginal growth and slow development in stream-resident bull trout populations are probably caused by limited resource availability (i.e., food) within these systems.

Isolated life history types typically occur as disjunct populations in streams above a barrier. Thus, at best they are restricted to one-way, downstream displacements by natural (e.g., falls, dry stream reaches, beaver dams) and man-made (e.g., dams, diversions) barriers (Goetz 1989; McCart 1997). Isolated life history types are not normally distinguished from stream-resident life history types in most of the literature. However, recognizing isolated types is important because these populations may be genetically distinct from stream-resident types. Further, isolated populations may have initially exhibited fluvial life history strategies but later changed as a result of human impacts (e.g., dams, diversions, improperly constructed winter roads etc.) or natural factors (e.g., beaver dams, mudslides etc.). Most fluvial populations in the Oregon and Washington regions are now adfluvial, isolated or stream-resident populations because of man-made barriers and habitat disturbance (Goetz 1989).

All life history types found within the species exhibit the same general life cycle. Redds are constructed at spawning sites in the fall (September to October) in cold, clean streams. Eggs are deposited in areas with sufficient flow to provide oxygen during incubation (Ford et al. 1995). Once eggs are laid they remain covered in redds for 35 to 120 days, and typically hatch during late winter (McPhail and Baxter 1996). Alevins remain within the substrate until three weeks after the yolk sac is absorbed. Juveniles emerge in the spring but stay at or near the substrate until they are able to move to low velocity areas, such as pocket pools and channel margins. Juveniles remain in their natal streams for the first three to five years of life. Once juveniles become sexually mature, typically in their fourth or fifth growing season, they join the adult population and become piscivorous (Goetz 1989; McPhail and Baxter 1996).

Like most salmonids, bull trout have a relatively narrow range of habitat requirements (Baxter and McPhail 1996). Young-of-the-year emerge from redds and typically stay close to the bottom of low velocity side channels and backwater areas. After emergence fry are generally associated with loose cobble and use interstitial habitat for cover (Baxter and McPhail 1996; Baxter 1997b). Once fry are large enough to forage they prefer shallow (range 0 – 20 cm), low velocity areas (range 0.0 – 0.3 m/s) with substrate ranging from 6 mm to 250 mm in diameter. Fry prefer to remain close to large substrate, which provides cover (Baxter 1997b; Goetz 1997). Juveniles typically inhabit deeper areas (range 20 – 60 cm) than fry but also prefer to remain in low velocity areas ranging from 0.0 to 0.3 m/s. Juvenile bull trout prefer larger cover, such as cobble to boulder-type substrate (range 125 – 256 mm), large woody debris, and frequently inhabit cavities, such as undercut banks (Baxter and McPhail 1996; Baxter 1997b).

Adults spawn in cold (~9°C), high gradient, headwater streams. Spawning migrations start as water temperatures decline during late summer and early fall, although it is unclear if temperature is the only environmental variable that influences such movements (Swanberg 1997). Fraley and Shepard (1989) suggest that photoperiod and stream flow also influence spawning migrations. Spawning usually occurs sometime between late August and October with little variation in actual spawning time related to latitudinal variation. Spawning sites are typically found in shallow areas at depths ranging between 20 and 60 cm. Redds are generally constructed at sites, which have water velocities ranging from 0.1 to 0.4 m/s and predominantly cobble (64 – 125 mm) sized substrate (Goetz 1989; Ford et al. 1995; Baxter and McPhail 1996). However, bull trout will spawn in substrate ranging from 2 mm to 130 mm. Bull trout redds are not necessarily located adjacent to or below cover, but spawning usually takes place in close proximity to some form of cover. Overhead vegetation, woody debris, and cavities (e.g., undercut bank) are the most typical cover associated with spawning habitat (Goetz 1989; Baxter and McPhail 1996; James and Sexauer 1997).

Of all salmonid species, bull trout may have the most specific spawning and rearing habitat requirements (Baxter and McPhail 1996). Many bull trout populations have relatively concentrated redd distributions despite having access to a large proportion of suitable spawning habitat (Boag and Hvenegaard 1997; Baxter 1997a; Baxter et al. 1999), which is indicative of specific habitat preferences. In some situations this is so pronounced that a high degree of redd superimposition occurs (Fairless et al. 1994; Baxter and McPhail 1996; Baxter 1997a). Redd superimposition is typically observed in areas where there is discharging groundwater which has been demonstrated to increase spawning success, especially for early development stages (Boag and Hvenegaard 1997; Baxter and McPhail 1999). However, it is not clear if groundwater is the only variable which influences redd superimposition. It is apparent that bull trout as well as other char frequently spawn in areas where there is discharging groundwater (e.g., Arctic char, *Salvelinus alpinus*, Cunjak et al. 1986; brook trout, *Salvelinus fontinalis*, Curry and Noakes 1995; Blanchfield and Ridgeway 1996, 1997).

1.1. ISSUE STATEMENT

Continual downward trends in bull trout populations have occurred in various watersheds across the range during the last 30 years (Goetz 1989; McPhail and Baxter 1996; Baxter et al. 1999). Aggressive research and management programs have been implemented in response to the decline of local populations in many watersheds from the southern and central parts of this species' range. Most research has focused on describing bull trout habitat with the intent of protecting it, especially in areas where resource development is prevalent. In Alberta, research, education and management programs have been implemented, and most populations are reported to have stabilized or are increasing compared to previous rates of decline during the last decade (Post and Johnston 1999). However, in the northwestern United States most populations are still in decline and only a small number are stable or increasing (Lohr et al. 2001). In British Columbia most populations are stable, but the species is considered to be highly susceptible to declines based on their sensitivity to impacts on habitat (Pollard and Down 2001).

In response to population trends across the range during the past decade, bull trout were listed as "Threatened" within the contiguous United States (U. S. Fish and Wildlife Service 1999) and "Sensitive" in Alberta, British Columbia, and the Yukon Territory (Canadian Endangered Species Conservation Council 2001). In the NWT bull trout have been given the designation of "May Be at Risk" and are a candidate for a detailed assessment in the region (Government of the Northwest Territories, Department of Resources, Wildlife and Economic Development 2000; Canadian Endangered Species Conservation Council 2001).

Recent work has confirmed that several self-sustaining bull trout populations occur well north of the 60th parallel and could be more widespread than first thought in the NWT (Reist et al. 2002). The confirmation of several bull trout populations in the central NWT raises several management concerns. The geographical distribution and biology of bull trout populations that occur in the NWT are poorly understood. Furthermore, Dolly Varden, which are closely related to bull trout, both taxonomically and ecologically, also occur in the NWT. The lack of clear, easily applied criteria for identification has resulted in misidentification of these two char species in the region (Reist et al. 2002).

Bull trout populations found in the central and southern portion of the range have been well studied (Haas and McPhail 1991; Adams 1994; Rieman and McIntyre 1995;

Baxter and McPhail 1996; Ratliff et al. 1996; Watson and Hillman 1997; Baxter et al. 1999; Baxter and McPhail 1999). However, few studies have examined bull trout populations in relatively pristine environments of remote areas where fishing pressure is light or absent. Most bull trout populations discovered to date in the NWT occur in such areas, which are favorable for the long-term persistence of healthy widespread populations (Reist et al. 2002). Thus, research will be required to gain a better understanding of the actual geographical distribution, population size, life history, and habitat use of populations in the NWT. The urgency of such research is heightened by existing and anticipated resource development along the Mackenzie River Valley, which could adversely affect bull trout populations.

1.2. OBJECTIVES

This study was conducted to examine the distribution, life history, and habitat use of bull trout populations found in the southern and central NWT. Specific objectives were to:

1. determine the distribution of bull trout in the study area,
2. examine which of the life history patterns of bull trout are exhibited by populations found in the study area,
3. describe biological traits of populations from different streams in the study area,
4. describe habitat use and availability for known bull trout populations in the region,
5. compare these bull trout populations and their habitat to bull trout populations found south of 60° latitude, and

6. provide management recommendations for bull trout populations in the region.

1.3. STUDY AREA

This study was conducted in the Franklin Range, Nahanni Range, and Mackenzie Mountains of the southern and central NWT (Locations 1, 2, and 3 on Fig. 1.5). The study site located in the Franklin Mountains is approximately 50 km northwest of Fort Liard (Location 1 on Fig. 1.5). The unnamed stream studied in this region is a 1st order stream, according to the Strahler system (Gallagher 1999). This stream flows east into the Kotaneelee River, which is a tributary of the Liard River, and has headwaters that originate in the Franklin Mountains at an approximate elevation of 800 m. Both the Liard and Kotaneelee are turbid rivers that do not completely freeze to the bottom in the winter. In the Nahanni Butte area nine streams were examined in the lower South Nahanni watershed (Location 2 on Fig. 1.5). The central study area is about 100 km northwest of Nahanni Butte. Funeral and Galena creeks are small (i.e., 3 to 5 m wide) high-gradient mountain streams. Specific sites in Funeral Creek do not completely freeze to the bottom in winter due to depth and likely discharging groundwater, which is common in the area (Chuck Blight, Nahanni National Park Superintendent, pers. comm. 2002). Both streams are tributaries of Prairie Creek, which is a 2nd order tributary that flows southeast into the South Nahanni River. Marengo Creek is a tributary of the South Nahanni River approximately 10 river kilometers downstream of Virginia Falls. At a height of 90 m, Virginia Falls is a barrier to fish passage. The South Nahanni River is a large

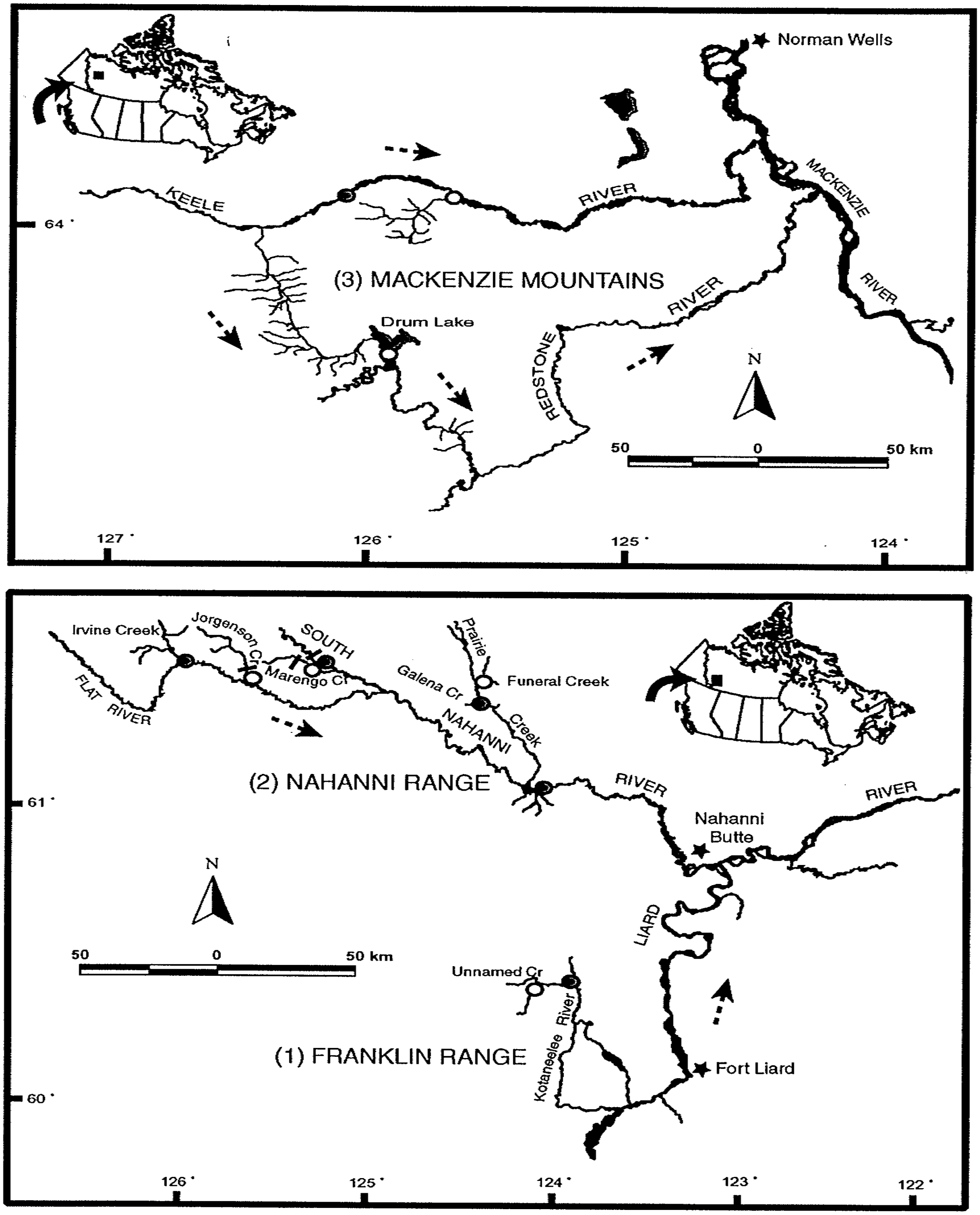

Figure 1.5. Study sites showing habitat (○) sampling sites and locations where bull trout were captured (● & ○) in the central (top) and southern (bottom) Northwest Territories. Note that dashed arrows show flow direction, solid bars (—) represent impassable falls, and only partial drainages are shown for clarity.

(i.e., 20 to 30 m wide), relatively turbid river that is influenced by precipitation throughout the year with peak high water periods in the early spring and low water in the late fall. Jorgenson and Irvine creeks are clear, high-gradient streams that flow into the Flat River. Jorgenson and Marengo creeks have small falls (i.e., 10 to 20 m) in the lower reaches that prevent fish passage.

Two study areas were examined in the Mackenzie Mountains, which were part of the Keele River and Drum Lake systems (Location 3 on Fig. 1.5). A total of seven tributaries were sampled in the Keele River watershed during the study. The central study area is approximately 125 km southwest of Norman Wells. The unnamed stream studied in this area flows northeast into the Keele River at an approximate elevation of 600 m. This 1st order stream is located approximately 114 river kilometers upstream of the Keele and Mackenzie River confluence. Depth and groundwater flow prevent this stream from completely freezing to the bottom in most areas during the winter season. The Keele River is a large (i.e., 30 to 50 m wide) braided river that does not completely freeze to the bottom in the winter. The water level and turbidity is influenced by precipitation throughout the open-water season.

Drum Lake (local name = Wrigley Lake) is a clear, cold, deep (maximum depth >50 m) lake (Fig. 1.5). The most abundant sport fish found in Drum Lake are lake trout, Arctic grayling (*Thymallus arcticus*), and bull trout (Hanks 1996). The lake receives water from the Keele River system at the inlet, which is located at the northwest end of the lake. The outlet tributary located at the south end of the lake flows southeast where it joins the Redstone River.

The tributary streams that flow into mainstem tributaries in the three study areas have headwaters that originate from snowmelt and groundwater upwellings. Most are cold, clear, high-gradient mountain streams that have marginal productivity compared to similar streams found at more southern latitudes, due to short growing seasons and cooler temperatures during the year. The riparian vegetation found along these streams is dependent upon slope, aspect, and elevation. Species' diversity and abundance typically decreases as latitude and elevation increase in this region.

In the Fort Liard area the predominant vegetation zone is boreal forest. Streamside vegetation is composed of black spruce (*Picea mariana*), white spruce (*Picea glauca*), balsam poplar (*Populus balsamifera*), jack pine (*Pinus banksiana*), trembling aspen (*Populus tremuloides*), and white birch (*Betula papyrifera*). The understory in this area is rich in mid-summer with shrubs and willows providing excellent bank stabilization. High flow in the spring creates logjams and rootwads from large woody debris, which provides ample in-stream cover for fish throughout the year. Although the growing season is short, insect hatches are numerous throughout the summer and terrestrial insects are abundant.

In the Nahanni area the distribution of vegetation types is closely related to elevation and latitude. The vegetation in the area encompasses a number of vegetation zones ranging from boreal forests in the lowlands to alpine tundra at higher elevations. The dominant tree species found in this area are white and black spruce, lodgepole pine (*Pinus contorta*), jack pine (*Pinus banksiana*), subalpine fir (*Abies lasiocarpa*), larch (*Larix lancina*), balsam poplar, trembling aspen, and white birch. Approximately 85 percent of the land is vegetated and the other 15 percent is higher elevated areas, which consist of snow, ice, bare soils and exposed rock (Parks 1984).

The Mackenzie Mountain area can be classified as a subalpine to alpine tundra vegetation zone, which is dominated by white and black spruce, trembling aspen, and white birch. At higher elevations bare soils and exposed bedrock are found in vegetated areas while a permanent cover of ice and snow characterize the highest slopes. Most of the vegetated area that supports forest stands or non-forest plant communities exhibits marginal growth compared to more southern latitudes as a result of continuous and discontinuous permafrost throughout the region.

The climate throughout the region is classified as being cold continental and exhibits wide annual temperature and precipitation variations. Winters are cold and long, while summers are short but can be extremely warm (i.e., 25 to 30° C), especially in southern areas at lower elevations. Most lakes remain ice covered for at least eight months of the year, and small rivers and streams freeze completely to the bottom in the winter unless sufficient depth (i.e., ~ 1.5 to 2 m), flow, and (or) discharging groundwater are present. The water level and turbidity of rivers and streams throughout the region are influenced by seasonal precipitation.

Bull trout and associated species in the southern and central NWT can be interpreted as having recolonized the Wisconsinan-glaciated southern and central NWT independently from the Bering, Mississipian, and (or) Nahanni refugia (Haas and McPhail 2001a). Lake trout, a related char found throughout the same regions in the NWT, are also thought to be from the Nahanni refugium based on their absence from much of the Yukon River drainage (Wilson and Hebert 1998). The complex glacial history and postglacial drainage connections in the NWT suggest that either hypothesis is possible.

1.4. METHODS

Bull trout distribution, life history, and habitat use were documented in the three study areas during the summer and fall of 2000 and 2001 (Locations 1, 2 and 3 on Fig. 1.5). Biological information was obtained from each bull trout captured during the study (Methods, Chapter 2). Bull trout were captured by angling, gillnetting, and electrofishing. Suitable capture methods were employed based on local conditions (i.e., water level, depth, velocity) and logistical constraints. Voucher specimens were acquired from each study stream where char, identified in the field as bull trout, were captured. Meristic and morphometric measurements were taken from all voucher specimens to determine if these fish were bull trout or the closely related Dolly Varden (Methods, Appendix 1). The voucher specimens collected during the study were archived at the Department of Fisheries and Oceans, Freshwater Institute in Winnipeg.

Habitat data were obtained from six streams where bull trout were found during the study (Fig. 1.5). Physical habitat measurements, which included depth, velocity, temperature, cover, and substrate, were taken to determine macrohabitat, which are the general features of a stream (Goetz 1997). Microhabitat measurements, which are physical habitat attributes for fish at specific locations within a stream (Goetz 1997), were documented in one stream. Examining habitat use at the macro and micro-habitat level provided information at regional and local (i.e., site specific) scales in the study region.

1.5. ORGANIZATION

This thesis is presented in 4 chapters. Chapter 2 focuses on distribution and biology and chapter 3 examines habitat use and availability for bull trout in the region. Chapter 4 contains management recommendations for bull trout in the NWT based on findings from the research. All chapters are written as self-contained papers in the style of the North American Journal of Fisheries Management. Appendix 1 is a compilation of the raw data from the study. It is written in a data report style as outlined by the Canadian Data Report series of Fisheries and Aquatic Sciences. Appendix 2 provides further detail on identification methods and results for char captured during the study.

CHAPTER 2.

DISTRIBUTION AND BIOLOGY OF BULL TROUT, *SALVELINUS CONFLUENTUS* (SUCKLEY) POPULATIONS IN THE SOUTHERN AND CENTRAL NORTHWEST TERRITORIES

Abstract: The distribution and biology of bull trout (*Salvelinus confluentus*) populations in the southern and central Northwest Territories were examined in the summer and fall of 2000 and 2001. A total of 18 tributaries throughout three watersheds were electrofished, angled, and gillnetted during the two-year study. Voucher specimens of char captured from each sampling location were kept for meristic and morphometric identification. A linear discriminant function (LDF), demonstrated to be 100% effective in distinguishing Dolly Varden from bull trout, was used in conjunction with morphometric and genetic analyses to determine the identity of char captured. A total of 150 bull trout were captured from nine tributaries in the Liard, South Nahanni, and Keele River drainages. Three types of growth patterns were observed which correspond to adfluvial, fluvial, and stream-resident life history types. Adults from all life history types spawned in alternate years. Young-of-the-year and juveniles were captured in Funeral Creek, which provides evidence that this stream was used for spawning in previous years. Most populations found throughout the region are small but use a number of different habitats over large geographical areas within each watershed. Results from this study show that bull trout are more widely distributed in this region than previously thought.

2.0 INTRODUCTION

Understanding the geographic distribution and biology of fish species is essential for effective management. Most fish species found in Canada, which are harvested in commercial, domestic and sport fisheries, are well studied (Scott and Crossman 1973). However, little information is available for fish species that are not important food fish and occur in remote areas of northern Canada. Many of the fish species found in these areas are at the northern extent of their range and considered peripheral populations. Peripheral populations are separated spatially from central ones, and are expected to be genetically distinct from them (Lesica and Allendorf 1995). Increased concern with environmental issues, such as oil and gas development in the Northwest Territories (NWT), suggests a need for accurate knowledge of fish distributions and biology in the region.

Four species of the char are found in the northwestern portion of North America: Arctic char (*Salvelinus alpinus*), bull trout (*S. confluentus*), Dolly Varden (*S. malma*), and lake trout (*S. namayacush*) (Lee et al. 1980; Scott and Crossman 1973; Nelson and Paetz 1992). Although these four char species co-occur in many of the same drainages, their biology and distributions are generally different. Lake trout typically inhabit large, deep lakes across North America (Lee et al. 1980). Arctic char are primarily a northern species found mainly in inshore marine waters, and coastal lakes, and rivers of Arctic North America. However, isolated Arctic char populations do occur in southeastern regions of North America (Scott and Crossman 1973; Lee et al. 1980). Dolly Varden are generally a riverine species found in coastal and inland rivers in western North America (Lee et al. 1980).

Bull trout is a char native to western North America, which typically occurs in cold, clear, high-gradient mountain streams. However, adfluvial (i.e., lake-dwelling) populations inhabit cold deep lakes for much of the year and anadromous populations, which are rare, occur in coastal and inland rivers (Baxter and McPhail 1996). The species' distribution originally extended west of the continental divide from the McCloud River, California (~ 41° N) north to the headwaters of the Yukon Territory (Cavender 1978; Haas and McPhail 1991). However, anthropogenic impacts which include overharvesting, fragmentation of habitat, habitat loss caused by industrial development, and interaction with exotic species have lead to the decline of populations in various watersheds across the range (Ford et al. 1995; McCart 1997; Baxter et al. 1999). The species' present known distribution extends from the northwestern United States (~42°N) throughout interior drainages of British Columbia, western Alberta, and the southern Yukon Territory, north through the Mackenzie River valley, NWT to about 64°N (Fig. 1.2; Haas and McPhail 1991; Reist et al. 2001; Reist et al. 2002).

Recent work confirmed that several self-sustaining bull trout populations occur well north (~ 500 km) of the previous northernmost known distribution (Prairie Creek, Liard River drainage), which was centered at 61°N, 125°W (Fig. 1.2; Reist et al. 2001; Reist et al. 2002). However, the closely related Dolly Varden also occur in NWT, and the similar appearance and lack of clear, easily applied identification criteria make it difficult, especially for non-experts to identify these two chars correctly. An angler study in Montana confirmed that most non-experts have difficulty correctly identifying bull trout and distinguishing them from other salmonids (Schmetterling and Long 1999). Such confusion between bull trout and Dolly Varden has lead to a poor understanding of the actual distributions and biology of these two chars in the NWT (Reist et al. 2002).

The objectives of this work are threefold: 1) determine the present distribution of bull trout in the region; 2) describe the life history and biology of bull trout populations found in the study area, and 3) discuss management issues that pertain to bull trout populations from the NWT.

2.1. METHODS

Fish sampling was conducted in three watersheds (Keele, South Nahanni, Liard) throughout the southwestern and central Mackenzie Valley, NWT in the summer and fall of 2000 and 2001 (Locations 1, 2, and 3 on Fig. 2.1). Large rivers (Keele, South Nahanni, Flat) and associated tributaries were sampled at various locations accessible only by boat or helicopter. A total of 18 sites were surveyed during the study across three watersheds from the communitry of Fort Liard approximately 500 km north to Norman Wells (Fig. 2.1). One river was surveyed in the Liard watershed, nine in the South Nahanni watershed, seven in the Keele River watershed, and one in the Carcajou watershed.

Sampling locations were selected based on previous literature reports and local knowledge of char captured in the area, as well as the presence of suitable habitat. 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, Type VII POW backpack electroshocker. Unwadable areas were angled using barbless hooks. At each sampling location co-ordinates were recorded using an Etrex handheld global positioning system

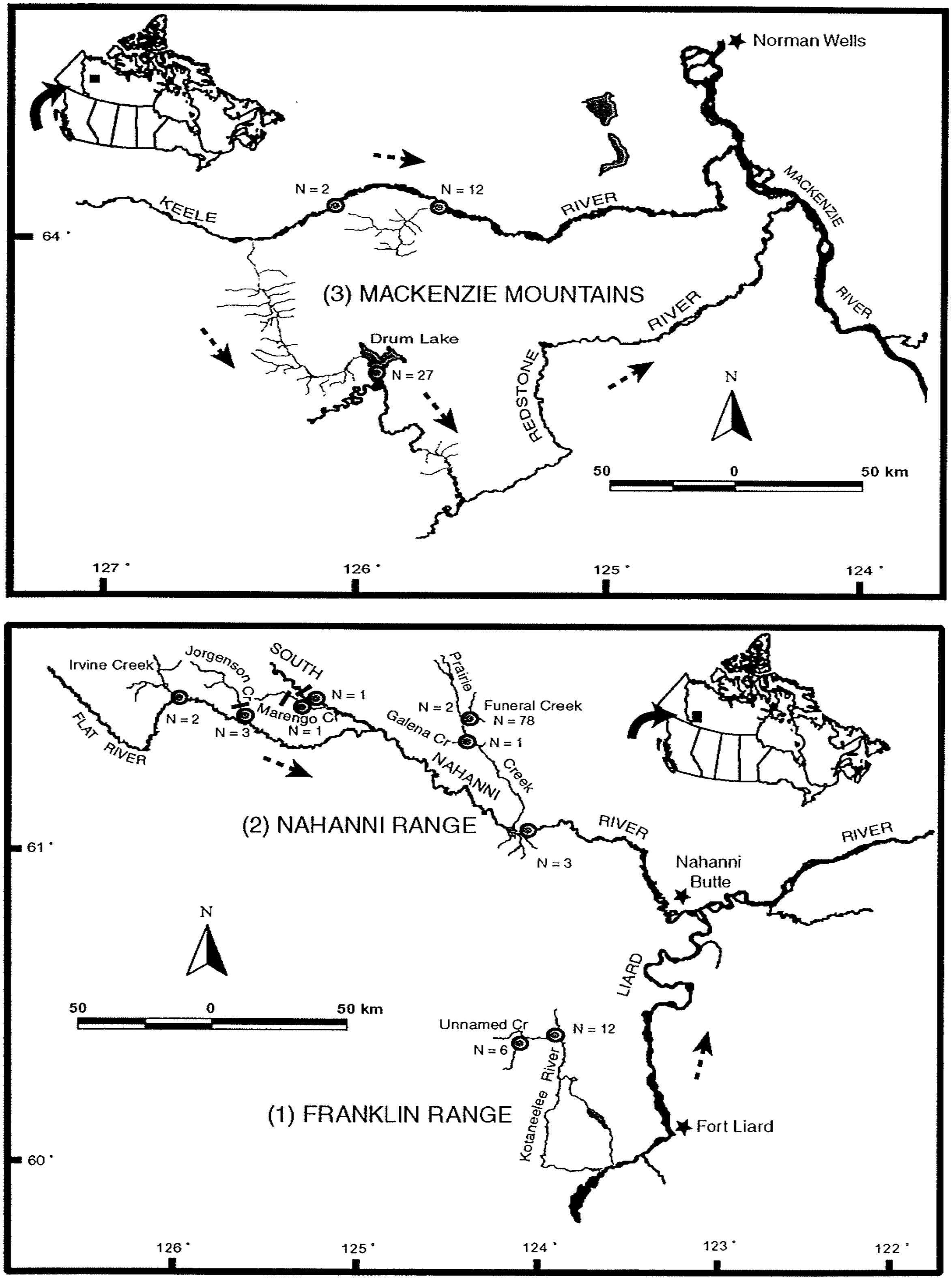

Figure 2.1. Study sites showing locations where bull trout were captured (●) in the central (top) and southern (bottom) Northwest Territories. Note that dashed arrows show flow direction, solid bars (—) represent impassable falls, and only partial drainages are shown for clarity.

(GPS). The GPS provided accuracy up to five meters; however, on average most co-ordinates were accurate within 5 to 10 m.

Population estimates were completed at four randomly selected reaches (~200 m each) in Funeral Creek (61° 36' N, 124° 48'W) using the Zippin three-removal method (Zippin 1958; Appendix 1). Two separate reaches (200 m) with homogeneous habitat were sampled in the late summer (August) and two reaches (100 m) were sampled in the fall (September). Funeral Creek was selected because it was the only site where bull trout were caught consistently, and was safely wadable during the sampling period. Each reach was blocked at the lower and upper end to prevent fish from moving into and out of the sampling area. A two-person crew completed three consecutive upstream electrofishing passes in the stream. After each electrofishing pass the reach was left undisturbed for 20 minutes. Each time a char was captured it was placed in a tub of ambient river water and transported to a holding bag located downstream of the sampling reach. The number of bull trout captured during each pass was entered into the "Microfish" program. This program calculates maximum-likelihood population estimates with corresponding confidence intervals based on the number of fish captured on each electrofishing pass (Van Deventer and Platts 1989). Fish densities (i.e., fish/100m^2) were calculated for each reach sampled.

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 state were determined where possible. All bull trout > 200 mm were fitted with an individually numbered Floy-tag inserted at the base of the dorsal fin between the posterior basal pterygiophores. A portion of the adipose fin was removed for genetic analyses and to evaluate tag loss. The first fin ray was removed from the left pelvic fin for age determination.

Voucher specimens were kept from each sampling area for confirmation of species' identity and to obtain biological information (i.e., sex, maturity, age). These specimens were archived at the Department of Fisheries and Oceans, Freshwater Institute in Winnipeg. Char retained from field sampling were compared to known bull trout at Fisheries and Oceans, Canada, Freshwater Institute in Winnipeg. A linear discriminant function (LDF) proven to be 100% effective in distinguishing Dolly Varden from bull trout (Haas and McPhail 1991) was used to confirm species identity for all char captured during the study. The LDF was developed and tested on 1580 char from 310 sites representing all life stages. The majority of char used to test the LDF were from the southern and central range; however, five char captured in Prairie Creek, NWT (~61°N) were included in the study (Haas and McPhail 1991). The effectiveness of the LDF has been reassessed and supported by numerous data since it was developed (Baxter et al. 1997; Haas and McPhail 2001b; Reist et al. 2002; Gordon Haas, Professor, University of Alaska Fairbanks, School of Fisheries and Oceans Sciences, Fairbanks Alaska, pers. comm. 2002). LDF scores less than zero are Dolly Varden and those higher than zero are bull trout. Intermediate scores which are at or near zero (range –0.25 to + 0.25) represent hybrids (Haas and McPhail 1991; Baxter et al. 1997).

Mitochondrial DNA (mtDNA) analyses (Baxter et al. 1997) were run on tissue samples from 114 char specimens, which included the 42 samples used in the LDF analyses, by individuals from the fish genetics laboratory at the Freshwater Institute in Winnipeg. Ribosomal DNA (rDNA) analyses (Baxter et al. 1997) were run on ten tissue samples, which were also included in both mtDNA and LDF analyses, by individuals from the genetics laboratory at the University of British Columbia. The identification results of voucher specimens examined in the laboratory were accepted if two or more of the analyses (i.e., morphological, mitochondrial DNA, LDF, ribosomal RNA) were in agreement.

Biological processing, which included meristic and morphometric measurements (Reist et al. 1997), age determination from whole and sectioned otoliths, sex and maturity determination, and stomach content analyses, was completed on 42 specimens (for further details see Methods, Appendix 1). Otoliths were placed in distilled water and viewed under a microscope with reflected light. Young-of-the-year fish were expressed as zero (i.e., 0) in tables and figures. 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 (McGowan 1992; Table A1.1, Appendix 1).

Stomachs were examined and contents were identified as terrestrial or aquatic insects, and fish. Where possible fish found in stomachs were identified to species.

2.2. RESULTS

2.2.1. DISTRIBUTION AND ABUNDANCE

Bull trout populations were captured in nine 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. 2.1). 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, and their use of turbid mainstem rivers is documented but poorly understood in most systems.

In the Franklin Mountains, a total of 18 bull trout were captured in 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 several sites in the lower reach near the confluence with the Kotaneelee River (Fig. 2.1). In the Nahanni Butte area 91 bull trout were captured during the summer and fall (Fig. 2.1). 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, 25 bull trout were captured at the outlet of Drum Lake and two juveniles were captured in a tributary stream flowing into the lake outlet. In total, 14 bull trout were captured in the Keele River (Fig. 2.1). The furthest west that bull trout occurred in the Keele River was approximately 110 river kilometers from its confluence with the Mackenzie River. Sites further west of this location were sampled, but no bull trout were captured.

2.2.2. IDENTIFICATION

The LDF showed that all but four char (#47332, 47335, 47263, 47264) examined in the lab were bull trout. However, mitochondrial DNA and morphological analyses indicate that all char captured and released in the field and those retained for analyses from the study area were bull trout (Table A2.1, Appendix 2). Furthermore, the median total branchiostegal ray count for these four fish was 26, which is within the reported range for bull trout (Haas and McPhail 1991).

2.2.3. BIOLOGY

Size-at-age data for bull trout populations captured from the three study areas show two types of growth patterns. Individuals from both sexes were either small, slow growing, and rarely exceeded fork lengths greater than 400 mm at sexual maturity or they were large, fast growing, and attained large sizes (500 – 700 mm) once sexual maturity was reached. Such growth patterns are represented by large mature bull trout of both sexes that ranged in size from 423 mm to 671 mm and smaller mature individuals that ranged in size from 266 mm to 400 mm (Tables 2.1, 2.2, Fig. 2.2). 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. 2.2, 2.3). Resting males and females were observed in all locations (Table 2.1). Resting females typically had ovaries, which filled approximately half of the body cavity, eggs which were small and granular, and in some cases retained residual eggs. Resting males had fully developed gonads, which were the full length of the body, had no fluid in the center and were purplish in color.

Table 2.1. Biological data collected for bull trout captured in streams and rivers of the Northwest Territories and sacrificed for this study.

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	Stomach[5] contents
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. outlet	561	1806	2	05	9.3	9	AF	A	-
47262	09/13/00	Drum L. outlet	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	TI, AI
47327	08/10/01	Unnamed Cr.A	276	253	1	06	1.5	7	SR	A	SLSC
47328	08/10/01	Unnamed Cr.A	400	736	1	10	8.9	9	SR	A	TI, AI
47267	08/13/01	Funeral Cr.	168	53	1	06	-	4	SR	J	TI, AI
47268	08/13/01	Funeral Cr.	266	204	2	02	0.7	7	SR	A	TI, AI
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	TI, AI
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	TI, AI
47266	08/14/01	Funeral Cr.	289	281	1	07	3.8	9	SR	J	TI, AI
47325	08/15/01	South Nahanni R.	281	236	1	10	-	11	SR	A	AI
47330	09/11/01	Funeral Cr.	272	246	2	02	1.5	11	SR	A	TI, AI, BLTR
47331	09/11/01	Funeral Cr.	101	10	-	00	-	2	SR	J	AI
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	AI
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	AI
47337	09/11/01	Funeral Cr.	139	28	2	01	1.0	3	SR	J	TI, AI, FR
47596	09/15/01	Irvine Cr.	626	2870	2	05	17.2	12	F	A	FR
47338	09/15/01	Irvine Cr.	456	934	2	05	4.6	10	F	A	TI, AI, FR
47329	09/20/01	Keele R.	529	1268	2	05	-	9	F	A	-
47339	09/25/01	Drum L. outlet	423	711	1	10	0.3	9	AF	A	TI, AI, FR
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	AI
47342	09/25/01	Drum L. outlet	528	1561	1	09	3.0	10	AF	A	TI, AI, FR
47343	09/25/01	Drum L. outlet	639	2771	2	05	23.3	-	AF	A	TI, AI, FR
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	AI
47346	09/25/01	Drum L. outlet	561	1875	1	10	1.0	10	AF	A	TI, AI, FR
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	-

Table 2.1. (Continued).

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	Stomach[5] contents
47349	09/25/01	Drum L. outlet	635	2480	2	05	15.3	11	AF	A	TI, AI, LNSC
47119	09/27/01	Drum L. outlet	610	2360	2	05	-	12	AF	A	-
47350	09/27/01	Unnamed Cr.[B]	49	0.9	-	-	-	1	AF	J	-
47351	09/27/01	Unnamed Cr.[B]	57	1.8	1	06	-	1	AF	J	-

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.
5. TI = terrestrial insects, AI = aquatic insects, FR = fish remains, BLTR = bull trout, LNSC = longnose sucker, SLSC = slimy sculpin.

The diet of adults from all populations consisted primarily of aquatic and terrestrial insects as well as fish (Table 2.1). Bull trout captured during the study consumed Arctic grayling (*Thymallus arcticus*), lake chub (*Couesius plumbeus*), slimy sculpin (*Cottus cognatus*), and white sucker (*Catostomus commersoni*). The stomach of one adult bull trout contained a juvenile bull trout (Table 2.1). Juveniles (age 0 – 6) captured from all locations consumed only aquatic and terrestrial insects (Table 2.1).

Bull trout captured from an outlet tributary of Drum Lake ranged in size from 49 mm to 671 mm with the majority of these individuals in the 540 mm to 671 mm size range (A on Fig. 2.3). Two juvenile bull trout, which were determined to be one-year-old fish, were caught in an unnamed tributary flowing into the lake outlet (A on Fig. 2.3). On more than one occasion, groups of three to six bull trout were observed aggressively chasing one lure and biting one another. Large lesions were observed on several bull trout during sampling. The male/female sex ratio of bull trout captured in this area was 1:1 (females = 7, males = 7).

Table 2.2. Length range of various life history types for bull trout populations from drainages in the southern range and for bull trout captured in this study.

Location	Life History	n[3]	Length distribution of mature fish (mm)
Various systems across the range (latitude ~ 49 - 56° N)[1]	Stream-resident	-	140 - 410
	Fluvial	-	410 - 730
	Adfluvial	-	508 - 824
Northwest Territories (this study)			
Unnamed Creek (Kotaneelee River)	Stream-resident	12	270 - 400
Funeral Creek	Stream-resident	18	266 - 370
South Nahanni River[2]	Stream-resident[a]	1	281
	Fluvial[b]	1	510
Keele River	Fluvial	14	512 - 636
Flat River	Fluvial	2	456 - 626
Drum Lake	Adfluvial	25	423 - 671

1. Values are ranges for sites summarized from the available literature.

2. Bull trout were captured at two locations in the South Nahanni River: a) approximately 500 m downstream of the mouth of Prairie Creek, and b) near the base of Virginia falls.

3. Number of bull trout caught.

Bull trout captured in the Keele River ranged in size from 432 mm to 636 mm (B on Fig. 2.3). Although juvenile bull trout were not captured at this site, adults were observed during the late summer and fall congregating just below a clear, cold stream with cobble to boulder-type substrate. One adult bull trout, which was tagged in the summer, was observed moving upstream into this tributary during the fall (September).

Bull trout captured from Funeral Creek ranged in size from 35 mm to 370 mm, although the majority of individuals represented juvenile age classes in the 30 mm to 180 mm size range (C on Fig. 2.3). The estimated average annual growth of juveniles

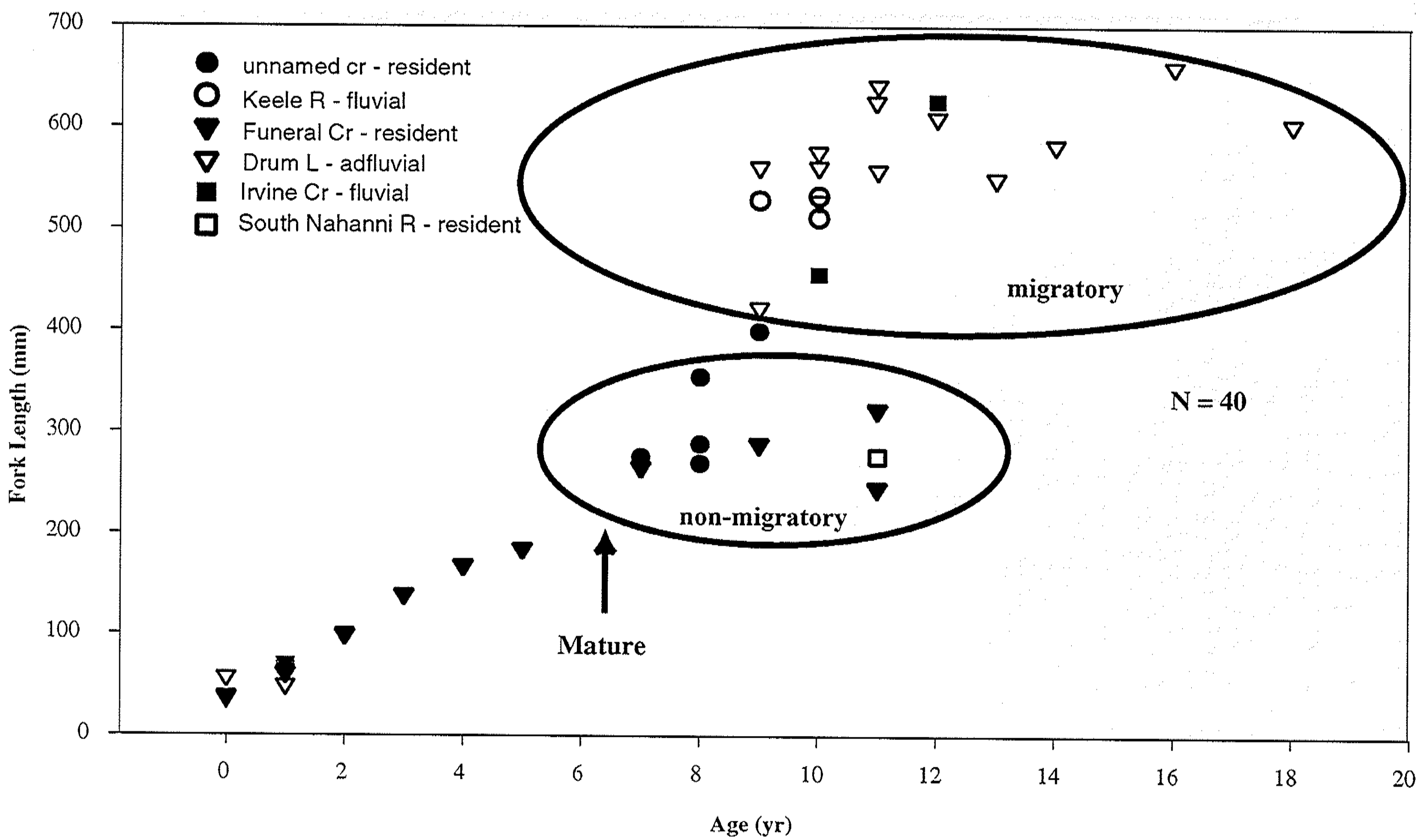

Figure 2.2. Size-at-age relationship of bull trout captured at six locations in the Northwest Territories during 2000 and 2001. Note that all points to the right of the arrow are mature fish and hypothesized life history types for corresponding tributaries are outlined in the legend. The points within the ellipses represent the two size ranges observed for mature fish, which are believed to correspond to migratory (top) and non-migratory (bottom) life history types.

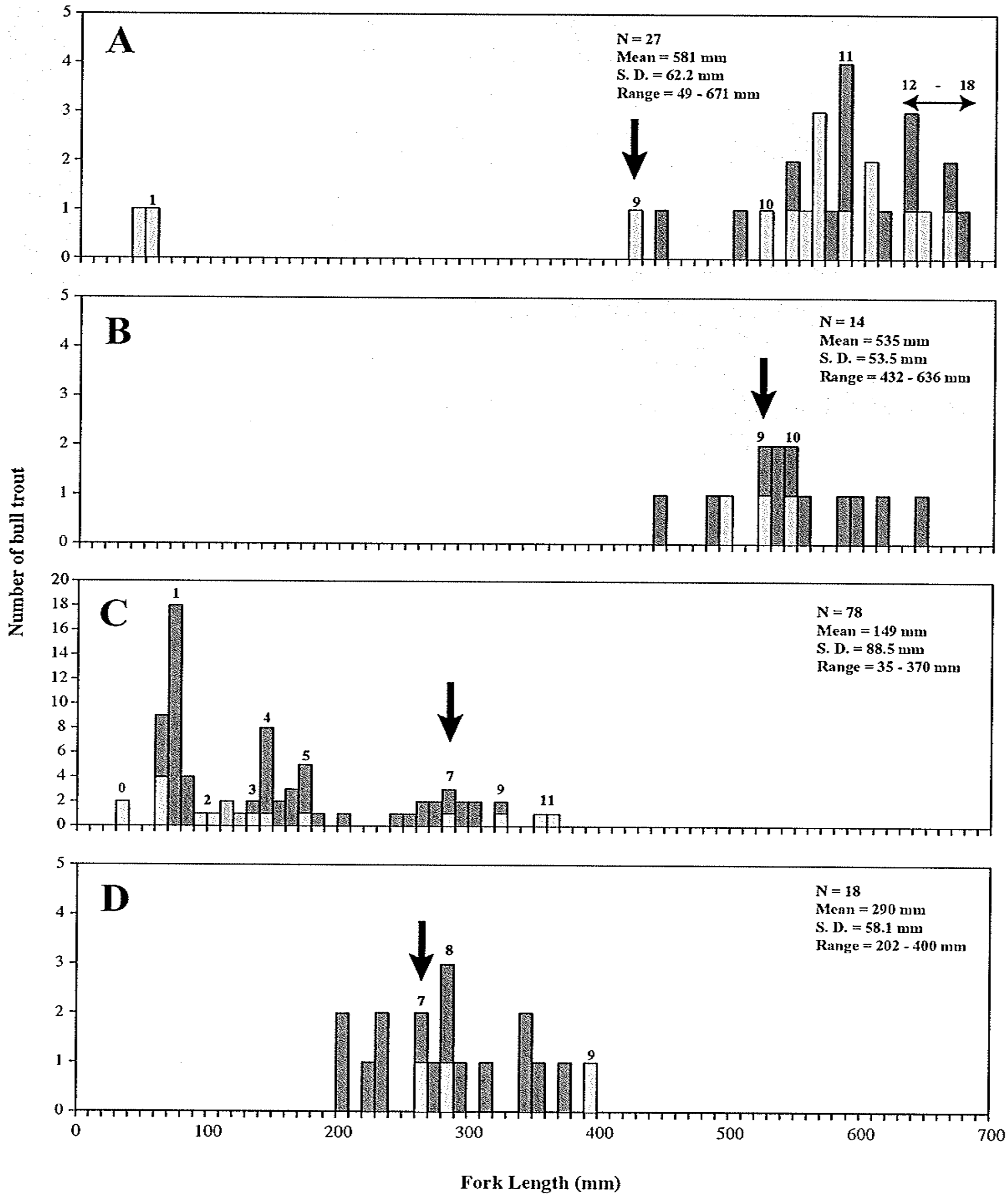

Figure 2.3. Length-frequency distributions of bull trout captured in Drum Lake (A), Keele River (B), Funeral Creek (C), and an unnamed stream in the Kotaneelee River system (D) during 2000 and 2001. Note that lighter shaded bars represent dead-sampled individuals with corresponding ages in bold above bars; darker shaded bars represent individuals released live after measurement. Mature fish are below and to the right of arrows.

captured (age 0 – 5) was 27.9 mm/yr, 14.2 g/yr; however, after age five the average annual weight gain increased to approximately 60 g/yr. The density of bull trout from all life stages captured in two separate reaches during August was 2.8 and 3.0 fish/100 m^2. The density of juveniles captured in two different reaches during September was 5.6 and 6.7 fish//100 m^2 (Table A1.9, Appendix 1).

Bull trout captured from an unnamed tributary in the Kotaneelee River system ranged in length from 202 mm to 400 mm with the majority of the individuals in the 200 mm to 350 mm size range (D on Fig. 2.3). Although no juveniles were captured at this site, unidentifiable juvenile salmonids were observed in this stream.

The majority of bull trout were captured in Funeral Creek; however, individuals were also captured from six other locations in the lower South Nahanni River watershed. Bull trout (# MC0035) was caught at the confluence of Galena and Prairie creeks (Fig. 2.1). Three bull trout (# 47325, MC0037, MC0038), which ranged in size from 281 mm to 402 mm, were captured from the South Nahanni River just below the confluence of Prairie Creek (Fig. 2.1, Table 2.1). Bull trout # MC0043 (FL = 510 mm, WT = 1250 g) was captured near the base of Virginia Falls. Bull trout # MC0044 (FL = 359 mm, WT = 475 g) was captured in a large pool at the base of a small falls (height ≅ 10 m) in Marengo Creek, and three bull trout (# MC0040, MC0041, MC0042), which ranged in size from 245 mm to 336 mm, were captured in a large pool at the base of a falls (height ≅ 15 m) in Jorgenson Creek (Fig. 2.1). Bull trout # 47338 (FL = 934 mm, WT = 456 g) and # 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. 2.1; Table 2.1; Table A1.7, Appendix 1).

2.3. DISCUSSION

2.3.1. DISTRIBUTION AND ABUNDANCE

Prior to investigations, which examined the range of bull trout in the Northwest Territories (Reist et al. 2001), the previous northernmost confirmed locality for the species was in Prairie Creek (~61° N, 125° W), a tributary of the South Nahanni River, NWT (Haas and McPhail 1991; Rescan Environmental 1994). Char captures have also been previously reported in this area (Ker, Priestman and Associates Ltd. 1980; Beak Consultants Ltd. 1982; Parks Canada 1984; Haas and McPhail 1991; Rescan Environmental 1994; Halliwell and Catto 1998), but only one report identifies these char specifically as bull trout. Results from this study confirm the presence of bull trout in nine different tributaries from the Liard, lower South Nahanni and Keele River watersheds. These drainages have few impassable barriers and appear to have a large proportion of suitable habitat (Discussion, Chapter 3). Repeated capture of bull trout over subsequent sampling trips in each of these watersheds confirms that several self-sustaining bull trout populations occur in the Sahtu and Deh Cho settlement areas.

Although bull trout were captured in nine of 18 tributaries sampled during the study, very few fish (i.e., < 30) were caught at most sites. Bull trout were abundant in Funeral Creek (n = 78), but most fish captured were juveniles. The low densities observed during the study suggest that most populations are relatively small and widespread in the area, which is consistent for populations found in the range (Goetz 1989; McPhail and Baxter 1996; Swanberg 1997; Baxter et al. 1999; Hvenegaard and Thera 2001). However, in local areas, such as Drum Lake minimal sampling effort over a short period resulted in capture of many large adults in the main outflow. The distribution of bull trout in this region may be influenced by competition for habitat and resources by other species. For example, Arctic grayling were abundant in most of the streams surveyed (Table A1.5. Appendix 1) and in many instances occurred in the same streams with bull trout. However, in streams where both species were present they rarely occurred in the same habitats together (i.e., pool, run, riffle). Further, the number of fish observed increased substantially for both species in streams (e.g., Funeral Creek, Bluefish Creek) where only one of the species was present (Table A1.5, Appendix 1).

2.3.2. Biology

Overall size and growth, particularly for adult bull trout, reflects differences in life histories (McPhail and Baxter 1996). Mature bull trout from stream-resident populations typically do not exceed 400 mm (Adams 1994; Spangler 1997) and adults from adfluvial and fluvial bull trout populations are generally 400 mm to 700 mm (McPhail and Murray 1979; Fraley and Shepard 1989; McPhail and Baxter 1996; Stelfox and Egan 1995; Ratliff et al. 1996; Hvenegaard and Thera 2001). Bull trout captured from different locations during the study showed distinct differences in overall size and growth, which correspond to adfluvial, fluvial, and stream-resident life histories.

Mature bull trout from Funeral Creek and an unnamed creek in the Kotaneelee River system were less than 400 mm, which suggests that these fish are from stream-resident populations. Bull trout from the Keele, South Nahanni (i.e., Virginia Falls), and Flat rivers were large (range 456 to 636 mm) compared to fish of similar age from Funeral Creek and the Kotaneelee River system. The nearest lake is over 200 km from the sites where bull trout were captured in both the South Nahanni and Keele river systems. The distance to connected lakes in these systems and size-at-maturity suggest that these fish are part of fluvial rather than adfluvial populations in these two drainages. All mature fish captured from the Drum Lake outflow were relatively large (i.e., 423 – 671 mm). Local reports by lodge owners and sport fishermen indicate that bull trout have also been caught in the lake (Hanks 1996). This suggests that these fish are probably from an adfluvial population that resides in Drum Lake.

Bull trout populations in watersheds across the range have demonstrated evidence of meta-population structure (Fitch 1997; Rhude and Stelfox 1997; Wissmar and Craig 1997; Baxter et al. 1999; Hvenegaard and Thera 2001). In the lower South Nahanni drainage small mature fish were caught in intermediate-sized streams that flow into mainstem rivers (e.g., Jorgenson Creek, Funeral Creek), and large mature fish were captured in larger tributaries (e.g., Flat River, South Nahanni River). The presence of these fish in the same drainage indicates that both fluvial and stream-resident populations likely occupy the watershed. Similar to other watersheds in the range, bull trout populations in the South Nahanni watershed show evidence of meta-population structure. Since no impassable barriers occur downstream of Virginia Falls, genetic exchange between wandering individuals from different areas and/or life histories is possible. Furthermore, headwater populations such as the one found in Funeral Creek, may actually be genetically connected to larger spawning populations. Rieman and Allendorf (2001) suggest that isolated headwater populations, such as the one in Funeral Creek, rely on straying individuals from other populations to maintain genetic variability in the population. Wandering fish strengthen regional populations by refounding and protecting the genetic diversity that is necessary for survival under constantly changing environments, thus facilitating the replenishment and long-term persistence of such populations (Quinn et al. 1991; NRC 1996; Policansky and Magnuson 1998).

Bull trout populations are typically slow growing and mature late (Goetz 1989; Ford et al. 1995; Baxter and McPhail 1996; McCart 1997). However, adfluvial and fluvial populations generally exhibit faster growth than stream-resident populations (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). Productivity in these streams is far lower than in streams and lakes that fluvial and adfluvial populations occupy (Goetz 1989; McPhail and Baxter 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; 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 considerably less than observed values for fluvial and adfluvial types.

The Funeral Creek stream-resident population is an example of an isolated, slow growing population that inhabits a relatively low productivity headwater stream. Average growth from age 3 to age 5 for Funeral Creek fish is about 35 to 40 mm/yr, which is within the range of values reported in other studies of similar populations. The low productivity combined with few forage fish available for the Funeral Creek population may explain 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 fishing and impacts on habitat. Furthermore, as latitude increases, productivity generally deceases due to colder temperature and shorter growing seasons. Populations that occupy drainages further north and at higher altitudes will likely be more susceptible to perturbations than those found further south.

Spawning in non-consecutive years is common for bull trout populations throughout their range (Goetz 1989; McPhail and Baxter 1996 and references therein; McCart 1997). Bull trout captured in all three watersheds exhibited alternate-year spawning patterns. Since both resting males and females were observed, it is likely that alternate-year (or less) spawning is an adaptation in response to low productivity typical of drainages north of 60° latitude. 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.

2.3.3. Management

The presence of bull trout populations throughout large geographic areas in the southern and central NWT raises several management concerns. The suggested present 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 (Fig. 1.2; Chapter 1; 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 present evidence demonstrates that the species range continues further north of this central area. Peripheral populations are typically small and more susceptible to extirpation due to random biotic or abiotic events. However, despite the small size and fragile nature of these populations, isolated peripheral populations are expected to be genetically distinct from more central populations because they typically live in unique environments (Lesica and Allendorf 1995; Quinn et al. 1991; NRC 1996; Policansky and Magnuson 1998; Dunham and Reiman 1999). Bull trout populations have demonstrated that individuals from regional spawning populations will stray and spawn with smaller headwater populations (Baxter et al. 1999; Hvenegaard and Thera 2001). Managers in the north should recognize the potential genetic value of peripheral bull trout populations, which occur in headwater habitats. Such populations should be viewed as of equal or greater value as larger downstream populations when considering management plans.

In order to conserve bull trout populations at the northern extent of the distribution it will be necessary 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. 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 (e.g., individuals fishing or surveying the area), sport fishers, consultants, and biologists from government agencies. The Northwest Territories Sport Fishing Guide has been recently updated (March 2002) to include bull trout as a separate species from Dolly Varden. The guide also describes the current known bull trout range, highlights morphological features used to identify the species, and provides conservative catch limits. Similar actions must be put into place for other aspects of fishery management (e.g., local 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 both of these situations have been documented in British Columbia (Haas and McPhail 1991; Baxter et al. 1997). If hybridization and sympatry occur, they will further complicate in-field identification for chars found in the area.

The size of bull trout populations in the NWT must 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, which include overharvesting and loss of habitat (see McCart 1997; Baxter et al. 1999). Managers must understand and recognize that populations exhibit different life histories, and each population has unique biological traits (e.g., growth) and requirements (e.g., habitat). Furthermore, vulnerability to anthropogenic impacts and stochastic events will be significantly different between life history types. Research and monitoring will be required for northern populations to ensure that overharvesting and habitat disturbances do not adversely affect their long-term persistence.

The structure of bull trout populations found during this study (e.g., South Nahanni Watershed) and across the range (Rhude and Stelfox 1997; Wissmar and Craig 1997; Baxter et al. 1999; Hvenegaard and Thera 2001) is consistent with the metapopulation concept (see Rieman and McIntyre 1993, 1995; McCart 1997; Dunham and Reiman 1999). 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 headwater resident populations, such as the one found in Funeral Creek, could lead to local extirpation, as these populations may rely on genetic exchange from larger regional populations to persist.

Given that meta-populations likely occupy the lower South Nahanni watershed, it will be critical to maintain migratory pathways to facilitate genetic exchange between individuals. Fragmentation of migratory corridors could create a group of increasingly isolated and dwindling populations that are more vulnerable to biotic and abiotic perturbations.

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 (metapopulations) 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 the relationships between them; and, 3) determining the connectivity between different populations at genetic and spatial scales. Finally, a better understanding of habitat requirements for various life history stages, and potential impacts on those habitats will be required to minimize adverse effects during anticipated industrial development.

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. Such environments are favorable for the long-term persistence of healthy populations; however, without proper levels of conservation and protection these populations may succumb to extirpation like many of their southern counterparts. Information on unexploited populations in the north could be used by managers in the south to design better recovery programs for populations that are at risk of extirpation. Given the anticipated and existing level of resource development in the region (Pete Cott, Fish Habitat Biologist, Department of Fisheries and Oceans Fish Habitat Management, Western Arctic Region, pers. comm. 2003), and the demonstrated hypersensitivity displayed by bull trout populations to disturbances, it will be critical to implement appropriate monitoring and protection programs as soon as possible.

CHAPTER 3.

HABITAT USE BY BULL TROUT, *SALVELINUS CONFLUENTUS* (SUCKLEY) IN SIX MOUNTAIN STREAMS OF THE SOUTHERN AND CENTRAL NORTHWEST TERRITORIES

Abstract: In the summer and fall, 2001, six streams were surveyed in the southern and central Northwest Territories to describe habitat use and availability for bull trout in the region. Depth, velocity, temperature, substrate, and cover were documented at the macrohabitat level for all six streams and at the microhabitat level for one stream. Results show that bull trout in the Northwest Territories prefer water depths ranging from 21.1 cm to 37.9 cm and water velocities, which range from 0.21 m/s to 0.49 m/s. Substrate found in the six streams ranged from 64 mm to 256 mm. Cobble to boulder-type (124 – 256 mm) substrate, followed by woody debris, and overhanging vegetation were the most common cover found in these streams. As latitude increased the diversity of available cover types diminished. Significant differences for mean depth, velocity, and substrate were observed among sites ($P < 0.01$). Although depth selection by juveniles and adults were significantly different ($P < 0.05$) in Funeral Creek, substrate and cover use was similar. Juveniles showed a distinct preference for cobble-type substrate in Funeral Creek. Although bull trout habitat in the north has similar characteristics to habitat documented at more southern latitudes, site-specific habitat preferences for substrate and cover were observed during the study.

3.0 INTRODUCTION

Effective management of fish populations requires an understanding of population size, structure, and habitat use. During the last two decades it has been demonstrated that degradation and loss of habitat are major factors contributing to declining salmonid populations (Bottom et al. 1985; Grant et al. 1986; Eaglin and Hubert 1993; NRC 1996; Gregory and Bisson 1997; Baxter et al. 1999). As a result the emphasis of fisheries research has shifted to focus more on habitat use by salmonids. It has been documented that many salmonids have a narrow range of habitat requirements (Reiser and Bjornn 1979; NRC 1996). For example, redd reuse and superimposition of redds are frequently observed in salmonid populations (pink salmon, *Oncorhynchus gorbuscha*, McNeil 1967; brook trout, Blanchfield and Ridgeway 1997; bull trout, Baxter and McPhail 1999) and an indication of specific habitat preferences. Furthermore, the availability of suitable habitat is considered to be the main factor limiting population success for many salmonids (McPhail and Baxter 1996; NRC 1996; Blanchfield and Ridgeway 1997).

Like other salmonids, degradation and loss of habitat are also associated with declining bull trout populations (Reiman and McIntyre 1995; McCart 1997; McPhail and Baxter 1996; Wissmar and Craig 1997). In the Swan River Basin, land use, specifically logging roads, appears to have adversely affected bull trout populations (Baxter et al. 1999). In Gold Creek, Washington, the mortality of spawning bull trout was directly attributed to channel de-watering, caused by water regulation and/or natural drought in the area (Wissmar and Craig 1997).

To protect bull trout habitat in areas where resource development activities are prevalent it is necessary to understand habitat use and preferences. Many studies in drainages across the southern and central range have described habitat use of bull trout for the overall general stream and at fish positions within a stream (Adams 1994; Fairless et al. 1994; Saffel and Scarnecchia 1995; Baxter 1997b; Goetz 1997; Spangler 1997; Baxter and McPhail 1999). Despite a large body of literature on bull trout habitat use and preferences, it is still evident that bull trout have specific spawning and rearing habitat requirements which are poorly understood (Goetz 1989; Baxter and McPhail 1996; Baxter et al. 1999; Baxter and McPhail 1999).

Self-sustaining bull trout populations occur in the NWT; however, similar habitat data as described in other areas are lacking (Reist et al. 2002). Furthermore, resource development in the NWT is evolving at a rapid rate. This study was designed to examine stream habitat that known bull trout populations occupy over as large a geographic area in the NWT as possible. Objectives of the study were to: 1) describe bull trout habitat use and availability; 2) compare bull trout habitat use and preferences in the NWT to other areas; and 3) discuss management issues as they pertain to bull trout habitat in the NWT.

3.1. METHODS

3.1.1. STUDY SITES

To obtain baseline data on bull trout habitat use in the NWT, six streams reported to contain bull trout were selected (see Results, Chapter 2). Funeral Creek, Jorgenson Creek, Marengo Creek, and three unnamed streams located in the Keele and Liard River watersheds (see Chapter 1, Locations 1, 2, and 3 on Fig. 1.5) were surveyed in the summer and fall of 2001. The streams surveyed are medium to high-gradient mountain streams with headwaters that originate from snowmelt and underground upwellings.

Barriers to fish migration occur in the South Nahanni watershed at Virginia Falls (~90 m), and Jorgenson and Marengo falls (~10 m) (see Chapter 1, Fig. 1.5).

Location 1: Habitat surveys were completed at 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 elevation of approximately 1500 m. The unnamed stream is a second order stream, based on the classification system of Strahler (see Gallager 1999), that flows east into the Kotaneelee River (Location 1 on Fig. 1.5). Location 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. 1.5). Funeral Creek is a first order stream and Jorgenson and Marengo creeks are second order streams. All of the streams surveyed in the Nahanni Butte area have headwaters that originate in the Nahanni Range at an elevation of approximately 2000 – 3000 m and flow into the South Nahanni River (Fig. 1.5). Location 3: Habitat was documented in an unnamed creek (60°14'N, 125°59'W), which is a tributary of the Keele River and in a tributary of the Drum Lake system (63°48'N, 126°09'W) (Location 3 on Fig. 1.5). Tributaries flowing into Drum Lake and the Keele River originate in the Mackenzie Mountains at an elevation of approximately 1500 – 2000 m.

3.1.2. FISH SAMPLING

Fish sampling was conducted in the six study streams in the summer and fall of 2001 (for complete details of the study sites and sampling procedures see Methods, Chapter 2). The streams were stratified into lower, middle, and upper sections. In each section randomly selected reaches (200 – 500 m) were electrofished moving upstream using a Smith Root, Type VII POW backpack electroshocker. Unwadable areas were angled using barbless hooks.

Char captured in each stream were identified to species prior to release. Fork length (nearest mm) and weight (nearest g) were measured, and sex and maturity state were determined where possible. All bull trout with fork lengths that exceeded 200 mm were fitted with an individually numbered Floy-tag inserted at the base of the dorsal fin between the posterior basal pterygiophores. A portion of the adipose fin was removed for genetic analyses and to evaluate tag loss. The first fin ray was removed from the left pelvic fin for 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. Genetic analyses and a linear discriminant function (LDF) proven to be 100% effective in distinguishing Dolly Varden from bull trout (Haas and McPhail 1991) were used to confirm species identity for char captured (Methods, Chapter 2).

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 (Methods, Chapter 2 and Appendix 1).

3.1.3. Macrohabitat

During the summer and fall of 2001 habitat surveys were conducted in the six study streams. Habitat use was quantified at the macrohabitat level for all streams and at the microhabitat level for one stream. Macrohabitat represents general physical features (e.g., depth, velocity, substrate, wetted width) of a stream. Microhabitat represents the physical features within a stream at specific sites where fish are captured.

Macrohabitat data were obtained from 22 randomly selected reaches of six streams in the NWT. Reaches that were 200 to 400 m long were selected in the lower middle and upper sections of each stream for sampling. Within each reach a series of at least two pool, riffle, run sequences were randomly selected and the habitat units (i.e., pool, riffle, run) were sampled. A total of 81 pools, 55 runs, and 61 riffles were sampled during the study. The macrohabitat data from each stream were used to determine general stream characteristics for the six study streams. Habitat typing followed the technique of Bisson et al. (1988) based on hydraulic characteristics of each stream. However, habitat was not classified past the pool, run, and riffle level.

To determine physical features of each randomly selected habitat type within a reach, three equidistant transects were placed parallel and perpendicular to water flow within each habitat unit. The transects extended across the entire distance of each habitat unit in each direction. At each of the habitats, 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 five cm for each point using a modified Wentworth scale (Table 3.1), and cover was estimated visually at each point according to a ranked classification scale (Table 3.2). The wetted width of the stream was randomly measured at 50 m intervals throughout all sampling reaches in each stream.

Table 3.1. Categories used to define substrate composition for habitat surveys in this study.

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 3.2. Cover classification defining types used for habitat surveys in this study.

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

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 among and within streams.

3.1.4. MICROHABITAT

Microhabitat data were collected in Funeral Creek during September 2001. Microhabitat measurements were similar to macrohabitat measurements; however, microhabitat was measured only in habitat units where bull trout were captured. Conversely, macrohabitat was measured in randomly selected habitat units within a stream regardless of the presence or bull trout. A two-person crew electrofished two randomly selected reaches (200-300 m) using a Smith-Root, Type VII POW gas-powered backpack electroshocker. Each time a bull trout was captured a weighted object with either blue or orange flagging tape was placed in the habitat unit for later identification. Blue markers represented juveniles and orange represented adults. Lengths (nearest mm) and weights (nearest g) were recorded for all bull trout captured in the field. All bull trout larger than 200 mm (FL) were considered adults, and all those less than 200 mm (FL) were juveniles. The size criteria for juveniles and adults were based on size-at-age and maturity data (see Results, Chapter 2).

After electrofishing was complete, physical habitat parameters were measured in marked habitat units where bull trout were captured. Three transects parallel and perpendicular to flow, were placed in each habitat unit where bull trout were captured, and depth, velocity, dominant substrate and cover were recorded at nine points as described above.

3.1.5. STATISTICAL ANALYSES

Boxplots and frequency histograms of macro and micro-habitat use and availability for bull trout were constructed in order to provide a visual representation of the data. Comparisons of macrohabitat among streams were made using descriptive statistics.

Differences in velocity and depth among pool, run, and riffle habitats were analyzed. The pooled velocity and depth data for each habitat type from all locations were compared using a one-way analysis of variance (ANOVA). Since the data were not normally distributed, they were transformed ($\log_{10} X+1$) to account for any zero or low values in the data (Zar 1999).

Differences among streams for mean depth and velocity were compared using a one-way ANOVA. The mean depth and velocity data were pooled for all habitat types at each site. Differences among substrate and cover use for each stream were compared using a Kruskal-Wallis one-way ANOVA, as these were nominal data.

The Kolomogorov-Smirnov test was used to determine if substrate and cover use were the same as habitat availability in Funeral Creek for juveniles and adults. Differences in mean water depth for adults and juveniles were compared in Funeral Creek using a Mann-Whitney U-test, as variances were not homogeneous (i.e., the assumptions of the parametric test were not met). The Mann-Whitney test was also used for nominal data (i.e., cover and substrate) to compare use by adults and juveniles in Funeral Creek. Differences in velocity use by juveniles and adults in Funeral Creek were compared using a two-sample t test. For all statistical tests, significance was assessed at either $\propto = 0.05$ or $\propto = 0.01$.

3.2. RESULTS

3.2.1. DISTRIBUTION AND ABUNDANCE

Morphological and genetic data indicate that all char captured during the study were bull trout (Results, Chapter 2 and Appendix 2). Although bull trout were found in all six streams, the number of individuals captured in most streams was low (i.e., < 30). The only location where bull trout were abundant was Funeral Creek (n = 78); however, the majority were young-of-the-year and juveniles (Chapter 2, Table 2.1). At the Liard study stream bull trout did not occur in high densities (n = 18), but they were distributed throughout a large proportion (2 – 4 km) of this stream. Few bull trout were captured at Marengo Creek, Jorgenson Creek, Drum Lake, and Keele River study sites (Chapter 2, Fig. 2.1). At the Jorgenson and Marengo sites impassable falls prevented upstream fish movement, but individuals were captured at the base of the falls in both locations.

3.2.2. MACROHABITAT

Water temperatures for the six streams surveyed during August and September ranged from 3.6 to 12.7° C (Table 3.3). The elevation for the six streams ranged from 400 to 2000 m and all streams surveyed were first to third order (Table 3.3). The tributaries sampled represented small to intermediate-sized streams with the smallest stream (Funeral Creek) having an average wetted width of 2.3 m, and the largest (Unnamed Creek, Keele drainage) with an average of 9.9 m (Table 3.3).

Table 3.3. Physical habitat characteristics of streams where habitat use of 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 3.1 and 3.2.

Location	Site	Stream order (map scale 1:50, 000)	Average wetted width (m)	Average temp (°C)	Month sampled	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	Large 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

Bull trout were found in pool, riffle, and run habitats in all six streams. Pools found across the six streams were the deepest, followed by runs and riffles (Fig. 3.1). Depth and velocity both differed significantly among habitat units [Depth ($F_{[2,194]}$ = 38.09, P < 0.01)], [Velocity ($F_{[2,194]}$ = 96.42, P < 0.01)]. Depth and velocity showed an inverse relationship between pools and riffles. Pools were deepest and had the lowest velocities, and riffles were shallowest and had the highest velocities. Runs were relatively deep compared to riffles and had moderate to fast-water velocities (Fig. 3.1).

Habitat availability histograms show that pools possessed the most diverse array of substrate, followed by runs and riffles which had larger proportions of pebble to cobble-type substrate (Fig. 3.2). Small cobble was the dominant substrate found in all three habitats for the six streams (Fig. 3.2). Cover data for pool, run and riffle habitats across the six sites indicate that boulder (substrate) was the most common type of cover available, followed by turbulence, cobble, overhead vegetation, large wood and depth (Fig. 3.3). Pools had the most diverse cover available, followed by runs, and riffles (Fig. 3.3).

Depth availability data show that all streams had a large proportion of habitat in the 0 to 60 cm range (Fig. 3.4). There was a significant difference in water depth among the six sites ($F_{[5,191]}$ = 5.97, P < 0.01). Funeral Creek and an unnamed creek in Drum Lake possessed a large proportion of shallow water habitat (0 – 20 cm), whereas Jorgenson, Marengo, and unnamed creeks in the Liard and Keele drainages had a greater proportion of deeper water (20 – 60 cm) habitat (Fig. 3.4).

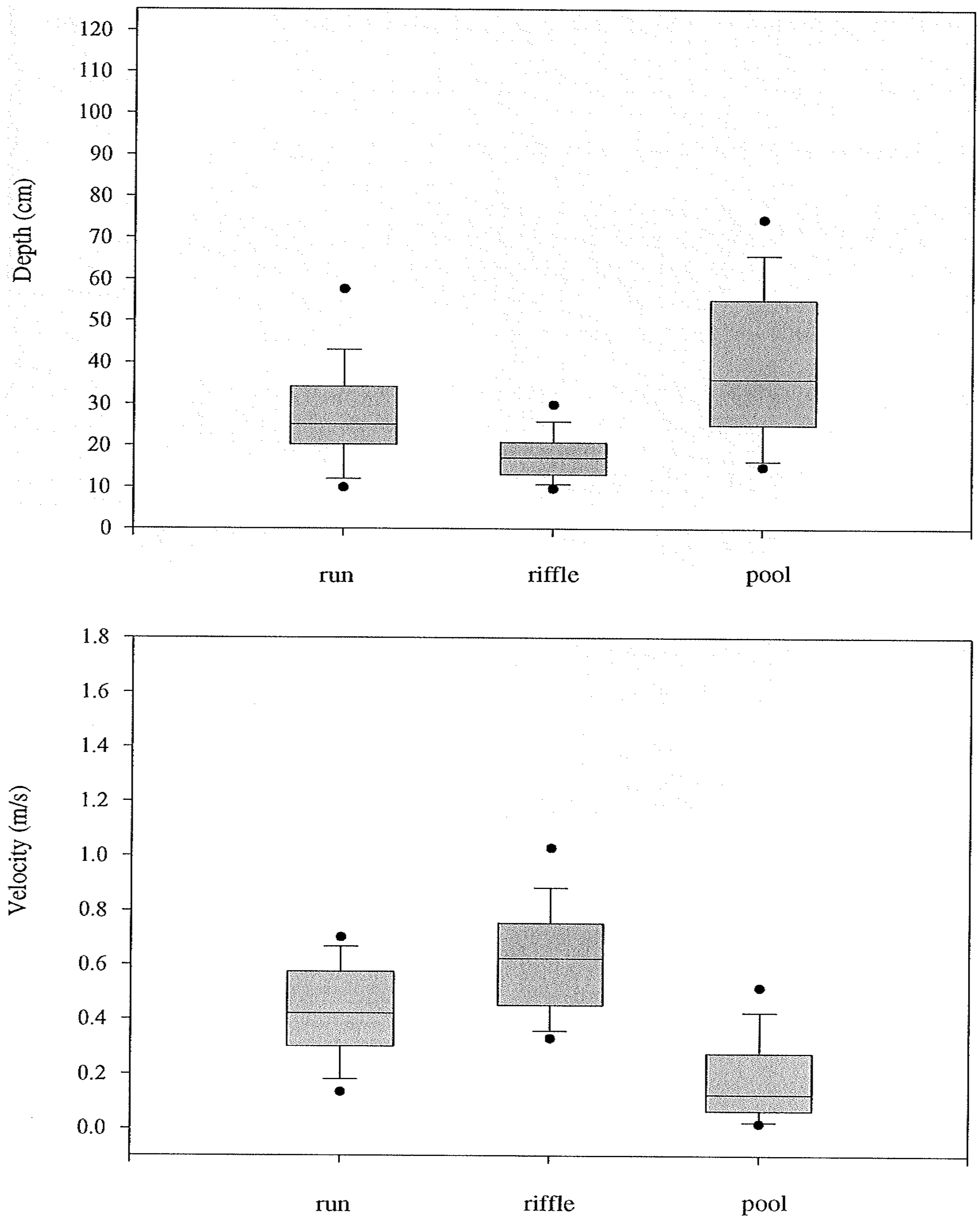

Figure 3.1. Box plots showing from the bottom the 5th (dot), 10th, 25th, 50th, 75th, 90th (horizontal lines), and 95th (dot) percentiles for mean water depth (top panel) and velocity (bottom panel) of pool, riffle, and run habitat units measured from six streams in the southern and central Northwest Territories.

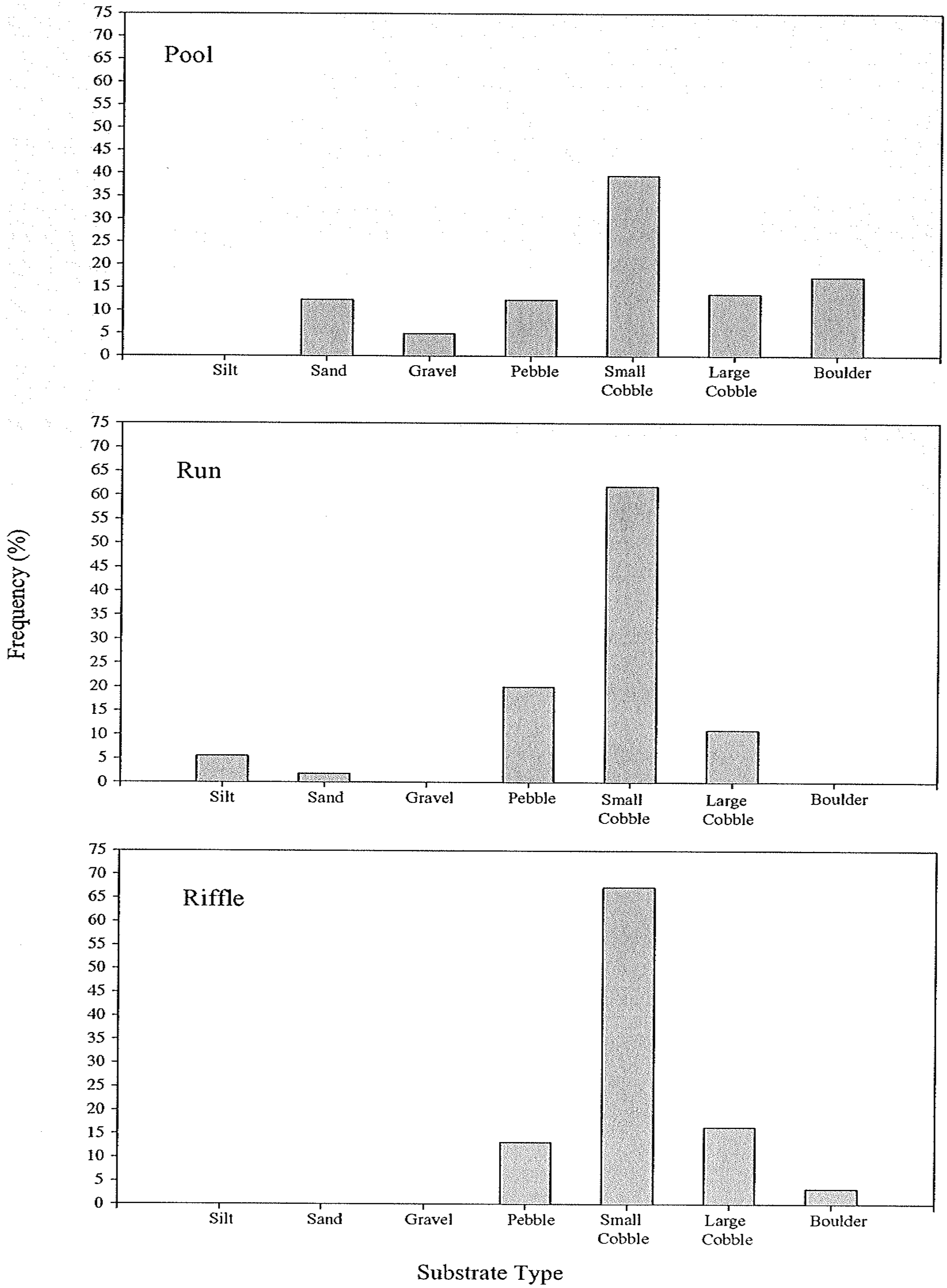

Figure 3.2. Habitat availability data for substrate in pool, run, and riffle habitats from six streams in the Northwest Territories.

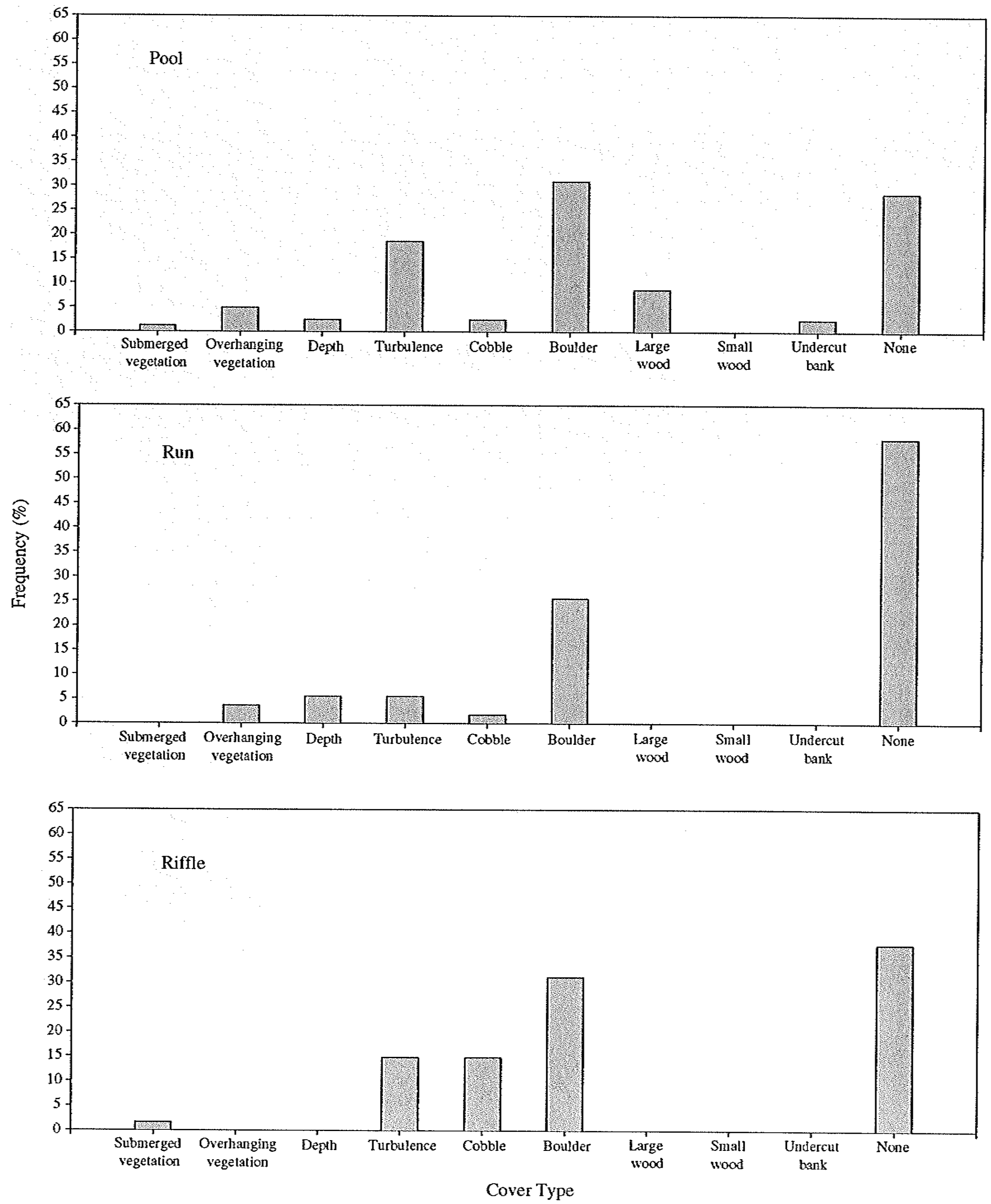

Figure 3.3. Habitat availability data for cover in pool, run, and riffle habitats from six streams in the Northwest Territories.

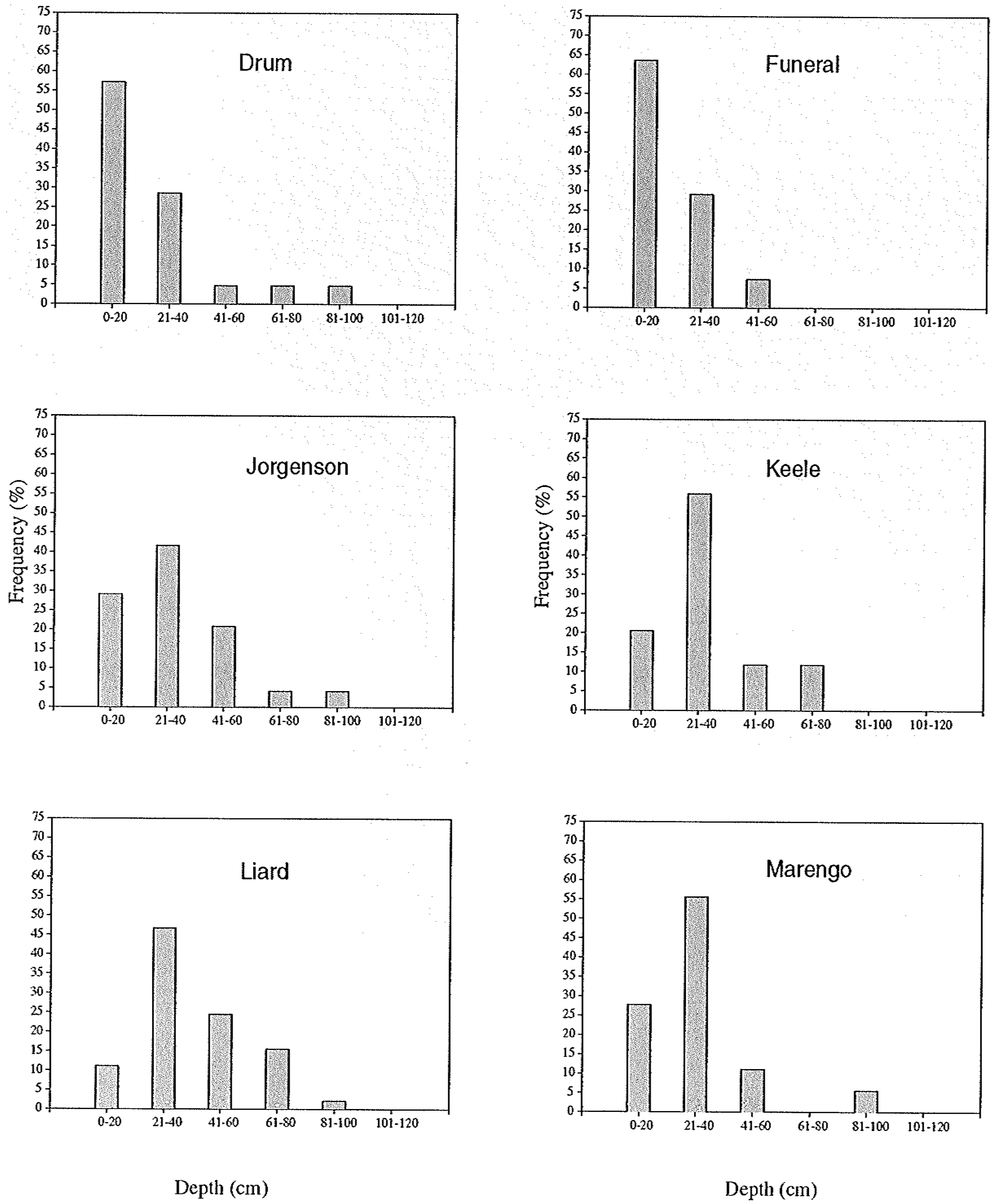

Figure 3.4. Frequency histograms of water depth availability for pool, run, and riffle habitats from six streams surveyed in the summer and fall of 2001.

Overall, there was a significant difference in mean water velocity among the six sites (H_2 = 24.8, P < 0.01). Funeral Creek and the Drum Lake tributary had lower mean velocities than Jorgenson, Marengo, and the Liard and Keele tributaries (Table 3.4, Fig. 3.5).

Small cobble was the dominant substrate found in four of the streams (Fig. 3.6). The overall substrate composition was significantly different among the six sites (H_2 = 43.7, P < 0.01). The stream surveyed in the Liard drainage showed the greatest number of substrate types, and the Drum Lake tributary had the largest proportion of silt and sand, which is not substrate typically used by bull trout (Fig. 3.6). Marengo Creek had a relatively even distribution of small to large cobble and boulder-type substrate (Fig. 3.6). Boulder was the dominant cover in Funeral, Jorgenson, and Marengo creeks, and in an unnamed tributary of the Keele River drainage (Fig. 3.7).

The Liard tributary had the largest proportion of woody debris available for cover of all the streams (Fig. 3.7). The Drum Lake and Liard tributaries had the greatest proportion of overhead vegetation of all the streams surveyed (Fig. 3.7). Although there were apparent differences in cover availability between sites, these differences were not statistically significant (H_2 = 5.87, P = 0.319).

3.2.3. MICROHABITAT

In the summer (August 13 – 15) and fall (September 11 – 13) of 2001, a total of 60 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 3.5).

Table 3.4. Macrohabitat characteristics summarized for bull trout across the range, and measurements taken from six streams in the Northwest Territories during this study.

Location	n[3]	Life Stage	Water depth (cm)	Water velocity (m/s)	Substrate size (mm)	Dominant Cover
Various systems across the range (latitude 49 - 56° N)[1]	-	Spawn/egg	20 - 60	0.02 - 0.99	20 - 130	wood, cavity
	-	Young of the year	0 - 20	0.04 - 0.60	6 - 250	substrate (turbulence)
	-	Juveniles	20 - 60	0.01 - 0.64	20 - 250	wood, substrate, cavity
	-	Adults	20 - 200	0.01 - 0.99	0.059 - 250	wood, substrate, cavity
Northwest Territories (this study)[2]						
Unnamed Creek, Drum Lake	27	Adults	24.9±5.0 (5.1-88.2)	0.21±0.03 (0.05-0.42)	0.059 - 256	substrate, overhanging vegetation
Funeral Creek, South Nahanni River	78	Adults, Juveniles	21.1±1.6 (8.7-55.0)	0.29±0.02 (0.02-0.72)	16 - 256	substrate (turbulence)
Jorgenson Creek, South Nahanni River	3	-	32.5±3.6 (11.3-83.2)	0.51±0.07 (0.01-1.27)	2 - 256	substrate
Marengo Creek, South Nahanni River	1	-	29.7±4.0 (13.0-83.3)	0.49±0.05 (0.06-0.87)	16 - 256	substrate (turbulence)
Unnamed Creek, Keele River	12*	Adults	33.7±2.9 (15.5-76.0)	0.41±0.05 (0.01-1.06)	0.06 - 256	substrate
Unnamed Creek, Kotaneelee River	18	Adults	37.91±2.6 (9.6-84.5)	0.45±0.04 (0.01-1.09)	0.06 - 256	turbulence, large wood

1. Values are ranges for sites summarized from the literature for all life history types and stages.
2. Values for water depth and velocity are given as the mean ± the standard error with ranges in parentheses, substrate is given as ranges, and cover as dominant types with less dominant types in parentheses.
3. Number of bull trout captured at each site. * Bull trout were caught in the Keele River at the mouth of this unnamed creek. A tagged bull trout was found moving upstream into this creek during the fall.

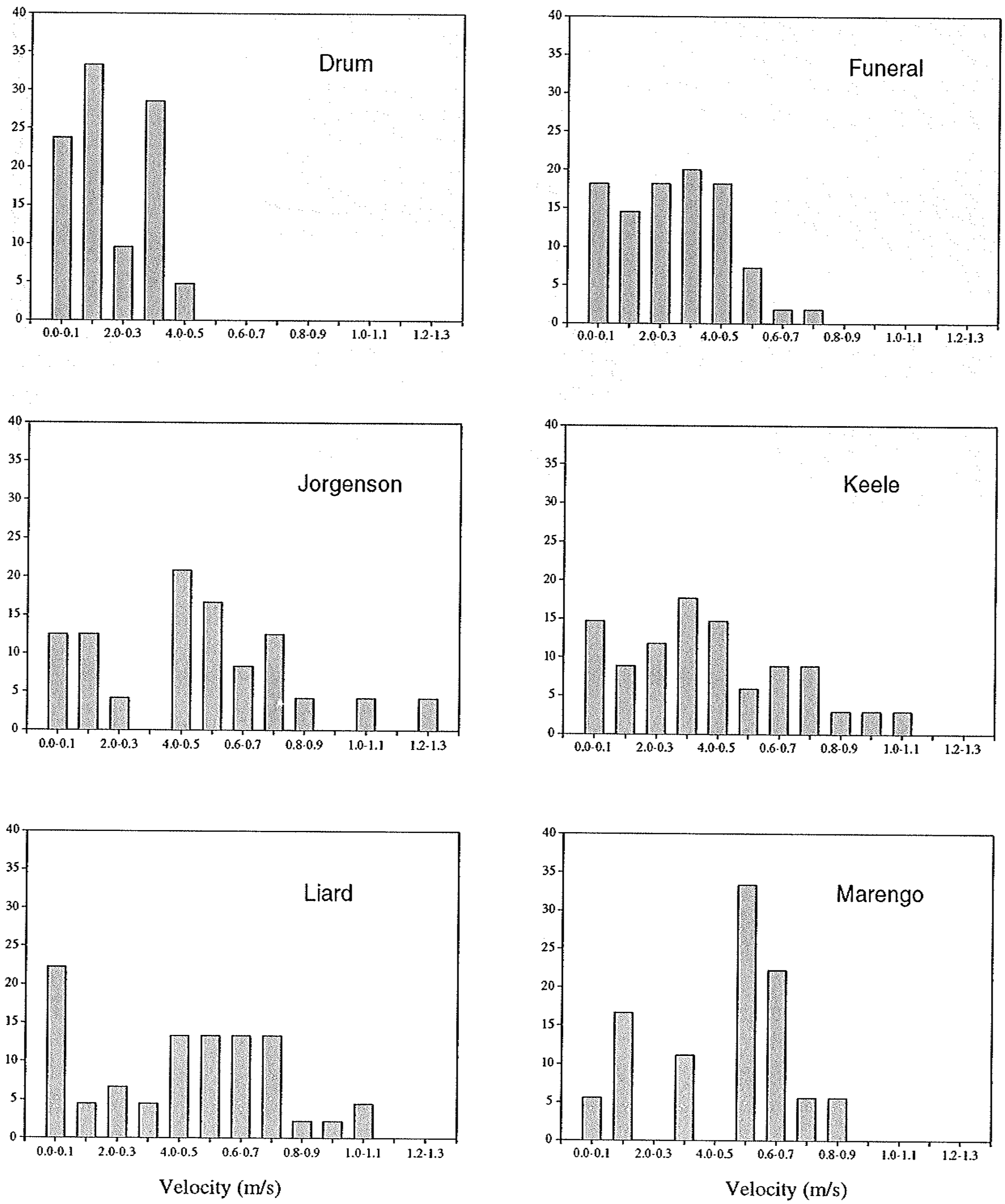

Figure 3.5. Frequency histograms of water velocity availability for pool, run, and riffle habitats from six streams surveyed in the summer and fall of 2001.

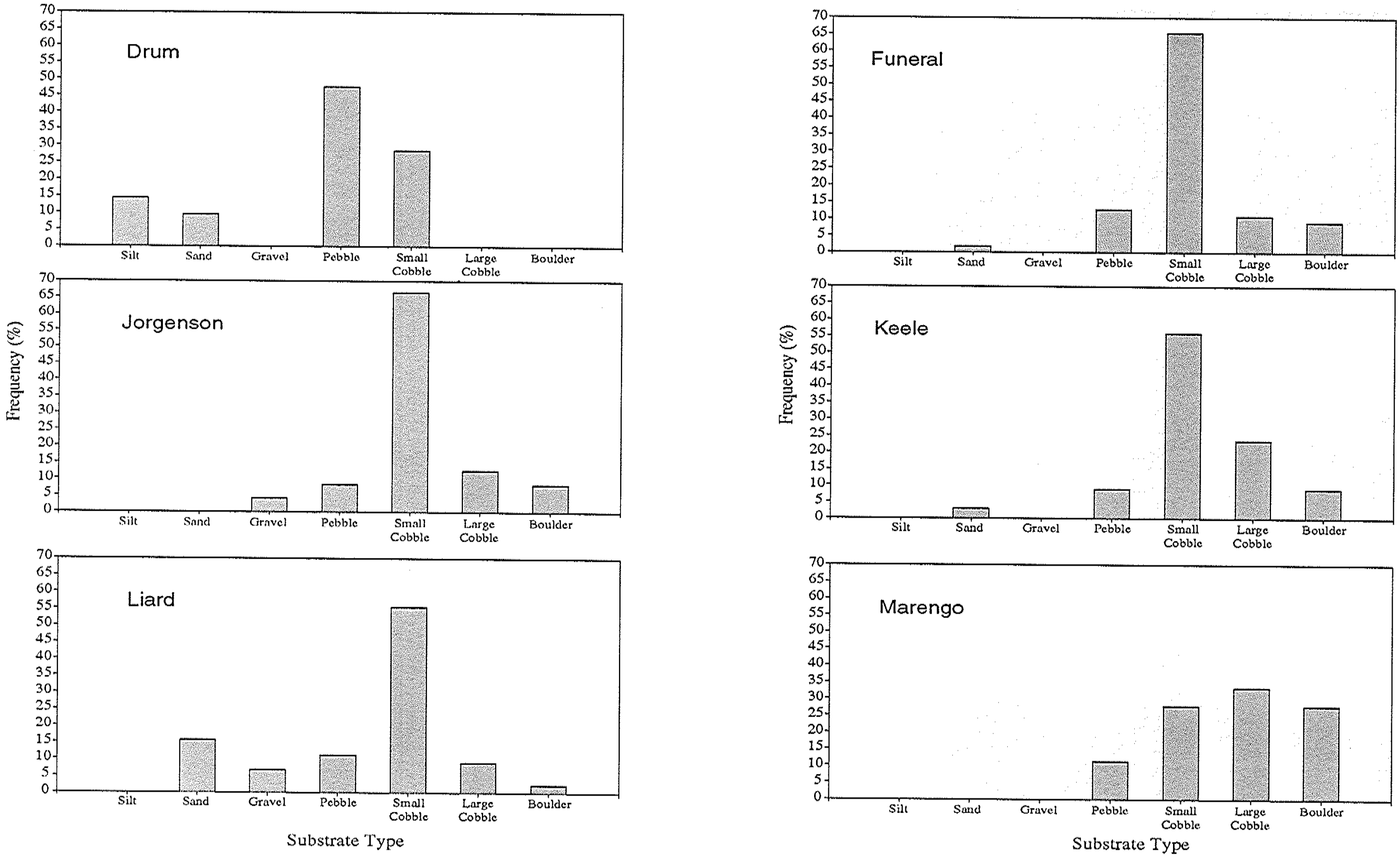

Figure 3.6. Frequency histograms of substrate availability for pool, run, and riffle habitats from six streams surveyed in the summer and fall of 2001.

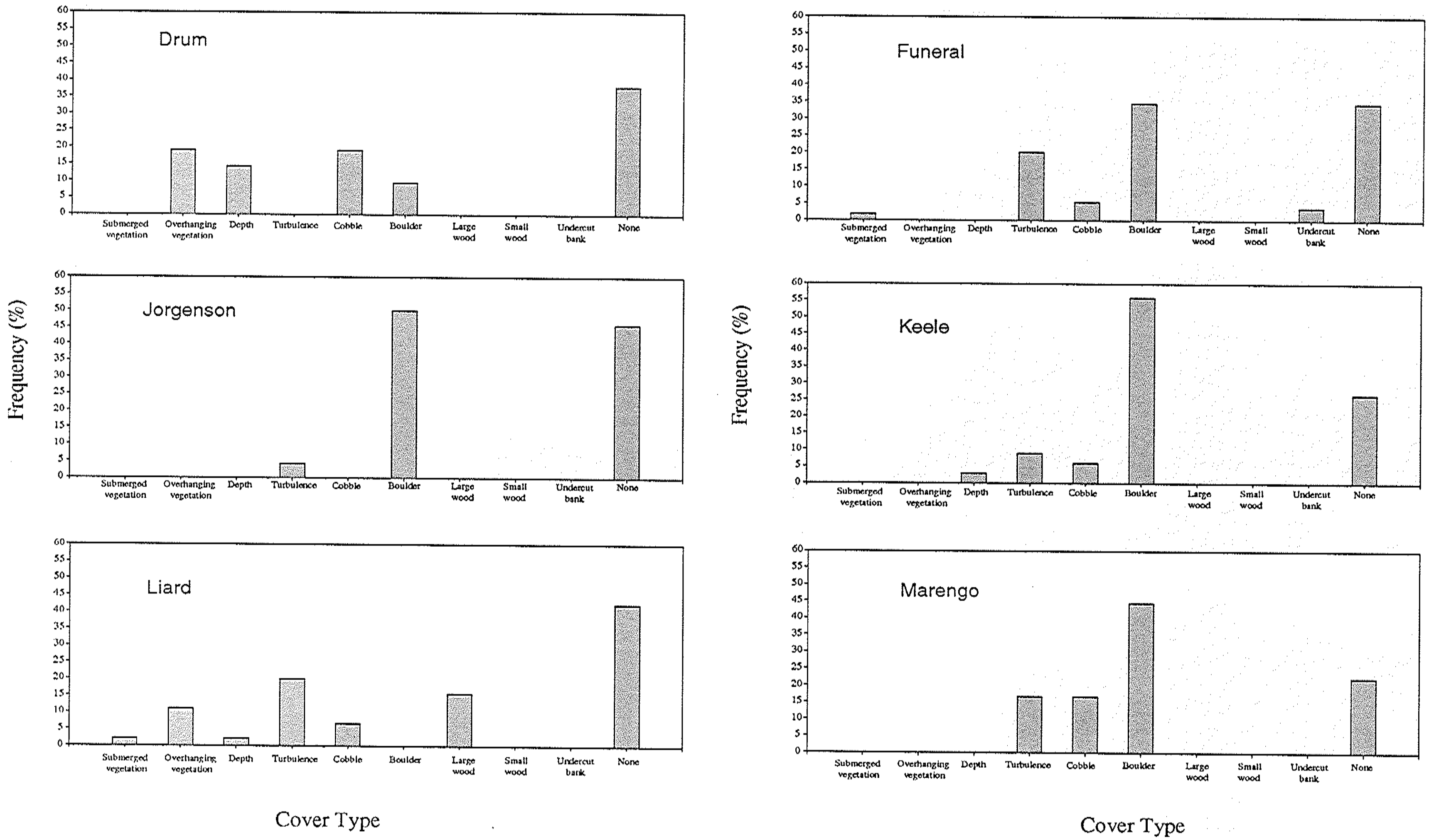

Figure 3.7. Frequency histograms of cover availability for pool, run, and riffle habitats from six streams surveyed in the summer and fall of 2001.

Table 3.5. Number of juvenile and adult bull trout using different microhabitats in Funeral Creek during the summer and fall of 2001. Note that the proportion of total fish caught using each habitat type is reported in parentheses.

Life stage	Pools	Runs	Riffles
Juvenile	19 (32)	2 (3)	39 (65)
Adult	12 (67)	0	6 (33)

Table 3.6. Microhabitat use by juvenile and adult bull trout during the summer and fall of 2001 in Funeral Creek. Values are means for water depth and velocity with standard deviations in parentheses and mode for substrate and cover. Asterisks denote significant differences between juvenile and adult use for a habitat variable.

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

Adults occupied pools and riffles, but were captured in pools most frequently (Table 3.5). Juveniles generally used shallow, high velocity sections of stream with an abundance of small cobble to boulder-type substrate (Table 3.6, Figs. 3.8, 3.9).

Juveniles were commonly found in pocket pools created by boulders and large cobble in these fast-water areas. There was no difference in frequency distributions for juvenile substrate use and availability ($Z = 0.22$; $P < 0.05$, Kolmogorov-Smirnov), but there was a significant difference in cover use and availability for juveniles ($Z = 2.09$; $P < 0.05$, Kolmogorov-Smirnov) (Figs. 3.8, 3.9). Boulders were the most abundant cover in Funeral Creek, however juveniles used cobble almost as often as they used boulders for cover (Fig. 3.9).

Adults used deeper (20 – 40 cm), low velocity (0.1 – 0.3 m/s) sections of the stream with an abundance of cobble to boulder-type substrate (Table 3.6, Figs. 3.8, 3.9). Adults were typically captured in pools and deeper riffles. There was no significant difference in frequency distribution between adult substrate use and availability ($Z = 0.292$; $P < 0.05$, Kolmogorov-Smirnov) or cover use and availability ($Z = 0.776$; $P < 0.05$, Kolmogorov-Smirnov) (Figs. 3.8, 3.9).

Juvenile bull trout were found in shallower water than adults ($U = 190$; $P < 0.05$, Mann-Whitney *U*-test). Although differences in mean bottom velocity use were apparent (Table 3.6), these differences were not statistically significant. There was no difference in substrate use between adults and juveniles in Funeral Creek ($U = 427.5$; $P < 0.05$, Mann-Whitney *U*-test).

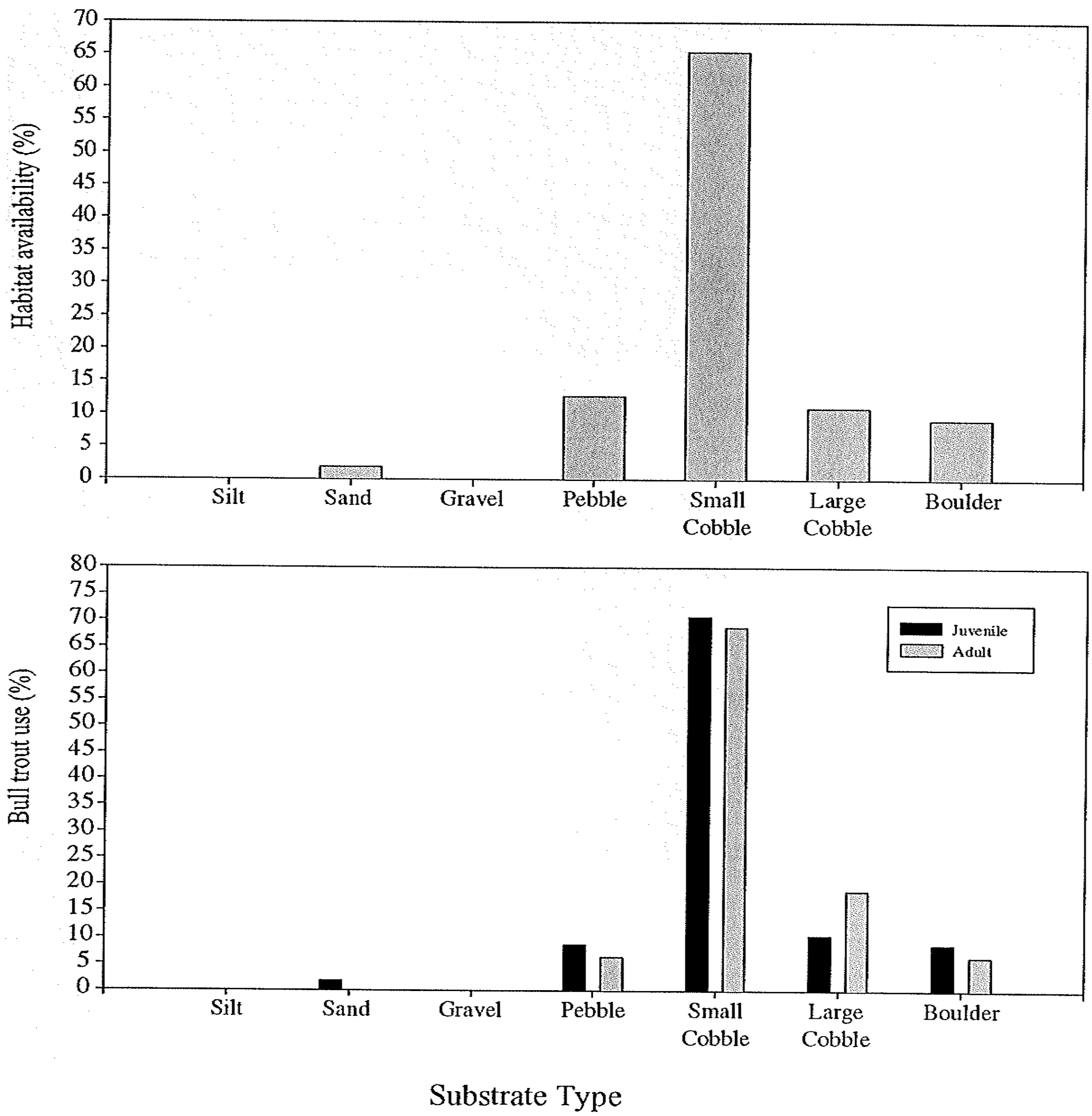

Figure 3.8. Substrate use and availability in Funeral Creek measured during the summer and fall of 2001. Note that the frequency histogram on the top shows substrate availability and the frequency histogram on the bottom shows habitat use by juvenile and adult bull trout.

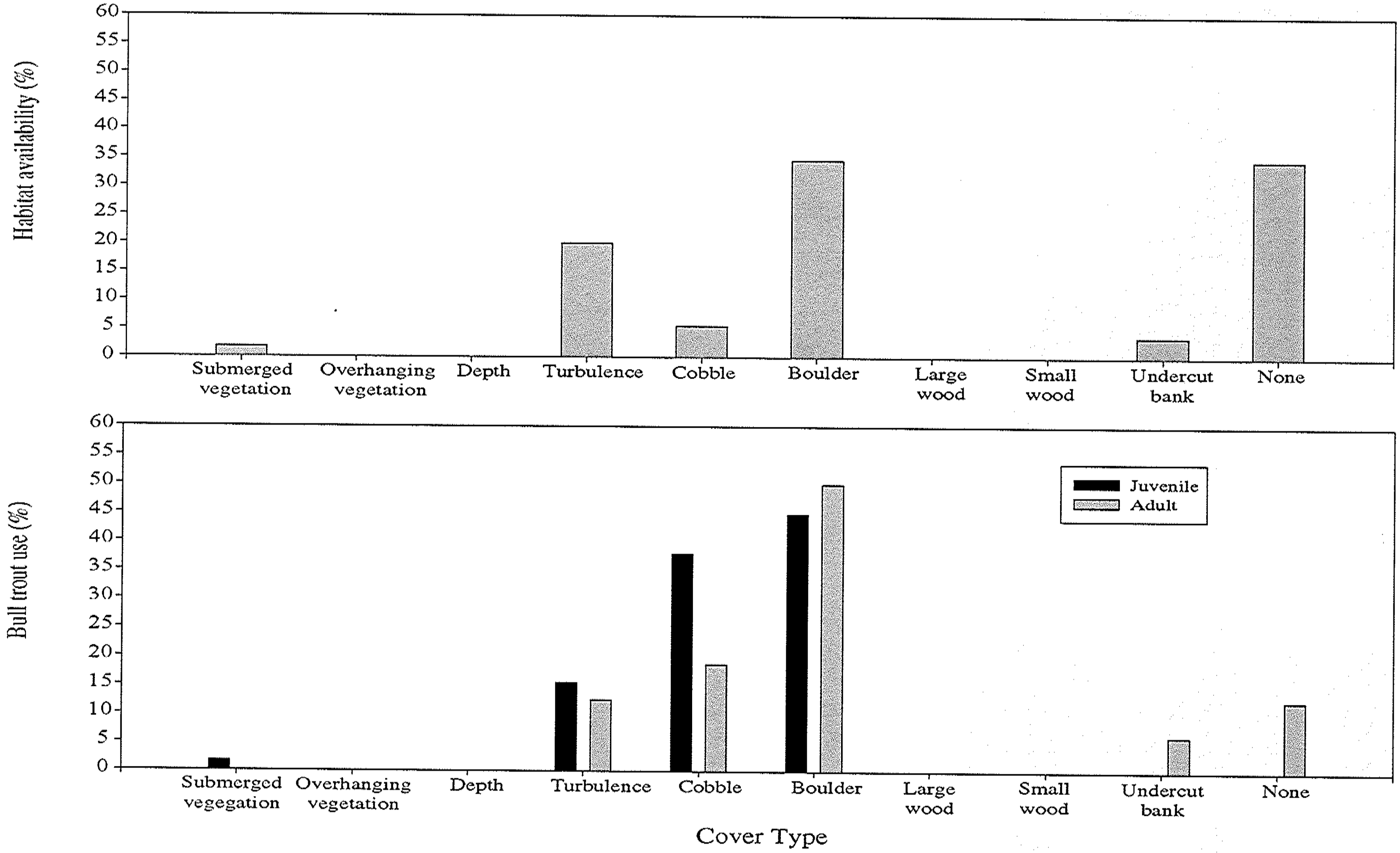

Figure 3.9. Cover use and availability in Funeral Creek measured during the summer and fall of 2001. Note that the frequency histogram on the top shows cover availability and the frequency histogram on the bottom shows habitat use by juvenile and adult bull trout.

3.3. DISCUSSION

3.3.1. DISTRIBUTION AND ABUNDANCE

Although a total of 18 tributaries were sampled across a relatively large geographic area, bull trout were only captured in nine of these tributaries and densities were relatively low (Results, Chapter 2), suggesting that populations are small and occur over large geographic areas in the NWT. This is consistent for bull trout in other areas across the range (Baxter et al. 1999). Small populations found in areas across the range are a result of slow growth, late maturation, and alternate-year spawning behaviour, which are probably adaptations to the harsh environments that these fish inhabit (Ford et al. 1995; Baxter and McPhail 1996). The presence and repeated capture of bull trout in tributaries of Drum Lake, Liard River, South Nahanni River, and Keele River suggest that self-sustaining populations occur in these areas.

3.3.2. LIFE HISTORY

Length-at-age data indicate that bull trout captured from the Liard and Funeral Creek sites have a stream-resident life history and likely spend their entire lives in these small headwater streams. Length data show that the fish caught in Marengo and Jorgenson Creeks were either adults from resident populations or juveniles from fluvial populations. Overall size and growth patterns provide evidence which suggests that fluvial populations occur in the Keele, South Nahanni, and Flat rivers, and an adfluvial population inhabits Drum Lake (Discussion, Chapter 2).

Since bull trout are often migratory fish that move between spawning and feeding areas, it is possible that bull trout could be using any of the study streams as feeding, spawning, rearing, and over-wintering habitat. Given that limited information exists on the distribution and biology for this species in the NWT (Reist et al. 2002), surveys completed in the six tributaries will provide baseline data on distribution, abundance, life history, and habitat use and availability for the region.

3.3.3. Macrohabitat

The six streams surveyed have habitat values which are within the ranges described in the literature for water depth, velocity, substrate, and cover use for bull trout populations across their geographic range (Adams 1994; Saffel and Scarnecchia 1995; Spangler 1997; Hauer et al. 1999). Cobble substrate, which is required for redd construction and is frequently used by juveniles as cover (Baxter and McPhail 1996; Baxter 1997b; Reiser et al. 1997; Saffel and Scarnecchia 1997; Sexauer and James 1997), was prevalent in all streams. However, specific habitat parameters such as large woody debris, demonstrated to be important for adult and juvenile (Baxter 1997b; Hauer et al. 1999) life stages, were limited in many of these streams.

Macrohabitat data show that populations found at higher latitudes in Nahanni Butte and the Mackenzie Mountains occupied a narrow range of habitats compared to those found at lower latitudes. The abundance of bull trout does not appear to be related to substrate and cover diversity among the streams; however, distribution within study streams may be affected by these parameters. For example, the Liard study stream, which is the most southerly site surveyed, had the most diverse substrate and cover habitat available. Bull trout were distributed throughout large reaches (i.e., 2 – 4 km) at this site. By contrast, the Funeral Creek, Drum Lake, and Keele River sites are further north and possess less diverse habitat. Bull trout were found at specific sites in fewer smaller reaches (100 – 200 m) in these streams. These findings suggest that suitable habitat is limited at these sites, and influences the distribution of bull trout in these streams. Reiman and McIntyre (1995) found similar results on a larger scale, suggesting that the area of suitable habitat influences the distribution of bull trout populations in the upper Boise River basin in Idaho.

Bull trout captured in the six study streams used a number of different habitat types based on availability (e.g., Liard study stream), but appear to have specific habitat preferences at each site (e.g., Funeral Creek). The presence of bull trout at particular sites within a stream reflects specific habitat preferences, and is commonly observed in populations from other geographic areas of the range (Baxter and McPhail 1996; Baxter et al 1999; Baxter and McPhail 1999). Bull trout were captured most frequently in two small (100 m) reaches in Funeral Creek. Although most young-of-the-year and juveniles were captured within a 200 m river section, habitat appeared to be relatively homogeneous throughout most of the stream (N. Mochnacz personal observation 2001). This implies that juveniles were selecting specific types of habitats within these small areas, but it is unclear which physical habitat parameters make this site favorable for juveniles.

Young-of-the-year bull trout remain in their natal streams for three to five years before reaching sexual maturity and joining adults in larger lakes or rivers (Goetz 1989; McPhail and Baxter 1996). The presence of young-of-the-year and juvenile bull trout (Table 2.1, Chapter 2) in Funeral Creek suggests that this stream supports spawning and rearing bull trout. The only other location where evidence of spawning was observed was at the Drum Lake site where two juvenile (age 1) bull trout were captured in a tributary stream. The water depth of this stream was extremely low, and the upper reaches were dry, suggesting that this tributary may have been used for spawning in past years but is no longer used because of limited flow.

Based on comparisons to documented spawning streams for bull trout in southern watersheds (see Fairless et al. 1994; Reiser et al. 1997), Funeral Creek and many of the tributaries flowing into Drum Lake have suitable substrate (cobble to boulder), water temperatures (6 – 9° C), velocity, and depth for successful spawning. Other locations, such as Marengo and Jorgenson creeks, have a large proportion of suitable spawning and rearing habitat; however, bull trout were not abundant (< 10). Observing fewer bull trout in these smaller streams should not preclude their importance as spawning and rearing tributaries if suitable habitat exists. Furthermore, as seen in Funeral Creek, bull trout may use specific sites in these tributaries, and limited sampling effort may have precluded capture of juvenile life history stages at these sites. Other salmonid species, such as cutthroat trout, rely on small streams for rearing habitat, which is critical for long-term conservation of these populations (Rosenfeld et al. 2000; Rosenfeld et al. 2002).

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 (Goetz 1989; Baxter and McPhail 1996). Studies suggest that discharging groundwater is a critical habitat characteristic that spawning bull trout seek as it provides a stable incubation environment for eggs during development, and increases spawning success (Baxter and McPhail 1999). Groundwater also provides overwintering habitat in areas where streams typically freeze to the bottom. Although groundwater was not measured in Funeral Creek, discharging groundwater has been observed in streams within the area (Chuck Blight, Nahanni National Park Superintendent, pers. comm. 2002); depth (max = 1 m) is likely not sufficient to prevent many areas of this stream from freezing completely to the bottom during the winter. Since juveniles typically overwinter in their natal streams, it is probable that discharging groundwater is a factor influencing their distribution in this stream.

3.3.4. MICROHABITAT

It has been well documented that adult and juvenile bull trout do not occupy similar habitats (Goetz 1989; McPhail and Baxter 1996; Saffel and Scarnecchia 1995; Baxter 1997b; Goetz 1997; Sexauer and James 1997). Adults tend to inhabit deep slow water areas with an abundance of large cover, whereas juveniles remain in shallow side channels and pocket pools (McPhail and Baxter 1996). Bull trout captured in Funeral Creek showed distinct preferences for specific microhabitats, and habitat use differed for juveniles and adults. Adults were generally found in deep, slow-water areas staying relatively close to large cover (i.e., boulders), whereas juveniles were typically found in shallow, fast-water areas at or near the bottom, close to cover. Although juveniles were frequently found in fast-water habitat, such as riffles, most fish were occupying pocket pools or channel margins, presumably to avoid being swept downstream and for concealment from predators. Saffel and Scarnecchia (1995) reported that juvenile abundance increased as the number of pocket pools increased among four streams in Idaho. Remaining at or near the bottom close to cover is common behavior for juveniles, especially young-of-the-year, and is reported in other systems (Saffel and Scarnecchia 1995; Baxter 1997b; Goetz 1997; Sexauer and James 1997).

The difference seen in habitat use by juveniles and adults is probably a result of size difference, which corresponds to different feeding habits, physical capabilities, and energy requirements for each life stage. Drift feeding salmonids will occupy different hydraulic areas in streams to minimize energy expenditure and maximize energy intake (Fausch 1984; Bisson et al. 1988). As salmonids increase in size, position choice is further constrained by dominance hierarchies, whereby larger dominant fish hold optimal positions (i.e., large pool on the edge of a fast run) and achieve greater growth rates (Fausch 1984). The habitat use by juvenile and adult bull trout observed in this study is consistent with research by Fausch, and is probably a reflection of channel hydraulics and food availability in different habitats.

The water depth and velocities used by juvenile bull trout in Funeral Creek are consistent with those reported in other studies. Baxter (1997b) reported that bull trout fry and juveniles preferred depths between 10 and 40 cm and water velocities between 0.05 and 0.30 m/s. Sexauer and James (1997) found juvenile bull trout at night in water between 10 and 30 cm deep and water velocities from 0.05 and 0.25 m/s.

Juvenile bull trout in Funeral Creek used cobble to boulder substrates, and showed a high preference for boulder and cobble as primary cover types. Sexauer and James (1997) showed that juvenile bull trout used cobble to boulder-type substrates and primarily boulders for cover. Baxter (1997b) reported a high preference by juveniles for rootwads as primary cover followed by cobble and boulders. These studies are consistent with the data from this study, and show that habitat in Funeral Creek is similar to habitat found in other areas.

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 critical 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 (Goetz 1997; Baxter 1997b), and plays a critical role in creating and maintaining stream habitat for salmonids (Elliot 1986; Fausch and Northcote 1992; Hauer et al. 1999). Large woody debris was present in the Liard study stream, yet it was not found in any of the other study streams. Juvenile bull trout in Funeral Creek used cobble substrate for cover more than boulders; however, boulders were more abundant than cobble as cover in Funeral Creek. Microhabitat preferences exhibited by juveniles in Funeral Creek suggest that cobble is a critical cover type which influences their distribution in this stream.

3.3.5. Management

Most streams surveyed in this study are in remote locations and have not been disturbed by resource development activities. However, existing and anticipated resource development activities, such as oil and gas exploration, mining, and forestry, could significantly impact bull trout habitat. Furthermore, it has been demonstrated in other parts of the range that different life history types and life stages within each type have different thresholds for habitat disturbances (McCart 1997; Wissmar and Craig 1997; Baxter et al. 1999). Since productivity is typically low in drainages north of 60° and the growing seasons are short, bull trout populations that occupy streams in northern Canada could have a significantly lower tolerance to activities which disturb habitat. To avoid impacts which could compromise northern bull trout populations, greater care should be taken by managers to maintain and protect these pristine habitats in the north.

Streams that possess habitat within the ranges reported in this study should be monitored carefully during development activities to minimize impacts. In-stream work, such as culvert installation and fords that require bed crossings should be avoided. Watershed impacts that alter the discharge pattern of streams, such as clearcut logging in steep terrain, strip mining, channelization or channel straightening, and damming or diverting flows, should also be avoided. Any development activities which could create barriers (e.g., dams, diversions) separating contiguous bull trout habitat should also be avoided as these practices could create a group of isolated populations. Further, barriers prevent the genetic exchange between meta-populations which may occur in the region (Discussion, Chapter 2).

Despite many studies on bull trout habitat use, few managers have been able to detect specific habitat requirements, especially for spawning life stages (McPhail and Baxter 1996). Although habitat use of bull trout in the NWT is similar to other areas, there are still many unknown habitat parameters which may influence habitat suitability for bull trout in this region. As was evident in Funeral Creek, juveniles have specific habitat preferences. However, habitat preferences for other life stages may differ from habitat parameters determined for more southerly stocks. Thus, more research on microhabitat preferences is needed in this area.

This study has laid the foundation for future research on bull trout in the NWT. Future studies should be designed to: 1) further develop and determine the abundance and distribution of this species, 2) describe microhabitat use, especially for spawning and rearing life stages, and 3) determine the level of connectivity between different life history types and life stages within these types in the context of habitat use and availability. Such information will allow managers to implement conservation plans to protect bull trout populations in northern Canada and prevent declines seen in other areas.

CHAPTER 4.

MANAGEMENT RECOMMENDATIONS FOR BULL TROUT IN THE NORTHWEST TERRITORIES

4.0 INTRODUCTION

Bull trout populations across the range have declined as a result of impacts on populations and their habitat (Ford et al. 1995; McCart 1997; Baxter et al. 1999). This study was designed to acquire information on bull trout distribution and biology in the Northwest Territories (NWT) to prevent declines similar to those seen in other areas. The specific objectives were to determine the distribution, life history, population size, and habitat requirements for bull trout in the region.

Recent work has confirmed the presence of bull trout populations in the NWT; however, for much of the region the distribution and biology of this species is poorly understood (Reist et al. 2002). Managers could use information from this study to improve conservation practices for bull trout populations in areas where existing development activities are widespread (e.g., Fort Liard) and future development activities are forthcoming.

4.1. SUMMARY

The research has highlighted the following results which are important for the management of this species in the area: 1) bull trout populations are small yet more extensively distributed in the region than first thought, 2) populations exhibit different life histories which correspond to various growth patterns, and, 3) habitat requirements are similar to other areas, but site specific habitat preferences are apparent in the study area. The distribution, life history, population size, and habitat requirements of bull trout were examined during the study and are summarized.

4.1.1. Distribution

Bull trout range from just north of the British Columbia-Yukon-NWT border (~60°N) to drainages south of Norman Wells (~64°N) in the central NWT (see Chapter 1, Fig. 1.2; Chapter 2, Fig. 2.1). The presence of self-sustaining bull trout populations was confirmed in the Liard, lower South Nahanni, and Keele River drainages (see Chapter 2, Locations 1, 2, and 3 on Fig. 2.1). Bull trout were the only riverine char captured during the study, which suggests that this species is the dominant char in the study area. These results disagree with previous literature records (1974-80), which identified all chars as Dolly Varden in many of the same water bodies. This discrepancy can be explained by taxonomic confusion of the two species (which were not recognized as formally distinct species by Cavender until 1978), the similar appearance, and previous incorrect identification by non-experts. Local reports also suggest that bull trout populations may occur further north of the Great Bear River, but confirmed captures have not been documented north of this area to date.

4.1.2. Life history

The results from this study show that bull trout populations found in the NWT represent adfluvial, fluvial, and stream-resident life history types (see Results, Chapter 2). Fluvial populations exist in both the Keele and South Nahanni systems, an adfluvial population occupies Drum Lake, and stream-resident populations occur in the Liard and South Nahanni River systems.

The presence of these three life history types was documented across the study region; however, it is unclear if any of these life histories are genetically distinct from one another. If genetic differentiation occurs between life history types, it is likely that genetic exchange may have already occurred between different life history types or could take place in the future. Research on the bull trout assemblage in the Swan River Basin by Baxter et al. (1999) suggests that different populations do exchange genetic material. Adults move to non-natal spawning areas to interbreed with other individuals which has resulted in a metapopulation structure in the basin. Dunham and Reiman (1999) suggested that genetic exchange between populations and possibly life history types is a natural phenomenon across the range. Such exchange helps maintain genetic variability within these populations and increases the likelihood of long-term persistence of populations in variable environments. This process also replenishes or re-establishes populations which may have been reduced or eliminated by stochastic environmental factors. Fragmentation of migratory corridors between different populations can lead to a number of small isolated populations that continue to dwindle over time and ultimately can lead to extirpation. Furthermore, if one or more populations are isolated from regional breeding populations, the susceptibility of the entire population structure to natural and anthropogenic impacts may increase.

4.1.3. Population Size

Bull trout populations found in the NWT during the study were small and relatively widespread, which is consistent for this species (Goetz 1989; McPhail and Baxter 1996 and references therein; Baxter et al. 1999). The exception to this were the stream-resident populations from the Liard and South Nahanni systems, for which larger numbers were found in local areas. In the South Nahanni and Keele River watersheds bull trout were captured in a number of different locations. However, despite significant effort few fish (i.e., < 30) were captured at one location. Bull trout were most abundant in Funeral Creek (n = 78), however, most fish captured were juveniles and substantial fishing effort was allocated to this site because it was identified as a likely spawning tributary.

4.1.4. HABITAT

Habitat used by bull trout in the NWT is similar to that described in the literature for more southerly latitudes such as Alberta (Fairless et al. 1994; Boag and Hvenegaard 1997), British Columbia (Baxter 1997b; Baxter and McPhail 1999), and Idaho (Adams 1994; Saffel and Scarnecchia 1995; Spangler 1997). Most streams that bull trout occupied were characterized by clear, cold water, relatively steep gradients, and an abundance of cobble to boulder-type substrate (see Results, Chapter 3). Also, as observed in other areas across the range, bull trout in the NWT (i.e., north) appear to have specific habitat preferences. Many of the habitat characteristics (i.e., depth, velocity, substrate) of bull trout streams examined in the NWT were similar to those seen in other areas in the range, although some habitat types were not present especially at more northern locations. The lack of large woody debris in streams further north and at higher altitudes in the study area was apparent, and presumably a result of the different vegetative ecozones found in the region. Since bull trout have been shown to use large woody debris for cover in drainages further south of the study area (Baxter 1997b; Hauer et al. 1999), it is likely that northern populations have adapted to use other forms of cover in this area. Fewer typical cover types (i.e., woody debris, undercut banks, aquatic vegetation) were available and the dominant cover used was large substrate. This suggests that populations in the NWT are more dependent upon large substrate for cover than populations found in other areas.

Although a large proportion of suitable habitat appeared to be available in most of the tributaries where bull trout were captured, its distribution was patchy. The low abundance of bull trout in these rivers supports this argument. The areas in which bull trout were captured during the study suggest that fish were using specific areas in each of the study streams and moving through corridors from one suitable habitat to another to carry out life activities (i.e., spawning, rearing, feeding, overwintering). In some situations bull trout were moving from one water body (i.e., river or lake) to another to spawn, feed, or rest. For example, large mature bull trout were tagged in the Keele River during late summer feeding and were observed later in the fall moving upstream into a small tributary stream (Appendix 1, Table A1.3). Upstream migrations by bull trout during the fall typically coincide with movements to spawning locations (see Fraley and Shepard 1989; Stefox and Egan 1995; Baog and Hvenegaard 1997; Hvenegaard and Thera 2001). Reiman and McIntyre (1995) suggested that corridors between patches of suitable habitat are critical for long-term persistence of bull trout populations. Corridors allow fish to move between different habitats and facilitate genetic exchange of material.

4.2. MANAGEMENT RECOMMENDATIONS

The current level of management in the NWT for this species is minimal, partly because bull trout are not considered an important food fish for local people in most areas. However, as a top-level trophic predator in most systems, bull trout are an important component of aquatic ecosystems. Bull trout management in the NWT should be designed to address population and habitat management issues in the region. The following management recommendations should be considered in future management plans for this species.

1. Education programs/workshops with corresponding posters for biologists, First Nation fishers, sport fishers, consultants, and industry are needed to provide information on in-field identification criteria, known distribution for bull trout in the NWT, and sensitivity of this species to impacts.
2. Regional monitoring programs should be conducted annually to learn more about distribution, local movements, habitat use, and abundance. Such activities should be conducted to minimize adverse effects on bull trout populations.
    - 2.1. Reward programs for captured bull trout should be implemented to obtain information on distribution from local fishers, sport fishers, consultants, and industry.
    - 2.2. Floy-tagging programs are needed in areas where known populations occur, to learn more about local movements, life history, growth, survival, and annual recruitment.
    - 2.3. Mark-recapture programs can be incorporated with tagging programs to estimate population size.
    - 2.4. Radio-tagging programs are needed to locate spawning streams and identify redds. Once spawning sites are located, adults can be enumerated, using either conduit weirs or hoop nets in the fall.
3. Sport fishing for this species should not be allowed during the spawning season, which occurs between mid August through to the end of October. Such seasonal

fishing closures should be reflected in the Northwest Territories Sport Fishing Regulations. Seasonal fishing closures will be important in areas where tourist activity could be high, such as Nahanni National Park Reserve. Managers in these areas should also consider implementing catch size restrictions to protect adults and the use of barbless hooks only in these systems.

4. Currently, bull trout populations which occur in the NWT are recognized by the Government of the Northwest Territories as a species which "May Be at Risk". However, this designation does not protect the species and their habitat. Consequently, the listing should be upgraded to "Species at Risk" status, because populations are small, and little is known about the biology of this species in the region. To effectively prevent population declines similar to those of other regions, this species will require protection under the federal Species at Risk legislation. Once formally listed as a "Species at Risk", appropriate research programs can be implemented to obtain the necessary information to protect this species. After sufficient data on distribution and biology is obtained, the species can be downgraded to a lesser designation if research results show that the species is worthy (i.e., populations are stable or increasing) of such listing.
5. Future research programs are necessary which focus on the distribution, life history, habitat requirements, population size, and genetic relationships of northern populations.
6. Development activities planned in known spawning and rearing areas should be relocated. If development projects cannot be relocated appropriate mitigation

procedures should be implemented to minimize impacts to habitat (see recommendations below).

7. In watercourses that are within the present known range but do not have documented bull trout captures, habitat biologists should use the precautionary principle (Minns 1997). Proponents of development activities should be responsible for conducting a survey of the watercourse to determine if fish inhabit the area and assess habitat potential for those species. If bull trout and associated species are discovered, then the mitigation measures outlined below should be implemented during development to minimize impacts to fish habitat.
   - 7.1. In stream work should be avoided in areas with discharging groundwater, water depths ranging from 10 to 60 cm, water velocities ranging from 0.1 to 0.6 m/s, and/or cobble to boulder-type substrate (i.e., total length of 64 to 256 mm).
   - 7.2. Bed stream crossings such as fords and temporary ramps and in-stream work (e.g., culvert installation) should be avoided.
   - 7.3. Watershed impacts, such as clear-cut logging in steep terrain, strip mining, backfilling, channelization or channel straightening, and damming or diverting natural water flow, which could alter the discharge pattern and sediment input of streams, should be avoided.
   - 7.4. Ice bridge construction should maintain regular stream flow and fish passage, use only clean snow for backfill to minimize release of sediments into the watercourse, and use mushroom shoes or boots on all bladed vehicles.

7.5. Any development activities that require temporary (e.g., coffer dams) or permanent barriers (e.g., dams, diversions) should not be used as these may block migratory corridors, and adversely affect highly connected populations within a watershed.

8. Habitat research programs are needed to learn more about habitat use and availability for all life history types and stages within each type.

9. Ecosystem management projects should be designed with bull trout as the primary indicator species for habitat quality and ecosystem integrity. Managers could associate the presence of abundant, well-structured year classes from bull trout populations (i.e., healthy populations) with excellent ecosystem quality. Conversely, year-class losses and (or) declines within populations would be an indication of marginal ecosystem quality reflecting an impact to the watershed.

9.1. A pilot program in the South Nahanni River watershed could be conducted to test the effectiveness of bull trout as an ecosystem management tool in this area. A documented self-sustaining population has been found at Funeral Creek, and it is apparent that other populations occur in the region. These populations could be studied for one more season, and then the following year monitoring of one or more populations could commence. The Funeral Creek population is ideal for such a program because it is located near a proposed zinc mining operation. This population and others in the area would be excellent candidates for this project because they could be compared over time to assess environmental impacts on the aquatic ecosystem.

The preceding programs should be implemented by the Department of Fisheries and Oceans (DFO) and the Government of the Northwest Territories Resource, Wildlife, and Economic Development Department. Costs associated with research and monitoring programs are substantial as most populations occur in areas accessible only by aircraft or boat. However, these costs are not unmanageable if logistic and financial resources are pooled between government agencies. Sampling should be coordinated with similar activities in areas where bull trout populations occur. Education programs and reward programs for fish can be financed and managed through Federal and Territorial departments.

Developing and implementing these programs will require a collaborative effort across the region between different groups and organizations. Government agencies (e.g., DFO, Parks Canada Agency, RWED), First Nation communities, consultants, and private industry must work together to implement programs to conserve and protect northern bull trout populations. Cost sharing between organizations will allow larger research and monitoring projects to be implemented in a timely fashion.

Habitat protection and research should be implemented by the DFO Fish Habitat Management division. Fish Habitat Biologists must submit requests for research programs to be implemented by proponents prior to development activities in areas where little is known about fish and fish habitat. The cost of fish habitat research should be the responsibility of industry and accepted as a cost involved with development in the north.

4.2.1. Conclusions

The recommendations and proposed management methods should serve as the first step towards a proactive management process for bull trout in the NWT. Managers can prevent population declines similar to those seen in other areas for northern bull trout populations if appropriate research and management programs are implemented. Future research should focus on areas where known populations occur, and future work must be developed and implemented in areas where the biology and distribution of bull trout are poorly understood. Bull trout research and management will require a long-term commitment and monitoring well into the future. The long-term goal is to decrease uncertainty of our knowledge for bull trout populations in the region, and provide more effective management based on knowledge from research and monitoring programs.

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APPENDIX 1

BIOLOGICAL AND HABITAT DATA FOR BULL TROUT (*SALVELINUS CONFLUENTUS*) AND ASSOCIATED SPECIES FROM STREAM SURVEYS CONDUCTED IN THE SOUTHERN AND CENTRAL MACKENZIE RIVER VALLEY, NORTHWEST TERRITORIES, 2000 TO 2001.

Biological and habitat data for bull trout (*Salvelinus confluentus*) and associated species from stream surveys conducted in the southern and central Mackenzie River Valley, Northwest Territories, 2000 to 2001.

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2003

ABSTRACT

In the summer and fall of 2000 and 2001 stream surveys were conducted in 18 different tributaries from three major river systems in the southern and central Northwest Territories. Biological data for all species sampled during the two-year study are presented, with emphasis on bull trout. Habitat surveys were completed in six tributaries from the study area. General physical stream features were documented in these six streams, and physical attributes of habitat were also described in Funeral Creek at specific positions where bull trout were captured. The data presented in this report confirm the presence of bull trout in nine tributaries throughout drainages in the southern and central Mackenzie Valley. Results suggest that bull trout populations are small but wide ranging, using a variety of habitat types over a large geographical area. Much of the habitat that bull trout occupy in this region is similar to habitat in the southern part of their distribution. Complete data are provided for both biological sampling and habitat measurements taken during the study.

INTRODUCTION

The bull trout, *Salvelinus confluentus* (Suckley) is a native char found throughout western North America. West of the continental divide, the species' distribution originally extended from northern California (~ 41° N) and Nevada (McPhail and Baxter 1996), throughout central British Columbia, north into the southern Yukon Territory (Cavender 1978; Haas and McPhail 1991). East of the continental divide the distribution extended from northern Montana and throughout much of western Alberta (Nelson and Paetz 1992; McPhail and Baxter 1996; Fitch 1997). Peripheral populations in 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). A decline or absence of local populations has also been observed in Alberta (McCart 1997), and there is evidence of drastic declines in several local populations in Nevada, Washington, and British Columbia (Haas and McPhail 1991; McPhail and Baxter 1996).

Such declines have led to formal listings of bull trout as "threatened" within the coterminous United States (U. S. Fish and Wildlife Service 1999) and "sensitive" in Alberta, British Columbia, and the Yukon Territory (Canadian Endangered Species Conservation Council 2001). Bull trout are considered a species that could be at risk of extinction or extirpation in the Northwest Territories (NWT), and are a candidate for a detailed risk assessment (Government of the Northwest Territories, Department of Resources, Wildlife and Economic Development 2000). Impacts 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 (Ford et al. 1995; McCart 1997; Baxter et al. 1999). The present distribution extends from the northwestern United States (~ 42°N) throughout interior drainages of British Columbia, western Alberta, and the southern Yukon Territory, north throughout the south-central Mackenzie River valley, NWT (~ 64°N) (Fig. A1.1; Haas and McPhail 1991; Reist et al. 2002).

Recent work has confirmed that bull trout populations are more widespread than first thought in the NWT. Captures from locations east and west of the Mackenzie River confirmed the presence of this species approximately 500 km north of the previous northernmost known distribution (Fig. A1.1; Reist et al. 2002). Repeated capture of bull trout at these locations suggests that these fish are part of self-sustaining populations rather than strays from southern watersheds. However, the actual distribution and biology of bull trout populations occurring in the NWT are poorly understood (Reist et al. 2002). Furthermore, taxonomic confusion between bull trout and Dolly Varden (*Salvelinus malma*) in the past, and lack of clear, easily applied criteria for identification, have resulted in mis-identification of chars throughout the region.

In 2000, the Department of Fisheries and Oceans (DFO), Arctic Fish Ecology Assessment and Research section developed a two-year study designed to acquire distributional and biological information for riverine (fluvial) chars, specifically bull trout in watersheds of the southern and central NWT. The project was implemented during the summer and fall of 2000 and 2001 with assistance from DFO Fish Habitat Management and the Fisheries Management staff in the region. The intent of the work was to provide information to habitat managers that can be utilized when conducting environmental assessments of development proposals. If areas, times of use, and habitats are identified that may be sensitive for particular fish species, projects can be planned so these are avoided and thereby minimizing disturbance. The study will also provide fisheries managers with information on the distribution and biology of bull trout populations and associated species in the NWT. The two-year study was completed in the fall of 2001, and this report provides a compilation of habitat and biological data for bull trout and associated species captured during the two-year study.

MATERIALS AND METHODS

BIOLOGICAL DATA COLLECTION

Stream surveys were conducted in 18 different tributaries from the Keele, South Nahanni, and Liard river systems (Fig. A1.2). Fish were captured using a Smith-Root Type VII POW backpack electroshocker, angled using barbless hooks in larger tributaries where depth and flow prevented wading, and fished with multimesh gillnets in deep, low velocity areas. In 2000, streams were sampled in areas which char (i.e., bull trout and/or Dolly Varden) were reported to occur by local people or by consultants and government agencies that have worked in the region. In 2001, streams known to contain bull trout were stratified into lower, middle, and upper reaches and 200 – 500 m stretches were electrofished.

Population estimates of bull trout were completed at four randomly selected reaches (~200 m) in Funeral Creek (61° 36' N, 124° 48'W) using the Zippin three-removal method (Zippin 1958). Funeral Creek was the only stream where population estimates were conducted, as this watercourse was the only safely wadable site where bull trout were caught consistently during the study. Each reach was blocked at the lower and upper boundary by seine nets to prevent fish movement into and out of the sampling area. Three consecutive electrofishing passes were performed in an upstream manner and the number of bull trout captured during each pass was recorded. Approximately twenty minutes elapsed before subsequent electrofishing passes were conducted in each reach. The number of bull trout captured during each pass was entered into the "Microfish" program which calculates the maximum-likelihood population size estimates at 95% confidence intervals based on the number of fish captured on each electrofishing pass (Van Deventer and Platts 1989).

To minimize research impacts on the populations a combination of live- and dead-sampling was conducted. The data collected for each differed as described below.

LIVE SAMPLING

At each sampling location all fish captured were identified to species prior to release. Due to time and resource limitations during the study, biological data were only collected for randomly selected fish of species other than char. All char captured were held in a fish bag, which is a long tubular bag with mesh on the anterior and posterior ends to ensure water circulation. Fish bags were securely anchored in slow moving water to provide a well oxygenated holding facility before and after biological sampling. Biological data, which included fork length (nearest mm), weight (nearest g), sex and maturity state, were documented where possible. Life history type and life stages were assigned to bull trout based on external characteristics, such as size, colour, and presence of parr marks. All bull trout > 200 mm were fitted with an individually numbered Floy-tag inserted at the base of the dorsal fin between the posterior basal pterygiophores. A portion of the adipose fin was removed for genetic analysis and as a secondary marking method. The first fin ray was removed from the left pelvic fin to evaluate the effectiveness of non-lethal ageing using this structure. Once biological data were recorded and structures were taken, bull trout were placed back into the fish holding bag to recover and then released at the same location that they were originally captured.

DEAD SAMPLING

In locations where bull trout were captured, a limited number of fish were sacrificed for confirmation of species' identity and to acquire additional biological information. Char retained from field sampling were frozen whole and shipped to DFO in Winnipeg. These char were compared to positively identified bull trout to confirm species' identify from qualitative morphological criteria described in literature (Cavender 1978; Haas and McPhail 1991; Nelson and Paetz 1992; Reist et al. 2002). A linear discriminant function (LDF) shown to be 100% effective in distinguishing Dolly Varden from bull trout (Haas and McPhail 1991) was used to confirm the identity of all char captured. The linear discriminant function is based on four variables; branchiostegal ray number, anal ray number, and the ratio of total upper jaw length to standard length. These variables are used in the following equation to determine LDF scores for individuals:

$$LDF = 0.629N_b + 0.178N_a + 37.310\ L_j/L_s - 21.8$$

Where:

LDF	=	Linear Discriminant Function score
N_b	=	Total number of branchiostegal rays
N_a	=	Total number of anal fin rays
L_j	=	Total length of upper jaw
L_s	=	Standard length of fish

All fish with LDF scores greater than 0 are bull trout, and scores less than 0 are Dolly Varden.

Mitochondrial DNA (mtDNA) analyses (Baxter et al. 1997) were run on tissue samples from 114 char specimens, which included the 42 samples used in the LDF analyses, by individuals from the fish genetics laboratory at the Freshwater Institute in Winnipeg. Ribosomal DNA (rDNA) analyses (Baxter et al. 1997) were run on ten tissue samples, which were also included in both mtDNA and LDF analyses, by individuals from the genetics laboratory at the University of British Columbia. The identification results of voucher specimens examined in the laboratory were accepted if two or more of the analyses (i.e., morphological, mitochondrial DNA, LDF, ribosomal RNA) were in agreement.

Morphometric and meristic measurements were completed for all dead-sampled specimens. Morphometric measurements were measured to the nearest 0.1 mm and included: preorbital, orbital and postorbital lengths; interorbital width; trunk, dorsal, lumbar, anal and caudal peduncle lengths; head, body and caudal peduncle depths; maxillary length and width; pectoral, pelvic and adipose fin lengths; middle gill raker length, and lower arch length (Reist et al. 1997). Meristic variables that were counted included: dorsal, anal, pectoral, and pelvic principal fin rays; upper and lower gill rakers; and pyloric caecae. Biological variables documented included; standard and fork lengths (nearest mm), weight (nearest g), sex and maturity, gonad weight (nearest 0.1 g), stomach content analysis, and age determination (Reist et al. 1997). Sexual maturity was determined by internal examination of gonads and each fish was assigned a maturity code

(Table A1.1). Stomachs were examined and contents were described as fish, aquatic insects, or terrestrial insects.

Fish were aged using whole and sectioned otoliths. The whole otoliths were placed in distilled water and viewed under a microscope with reflected light. Age was estimated by counting opaque and dark bands (annuli), which represented one year of growth; opaque bands correspond to fast growth in the summer, and darker bands are a result of slower winter growth (Secor et al. 1992). Once ages were determined for whole otoliths, one otolith from each fish was embedded in epoxy-resin and left in a fume hood for seven days to harden. Once the resin was hard, embedded otoliths were cut into thin transverse sections through the sulcus on the dorsal-ventral axis with a diamond saw. The sections were viewed under a microscope with reflected light and annuli were counted to determine ages.

HABITAT DATA COLLECTION

During the summer and fall of 2001 habitat surveys were conducted in six study streams to describe bull trout habitat use in the region. The objective was to describe general stream features where bull trout have been captured and to determine specific habitat use at the habitat-unit level.

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 specific positions where fish are captured (Goetz 1997). Macrohabitat was quantified from randomly sampled habitat units (pool, run, riffle) in each study stream regardless of bull trout presence or absence. Microhabitat was quantified only at sites where bull trout were observed or captured in the stream.

MACROHABITAT DATA COLLECTION

Habitat data were obtained from 81 pools, 55 runs, and 61 riffles that were randomly sampled from 22 reaches in six streams. 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 long 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 the hydraulic characteristics of each stream; however, habitat was not classified at a scale beyond the pool, run, and riffle level.

To determine physical features of each habitat unit, three equidistant transects were placed parallel as well as perpendicular to water flow within each habitat unit. The transects running parallel with river flow crossed those running perpendicular to flow and resulted in a grid with nine points in each habitat unit. At points where the transects crossed, depth, velocity, substrate, and cover were measured giving nine measurements for each variable. Depth was measured with a meter stick, and 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 (Table A1.2), and cover was estimated visually at each point according to a ranked classification scale (Table A1.3). 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 zero depth (cm) at each bank (Platts et al. 1983). The mode was determined for substrate and cover in each habitat unit.

MICROHABITAT DATA COLLECTION

Microhabitat data were collected in Funeral Creek during September 2001. A two-person crew electrofished two randomly selected reaches (200-300 m). Each time a bull trout was captured a weighted blue or orange marker, representing either juvenile or adult 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 based on size-at-age data for sacrificed individuals from the stream. Three transects, parallel as well as perpendicular to flow, were placed in each habitat unit where bull trout were captured, and depth, velocity, dominant substrate and cover were recorded at nine points as described above.

RESULTS

Common and scientific names with corresponding abbreviations for all species captured are presented in Table A1.4. Table A1.5 shows location information, number of fish tagged and released, number of fish dead-sampled and the species for all fish captured during the 2000 and 2001 sampling seasons. Ten different species were captured during stream inventories. Arctic grayling (*Thymallus arcticus*) and bull trout were the most widely distributed species captured at most sampling sites. Arctic grayling were most abundant in Bluefish Creek where more than 300 individuals, representing many different age classes, including juveniles, were captured. Since grayling were abundant in this stream, only a sub-sample of the catch was measured for length and weighed. Table A1.6 summarizes the biological data obtained for all species captured from the NWT in 2000 and 2001.

Bull trout were captured in nine of the 18 streams surveyed (Fig. A1.2). Biological data for bull trout that were both live- and dead-sampled during the 2000 and 2001 field seasons are presented in Table A1.7. The majority of bull trout (n = 78) were captured from Funeral Creek. Quantitative and qualitative data from the bull trout sampled during this study, and used to identify char captured in 2000 and 2001, are shown in Table A1.8. These data include morphometric and meristic data used for the LDF and qualitative data based on external characteristics for bull trout described in literature. Qualitative data from bull trout sampled during the study, which included eye position, upper jaw shape and length, head shape, and head size, were consistent with bull trout described in the literature. Most of the char sampled had eyes positioned close to the top of the head, a long decurved upper jaw, and a large relatively flat, triangular-shaped head. Most char measured had LDF scores that suggested they were bull trout; however, a few had scores that corresponded to those observed for Dolly Varden. Also presented are mitochondrial and ribosomal DNA analyses, which include genetic identification of each char sampled. Mitochondrial DNA analyses show that all char captured were bull trout. Results from ribosomal DNA analyses suggest that seven of the char are bull trout and three could be Dolly Varden/bull trout hybrids (Table A1.8).

Population estimates for the Funeral Creek bull trout population are presented in Table A1.9. The data suggest that the adult and juvenile populations are small compared to other more prolific species (e.g., grayling). Habitat data by location are summarized for all study reaches and are presented in Table A1.10.

DISCUSSION

Based on the genetic and morphometric analyses, all char captured during the study were bull trout. All of the char with LDF scores corresponding to Dolly Varden values were juveniles and in some cases young-of-the-year fish. The LDF has an inherent bias by design, because all meristic counts are highest for bull trout. This implies that if errors in counts are made, which is not uncommon with small fish, they usually result in lower scores and coincide with inaccurate identification of bull trout as either hybrids or Dolly Varden. Since the LDF is very sensitive to branchiostegal ray counts, and most of these counts were difficult to perform accurately for small fish, it is likely that the individuals designated as Dolly Varden are actually bull trout. It is also possible, especially for young-of-the-year (YOY) fish that complete development of these meristic traits had not occurred. The only evidence that suggests Dolly Varden were present in the study area are the rDNA results. However, the sample size of char examined during the trial was extremely low and hybrids were only detected in one of three enzyme markers. In two out of three occurrences of hybrids at enzyme markers the signal was faint making these results suspect. Furthermore, a larger sample (n =114) of mtDNA was run and no samples showed any evidence that any of the char captured were Dolly Varden.

Arctic grayling were the most abundant species found during the study. In Bluefish Creek juvenile grayling were abundant (> 300) suggesting that this tributary is likely a spawning and rearing area. Not as many bull trout were captured as grayling in most sites. This is likely a reflection of the species' biology, as bull trout generally inhabit deep pools making capture difficult and top trophic-level predators are rarely as abundant as lower trophic-level prey species. The only location where bull trout were relatively abundant was in Funeral Creek; however, the higher density observed is likely a result of sampling effort allocated to this site. Since Funeral Creek was identified as a spawning tributary a large proportion of sampling effort was allocated to this area. Despite fishing more than half of the stream on two separate occasions in the late summer and fall, the number of adults captured was low (n = 16) suggesting that this population is relatively small.

The presence of young-of-the-year and juvenile bull trout in Funeral Creek suggests that this stream is used for spawning and rearing. Funeral Creek is a high-gradient mountain stream with predominantly cobble to boulder-type substrate. Given that discharging groundwater is common in this area (Chuck Blight, Nahanni National Park Superintendent, pers. comm. 2002) and relatively deep pools (> 1 m) are present in this stream, fish are likely able to overwinter at this location. Further, groundwater upwellings are frequently associated with bull trout redds and increase spawning success as they provide stable water temperatures for incubating eggs (Baxter and McPhail 1999).

Bull trout prefer small, high-gradient mountain streams with cobble to boulder-type substrate. Adults were associated with some type of large cover (e.g., undercut banks, deep pools, boulders) during the day. Juveniles were found most frequently in high velocity habitats at or near the bottom in pocket pools created by large cobble and boulders. Cover use appeared to be dictated by latitude and elevation as the cover type diversity (e.g., woody debris) tended to decrease in sample sites further north and at higher elevations. In all study streams, a large proportion of suitable spawning and rearing habitat was present. However, in Funeral Creek only a small area appeared to be used by juveniles, which suggests that these fish have specific habitat preferences. Similar site specific habitat requirements could be prevalent for populations in the north and warrant further investigation.

CONCLUSIONS

This two-year study has laid a foundation for future research on bull trout and associated species for streams in the southern and central NWT. Information obtained during the study indicates that bull trout populations are small, but wide ranging using a variety of habitat types over a large geographical area. Care must be taken to prevent impacts to bull trout habitat by ensuring that industrial development does not occur in or around such tributaries. It is also important to recognize that many of these watercourses likely provide critical spawning and rearing habitat for bull trout and other species. Protecting these areas will be essential for effective management of bull trout and associated species throughout the NWT.

ACKNOWLEDGEMENTS

This project was directly supported in 2001 through funding received from Fisheries and Oceans Canada and the Habitat Stewardship Program for Species at Risk sponsored by the Government of Canada. Funding and in-kind support was also provided by Parks Canada Agency, Fisheries and Oceans Canada, the Northern Scientific Training Program, Manitoba Wildlife Federation, Government of the Northwest Territories, Department of Resources, Wildlife and Economic Development, Tulita Renewable Resource Council, Nahanni Butte Renewable Resource Council, and the Natural Resources Institute. Robert Bajno and Anna Elz are thanked for preparing and analyzing the samples for the genetic component of this project. E. Taylor is thanked for providing the resources to analyze the samples at the University of British Columbia. Special thanks to L. Bataille, K. Bourassa, K. Cott, J. Demers, K. Ditz, K. Hickling, M. Low, A. Nande, G. Sibbeston, D. Tate, B. Vital, M. Vital, and S. Weaver for assistance in the field. Dr. R.K. Baydack, Dr. P.J. Blanchfield, P. Hvenegaard, and Dr. K.W. Stewart provided valuable technical assistance and advice that was integral for this project. Comments by K. Cott and S. Stephenson improved the manuscript.

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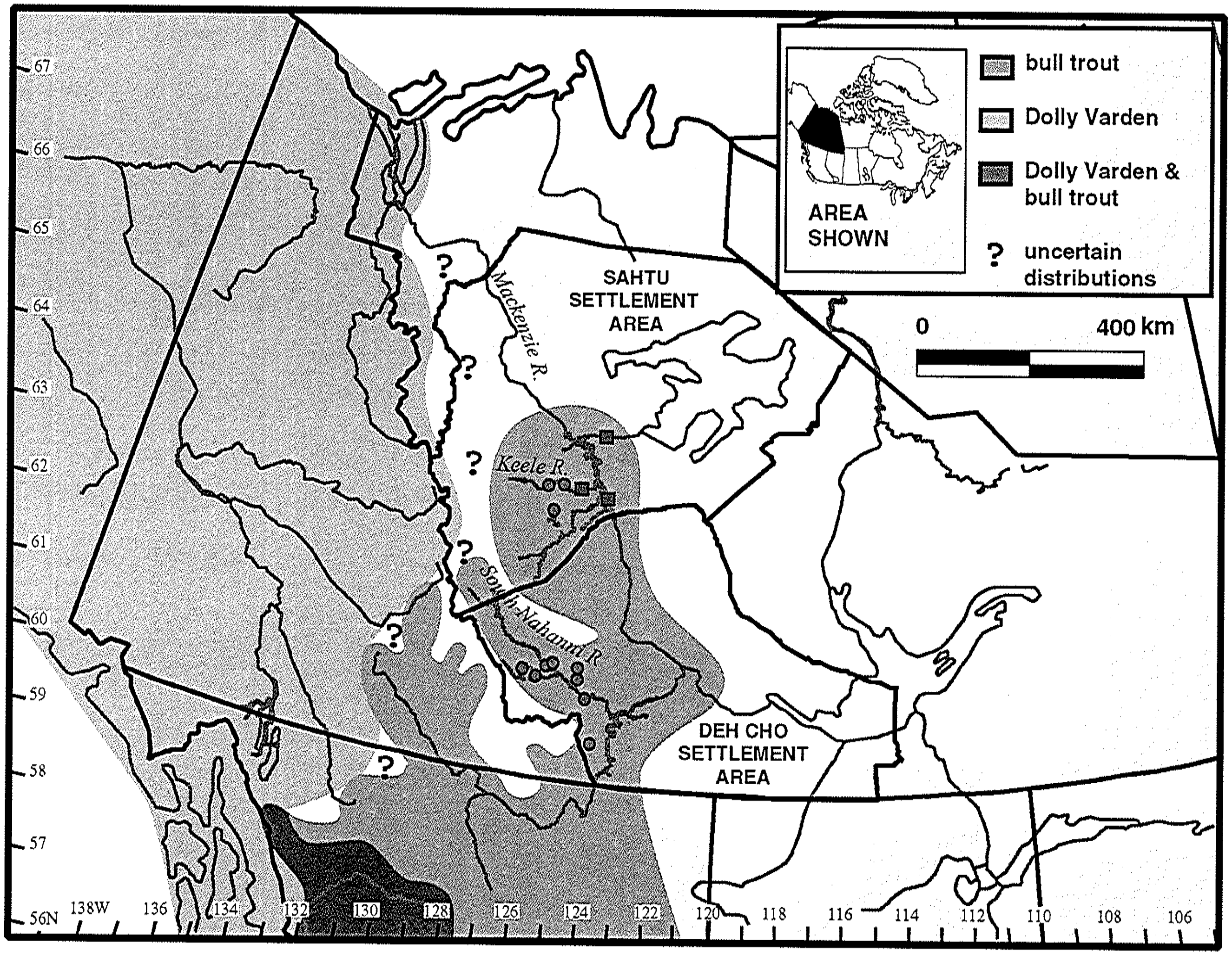

Figure A1.1. Distribution of bull trout and the related char, Dolly Varden, in Northwestern Canada showing locations of confirmed bull trout captures (● Mochnacz 2002; ■ Reist et al. 2002) in the Northwest Territories.

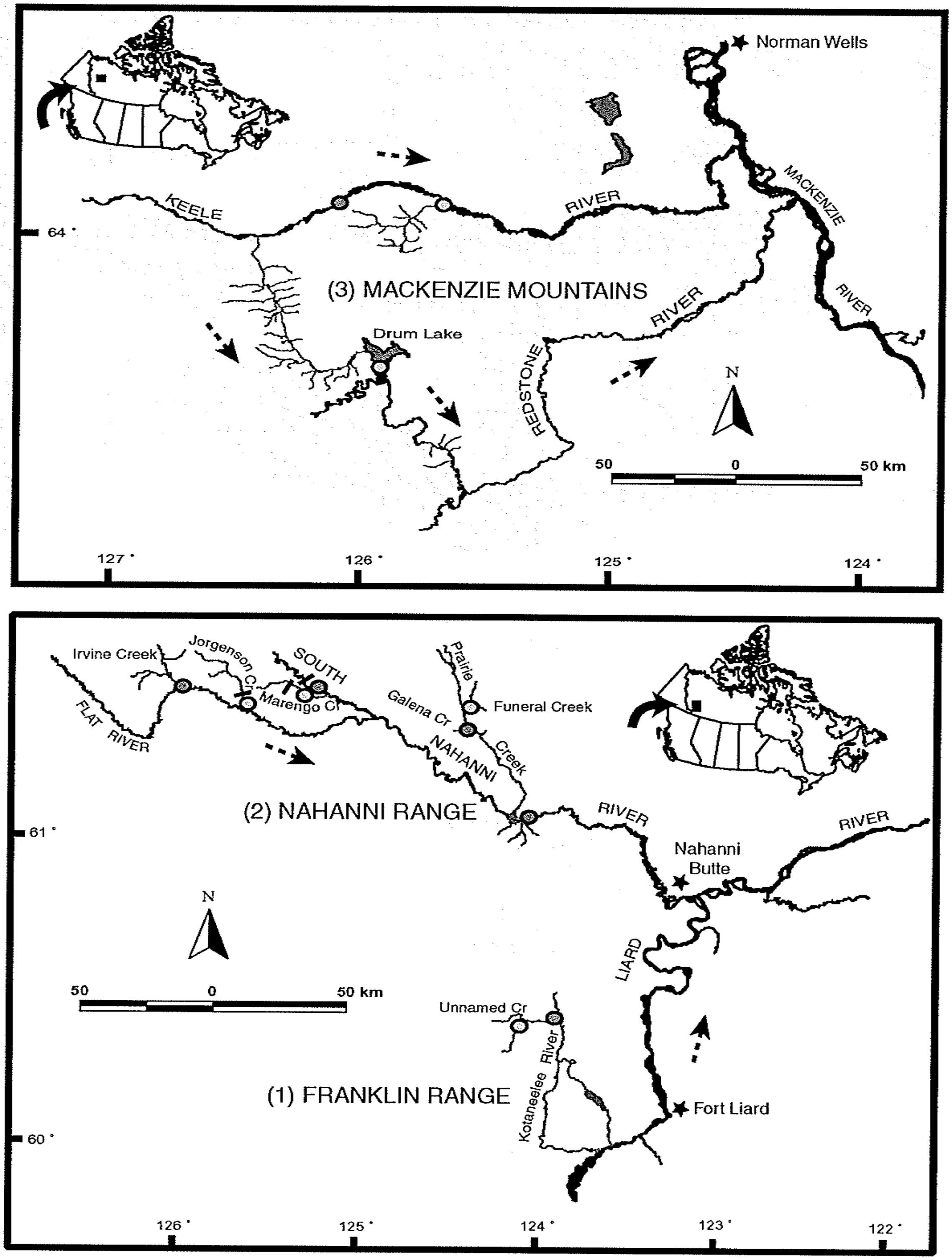

Figure A1.2. Study sites showing habitat (◎) and sampling sites and locations where bull trout were captured (◉ & ○) in the central (top) and southern (bottom) Northwest Territories. Note that dashed arrows show flow direction, "/" represent impassable falls, and only partial drainages are shown for clarity.

Table A1.1. Sexual maturity codes assigned to char captured during the study (McGowan 1992).

Maturity State	Male – 1	Female – 2
Immature	06 – testes long and thin, tubular and scalloped shape, up to full body length, putty-like firmness	01 – ovaries granular, hard and triangular, up to full length of body cavity, membrane full, eggs distinguishable
Mature	07 – current year spawner, testes large and lobate, white to purplish in cooler, centers may be fluid, milt not expelled by pressure	02 – current year spawner, ovary fills body cavity, eggs near full size but not loose and not expelled by pressure
Ripe	08 – testes full size, white and lobate, milt expelled by slight penetration	03 – ovaries greatly extended and fill body cavity, eggs full size and transparent, expelled by
Spent	09 – spawning complete, testes flaccid with some milt, blood vessels obvious, testes violet-pink in colour	04 – spawning complete, ovaries ruptured and flaccid, developing oocytes, visible, some retained eggs in body cavity
Resting	10 – testes tubular, less lobate, healed from spawning, no fluid in center, usually full length of body, mottled and purpulish in colour	05 – ovary 40 – 50% of body cavity volume, membrane thin and semi-transparent, healed from spawning, developing oocytes apparent with few atretic eggs, some eggs may be retained in body cavity
Unknown (virgin)	0 – cannot be sexed, gonads long or short and thin, transparent or translucent	
Unknown (non-virgin)	11 – resting fish, has spawned but gonads regenerated, or sexing not possible	

Table A1.2. Categories used to define substrate composition for habitat surveys in this study.

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 A1.3. Cover classification defining types used for habitat surveys in this study.

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

Table A1.4. Fish species captured during stream surveys in the Northwest Territories, 2000 and 2001.

Common Name	Scientific Name	Abbreviation
Arctic grayling	*Thymallus arcticus*	ARGR
burbot	*Lota lota*	BURB
bull trout	*Salvelinus confluentus*	BLTR
inconnu	*Stenodus leucichthys*	INCU
lake chub	*Couesius plumbeus*	LKCH
longnose sucker	*Catostomus catostomus*	LNSC
mountain whitefish	*Prosopium williamsoni*	MTWH
northern pike	*Esox lucius*	NRPK
slimy sculpin	*Cottus cognatus*	SLSC
white sucker	*Catostomus commersoni*	WHSC

Table A1.5. Fishery inventory data for all species from streams and rivers in the Northwest Territories during 2000 and 2001.

Capture location	Date	Latitude (N)	Longitude (W)	Species	N fish captured	N fish released live/tagged	N fish dead sampled
Kotaneelee River system							
Unnamed Creek	Jul-00	60° 36.226'	124° 01.518'	ARGR	15	15	0
	Jul-00	60° 36.226'	124° 01.518'	BLTR	12	10	2
	Aug-01	60° 36.060'	124° 13.900'	WHSC	2	2	0
	Aug-01	60° 36.060'	124° 13.900'	BLTR	6	3	3
Keele River system							
Keele River	Aug-00	64° 14.988'	125° 59.740'	BLTR	13	11	2
	Aug-01	-	-	BLTR	1	0	1
Unnamed Creek	Sep-01	64° 08.000'	126° 09.000'	MTWH	4	4	0
	Sep-01	64° 08.000'	126° 09.000'	SLSC	3	3	0
	Sep-01	64° 08.000'	126° 09.000'	ARGR	45	45	0
Mackenzie River system							
Great Bear River	Aug-00	64°58.967'	124°52.850'	ARGR	21	21	0
	Aug-00	64°58.967'	124°52.850'	NRPK	4	4	0
Saline Creek	Sep-01	64° 18.000'	124° 24.000'	ARGR	30	25	5
	Sep-01	64° 18.000'	124° 24.000'	SLSC	2	2	0
Drum Lake							
Drum Lake outlet	Sep-00	63° 49.977'	126° 11.149'	ARGR	10	10	0
	Sep-00	63° 49.977'	126° 11.149'	BLTR	2	0	2
	Sep-01	63° 49.000'	126° 11.000'	BLTR	23	11	12
	Sep-01	63° 49.000'	126° 11.000'	BURB	10	10	0
	Sep-01	63° 49.000'	126° 11.000'	LKCH	15	15	0

Table A1.5. (Continued).

Capture location	Date	Latitude (N)	Longitude (W)	Species	N fish captured	N fish released live/tagged	N fish dead sampled
	Sep-01	63° 49.000'	126° 11.000'	LNSC	5	5	0
Unnamed Creek	Sep-01	63° 48.000'	126° 09.000'	BLTR	2	0	2
	Sep-01	63° 48.000'	126° 09.000'	ARGR	75	75	0
	Sep-01	63° 48.000'	126° 09.000'	LKCH	5	5	0
	Sep-01	63° 48.000'	126° 09.000'	SLSC	20	20	0
Bluefish Creek	Sep-01	63° 47.000'	63° 47.000'	ARGR	300	295	5
	Sep-01	63° 47.000'	63° 47.000'	SLSC	20	20	0
	Sep-01	63° 47.000'	63° 47.000'	BURB	20	20	0
South Nahanni River system							
Fast Creek	Aug-01	61° 36.600'	124° 48.600'	SLSC	1	1	0
Funeral Creek	Aug-01	61° 36.000'	124° 48.000'	BLTR	31	23	8
	Sep-01	61° 36.000'	124° 48.000'	BLTR	47	39	8
Irvine Creek	Sep-01	61° 18.000'	124° 25.000'	BLTR	2	0	2
Mouth of Prairie Creek at Funeral Creek	Sep-01	61° 36.488'	124° 49.232'	BLTR	2	2	0
South Nahanni River	Aug-01	61° 14.963'	124° 24.488'	BLTR	3	2	1
	Aug-01	61° 14.963'	124° 24.488'	INCU	1	1	0
	Aug-01	61° 33.530'	124° 47.118'	ARGR	3	3	0
Galena Creek	Aug-01	61° 32.722'	124° 47.053'	BLTR	1	1	0
Prairie Creek	Aug-01	61° 14.958'	124° 24.482'	ARGR	25	25	0
Jorgenson Creek	Aug-01	61° 31.777'	126° 05.733'	BLTR	3	3	0
Marengo Creek	Aug-01	61° 35.535'	125° 48.043'	BLTR	1	1	0
	Aug-01	61° 35.535'	125° 48.043'	ARGR	15	15	0
	Aug-01	61° 35.535'	125° 48.043'	MTWH	1	1	0
	Sep-01	61° 35.535'	125° 48.043'	MTWH	1	1	0
	Sep-01	61° 35.535'	125° 48.043'	ARGR	4	4	0

Table A1.5. (Continued).

Capture location	Date	Latitude (N)	Longitude (W)	Species	N fish captured	N fish released live/tagged	N fish dead sampled
Virginia Falls (South Nahanni River)	Aug-01	61° 30.671'	126° 05.121'	BLTR	1	1	0
Sheaf Creek	Sep-01	-	-	SLSC	6	6	0
Carcajou River system							
Dodo Creek	Sep-01	64° 50.695'	127° 14.773'	SLSC	10	9	1
Dodo Creek	Sep-01	64° 50.695'	127° 14.773'	ARGR	22	22	0

Table A1.6. Biological data from both live- and dead-sampled fish species captured in the Northwest Territories during 2000 and 2001.

No.	Fish ID[1]	Location[2]	Date M/D/Y	Latitude (N)	Longitude (W)	Method[3]	Species	FL (mm)	Wt (g)	Life Stage Assigned	Notes[4]
1	-	Unnamed Cr.[A]	07/22/00	60° 36' 13.6"	124° 01' 31.1"	ANG	ARGR	271	190	Adult	15 additional ARGR caught (~200 - 400 mm)
2	MC001	Unnamed Cr.[A]	07/22/00	60° 36' 13.6"	124° 01' 31.1"	ANG	BLTR	350	400	Adult	-
3	MC002	Unnamed Cr.[A]	07/22/00	60° 36' 13.6"	124° 01' 31.1"	ANG	BLTR	380	460	Adult	-
4	MC003	Unnamed Cr.[A]	07/23/00	60° 36' 13.6"	124° 01' 31.1"	ANG	BLTR	228	130	Adult	-
5	MC004	Unnamed Cr.[A]	07/23/00	60° 36' 13.6"	124° 01' 31.1"	ANG	BLTR	286	450	Adult	-
6	MC005	Unnamed Cr.[A]	07/23/00	60° 36' 13.6"	124° 01' 31.1"	ANG	BLTR	300	590	Adult	-
7	MC006	Unnamed Cr.[A]	07/23/00	60° 36' 13.6"	124° 01' 31.1"	ANG	BLTR	240	190	Adult	-
8	MC007	Unnamed Cr.[A]	07/23/00	60° 36' 06.7"	124° 01' 55.4"	ANG	BLTR	234	100	Adult	-
9	MC008	Unnamed Cr.[A]	07/23/00	60° 36' 05.5"	124° 02' 04.3"	ANG	BLTR	265	180	Adult	-
10	MC009	Unnamed Cr.[A]	07/23/00	60° 36' 05.5"	124° 02' 04.3"	ANG	BLTR	344	380	Adult	-
11	MC0010	Unnamed Cr.[A]	07/24/00	60° 36' 06.1"	124° 01' 39.9"	ANG	BLTR	312	290	Adult	-
12	47257	Unnamed Cr.[A]	07/24/00	60° 36' 01.9"	124° 02' 11.0"	ANG	BLTR	289	235	Adult	-
13	47258	Unnamed Cr.[A]	07/24/00	60° 36' 01.9"	124° 02' 11.0"	ANG	BLTR	355	479	Adult	-
14	-	Great Bear R.	08/01/00	64° 58' 58.0"	124° 52' 51.0"	ANG	ARGR	-	-	Adult	21 additional ARGR caught (~230 - 400 mm)
15	-	Great Bear R.	08/02/00	64° 58' 58.0"	124° 52' 51.0"	ANG	NRPK	-	-	Adult	4 additional NRPK caught (~ 400 - 600 mm)
16	MC0011	Keele R.	08/03/00	64° 14' 33.5"	125° 59' 26.5"	ANG	BLTR	636	1220	Adult	-
17	48.835	Keele R.	08/03/00	64° 14' 59.3"	125° 59' 44.4"	ANG	BLTR	604	2000	Adult	-
18	48.814	Keele R.	08/03/00	64° 14' 59.3"	125° 59' 44.4"	ANG	BLTR	577	1790	Adult	-
19	48.872	Keele R.	08/03/00	64° 14' 59.3"	125° 59' 44.4"	ANG	BLTR	583	1410	Adult	-
20	48.695	Keele R.	08/03/00	64° 14' 59.3"	125° 59' 44.4"	ANG	BLTR	522	1230	Adult	-
21	48.854	Keele R.	08/03/00	64° 14' 59.3"	125° 59' 44.4"	ANG	BLTR	535	1300	Adult	-
22	48.774	Keele R.	08/03/00	64° 14' 59.3"	125° 59' 44.4"	ANG	BLTR	485	1000	Adult	-
23	48.754	Keele R.	08/03/00	64° 14' 59.3"	125° 59' 44.4"	ANG	BLTR	474	1000	Adult	-
24	MC0012	Keele R.	08/03/00	64° 14' 59.3"	125° 59' 44.4"	ANG	BLTR	432	730	Adult	-

Table A1.6. (Continued).

No.	Fish ID[1]	Location[2]	Date M/D/Y	Latitude (N)	Longitude (W)	Method[3]	Species	FL (mm)	Wt (g)	Life Stage Assigned	Notes[4]
25	48.715	Keele R.	08/04/00	64° 14' 28.6"	126° 25' 44.1"	ANG	BLTR	513	1150	Adult	-
26	48.795	Keele R.	08/05/00	64° 14' 28.6"	126° 25' 44.1"	ANG	BLTR	548	1540	Adult	-
27	47259	Keele R.	08/05/00	64° 14' 28.6"	126° 25' 44.1"	GN	BLTR	512	1435	Adult	-
28	47260	Keele R.	08/05/00	64° 14' 28.6"	126° 25' 44.1"	GN	BLTR	533	1341	Adult	-
29	47261	Drum Lake outlet	09/13/00	63° 49' 58.6"	126° 11' 08.9"	ANG	BLTR	561	1806	Adult	Observed 3 other BLTR, 1-2 ARGR lesions
30	47262	Drum Lake outlet	09/13/00	63° 49' 58.6"	126° 11' 08.9"	ANG	BLTR	583	2161	Adult	-
31	-	Drum Lake outlet	09/14/00	63° 49' 58.6"	126° 11' 08.9"	ANG	ARGR	-	-	-	10 additional ARGR caught (`200 - 400 mm)
32	-	Unnamed Cr.[A]	08/10/01	60° 36' 03.6"	124° 13' 54.0"	ANG	ARGR	-	-	-	15 additional ARGR caught (~200 - 450 mm)
33	47326	Unnamed Cr.[A]	08/10/01	60° 36' 03.6"	124° 13' 54.0"	ANG	BLTR	270	200	Adult	Stomach - terrestrial and aquatic insects
34	47327	Unnamed Cr.[A]	08/10/01	60° 36' 03.6"	124° 13' 54.0"	ANG	BLTR	276	253	Adult	Stomach - SLSC
35	47328	Unnamed Cr.[A]	08/10/01	60° 36' 03.6"	124° 13' 54.0"	ANG	BLTR	400	736	Adult	Stomach - terrestrial and aquatic insects
36	-	Unnamed Cr.[A]	08/10/01	60° 36' 03.6"	124° 13' 54.0"	ANG	BLTR	204	130	Juvenile	-
37	MC0018	Unnamed Cr.[A]	08/10/01	60° 36' 03.6"	124° 13' 54.0"	ANG	BLTR	202	200	Juvenile	-
38	MC0019	Unnamed Cr.[A]	08/10/01	60° 36' 03.6"	124° 13' 54.0"	ANG	BLTR	284	240	Adult	-
39	-	Fast Cr.	08/13/01	61° 36' 36.0"	124° 48' 36.0"	EF	SLSC	~50	-	-	-
40	-	Funeral Cr.	08/13/01	61° 36' 22.9"	124° 48' 28.8"	EF	BLTR	180	60	Juvenile	-
41	-	Funeral Cr.	08/13/01	61° 36' 22.9"	124° 48' 28.8"	EF	BLTR	142	30	Juvenile	-
42	-	Funeral Cr.	08/13/01	61° 36' 22.9"	124° 48' 28.8"	EF	BLTR	179	50	Juvenile	-
43	-	Funeral Cr.	08/13/01	61° 36' 22.9"	124° 48' 28.8"	EF	BLTR	155	40	Juvenile	-
44	-	Funeral Cr.	08/13/01	61° 36' 22.9"	124° 48' 28.8"	EF	BLTR	180	70	Juvenile	-
45	-	Funeral Cr.	08/13/01	61° 36' 22.9"	124° 48' 28.8"	EF	BLTR	170	50	Juvenile	-
46	MC0017	Funeral Cr.	08/13/01	61° 36' 22.9"	124° 48' 28.8"	EF	BLTR	208	100	Adult	-
47	MC0026	Funeral Cr.	08/13/01	61° 36' 22.9"	124° 48' 28.8"	EF	BLTR	281	360	Adult	-
48	MC0029	Funeral Cr.	08/13/01	61° 36' 22.9"	124° 48' 28.8"	EF	BLTR	292	280	Adult	-
49	MC0030	Funeral Cr.	08/13/01	61° 36' 22.9"	124° 48' 28.8"	EF	BLTR	329	360	Adult	-

Table A1.6. (Continued).

No.	Fish ID[1]	Location[2]	Date M/D/Y	Latitude (N)	Longitude (W)	Method[3]	Species	FL (mm)	Wt (g)	Life Stage Assigned	Notes[4]
50	MC0031	Funeral Cr.	08/13/01	61° 36' 22.9"	124° 48' 28.8"	EF	BLTR	302	370	Adult	-
51	47267	Funeral Cr.	08/13/01	61° 36' 22.9'	124° 48' 28.8"	EF	BLTR	168	53	Juvenile	Stomach - Aquatic and terrestrial insects
52	47268	Funeral Cr.	08/13/01	61° 36' 22.9'	124° 48' 28.8"	EF	BLTR	266	204	Adult	Stomach - Aquatic and terrestrial insects
53	47269	Funeral Cr.	08/13/01	61° 36' 22.9'	124° 48' 28.8"	EF	BLTR	354	495	Adult	Eggs retained from previous year
54	47270	Funeral Cr.	08/13/01	61° 36' 22.9'	124° 48' 28.8"	EF	BLTR	185	72	Juvenile	Stomach - Aquatic and terrestrial insects
55	MC0032	Funeral Cr.	08/14/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	272	220	Adult	-
56	MC0033	Funeral Cr.	08/14/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	307	315	Adult	-
57	MC0034	Funeral Cr.	08/14/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	370	500	Adult	-
58	-	Funeral Cr.	08/14/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	70	1	Juvenile	-
59	-	Funeral Cr.	08/14/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	78	0.9	Juvenile	-
60	-	Funeral Cr.	08/14/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	70	0.9	Juvenile	-
61	-	Funeral Cr.	08/14/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	70	0.7	Juvenile	-
62	-	Funeral Cr.	08/14/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	75	0.5	Juvenile	-
63	-	Funeral Cr.	08/14/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	75	0.9	Juvenile	-
64	-	Funeral Cr.	08/14/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	80	0.9	Juvenile	-
65	-	Funeral Cr.	08/14/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	75	0.8	Juvenile	-
66	-	Funeral Cr.	08/14/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	80	1	Juvenile	-
67	47263	Funeral Cr.	08/14/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	71	2.8	Juvenile	-
68	47264	Funeral Cr.	08/14/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	64	2.3	Juvenile	-
69	47265	Funeral Cr.	08/14/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	323	387	Adult	Stomach - Aquatic and terrestrial insects
70	47266	Funeral Cr.	08/14/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	289	281	Adult	Stomach - Aquatic and terrestrial insects
71	MC0035	Galena Cr.	08/14/01	61° 32' 43.3"	124° 47' 03.2"	ANG	BLTR	321	350	Adult	-
72	MC0037	South Nahanni R.	08/15/01	61° 14' 57.8"	124° 24' 29.3"	ANG	BLTR	330	250	Adult	-
73	MC0038	South Nahanni R.	08/15/01	61° 14' 57.8"	124° 24' 29.3"	ANG	BLTR	402	750	Adult	-
74	-	Prairie Cr.	08/15/01	61° 14' 57.5"	124° 24' 28.9"	ANG	ARGR	-	-	-	Caught + 20 - 30 ARGR (~200 - 500 mm)
75	-	South Nahanni R.	08/15/01	61° 14' 57.8"	124° 24' 29.3"	ANG	INCU	-	-	Adult	Captured 1 INCU (~700 mm)

Table A1.6. (Continued).

No.	Fish ID[1]	Location[2]	Date M/D/Y	Latitude (N)	Longitude (W)	Method[3]	Species	FL (mm)	Wt (g)	Life Stage Assigned	Notes[4]
76	-	South Nahanni R.	08/15/01	61° 33' 31.8"	124° 47' 07.1"	ANG	ARGR	-	-	Adult	Captured additional 3 ARGR (~300 - 400 mm)
77	47325	South Nahanni R.	08/15/01	61° 14' 57.8"	124° 24' 29.3"	ANG	BLTR	281	236	-	Stomach - small larval insects
78	MC0040	Jorgenson Cr.	08/16/01	61° 31' 46.6"	126° 05' 44.0"	ANG	BLTR	245	145	Adult	-
79	MC0041	Jorgenson Cr.	08/16/01	61° 31' 46.6"	126° 05' 44.0"	ANG	BLTR	320	455	Adult	-
80	MC0042	Jorgenson Cr.	08/16/01	61° 31' 46.6"	126° 05' 44.0"	ANG	BLTR	336	355	Adult	-
81	MC0043	South Nahanni R.	08/17/01	61° 30' 40.3"	126° 05' 07.3"	ANG	BLTR	510	1250	Adult	-
82	MC0044	Marengo Cr.	08/17/01	61° 35' 32.1"	125° 48' 02.6"	EF	BLTR	359	475	Adult	-
83	-	Marengo Cr.	08/17/01	61° 35' 32.1"	125° 48' 02.6"	EF	MTWH	~150	-	-	-
84	-	Marengo Cr.	08/17/01	61° 35' 32.1"	125° 48' 02.6"	EF	ARGR	-	-	-	Captured additional 15 ARGR (~200 -350 mm)
85	-	Funeral Cr.	09/11/01	61° 36' 22.9"	124° 48' 28.8"	EF	BLTR	168	50	Juvenile	-
86	MC0031	Funeral Cr.	09/11/01	61° 36' 22.9"	124° 48' 28.8"	EF	BLTR	302	260	Adult	-
87	MC0029	Funeral Cr.	09/11/01	61° 36' 22.9"	124° 48' 28.8"	EF	BLTR	278	240	Adult	-
88	MC0032	Funeral Cr.	09/11/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	250	200	Adult	-
89	-	Funeral Cr.	09/11/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	82	6.5	Juvenile	-
90	-	Funeral Cr.	09/11/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	117	18	Juvenile	-
91	-	Funeral Cr.	09/11/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	81	5	Juvenile	-
92	-	Funeral Cr.	09/11/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	80	5	Juvenile	-
93	-	Funeral Cr.	09/11/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	76	4	Juvenile	-
94	-	Funeral Cr.	09/11/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	80	6	Juvenile	-
95	-	Funeral Cr.	09/11/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	78	5.5	Juvenile	-
96	-	Funeral Cr.	09/11/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	64	3	Juvenile	-
97	-	Funeral Cr.	09/11/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	73	4	Juvenile	-
98	-	Funeral Cr.	09/11/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	76	3.9	Juvenile	-
99	-	Funeral Cr.	09/11/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	83	6	Juvenile	-
100	-	Funeral Cr.	09/11/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	74	5	Juvenile	-
101	FT0851	Funeral Cr.	09/11/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	258	230	Adult	-

Table A1.6. (Continued).

No.	Fish ID[1]	Location[2]	Date M/D/Y	Latitude (N)	Longitude (W)	Method[3]	Species	FL (mm)	Wt (g)	Life Stage Assigned	Notes[4]
102	-	Funeral Cr.	09/11/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	70	3.8	Juvenile	-
103	-	Funeral Cr.	09/11/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	77	3.5	Juvenile	-
104	-	Funeral Cr.	09/11/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	79	5	Juvenile	-
105	-	Funeral Cr.	09/11/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	77	4	Juvenile	-
106	-	Funeral Cr.	09/11/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	75	4	Juvenile	-
107	-	Funeral Cr.	09/11/01	61° 36' 37.5"	124° 44' 12.3"	EF	SLSC	-	-	-	Captured additional 30 SLSC (~30 - 100 mm)
108	47330	Funeral Cr.	09/11/01	61° 36' 22.9'	124° 48' 28.8"	EF	BLTR	272	246	Adult	Stomach - small BLTR # 47331
109	47331	Funeral Cr.	09/11/01	61° 36' 22.9'	124° 48' 28.8"	EF	BLTR	101	10	Juvenile	Stomach - small larval insects
110	47332	Funeral Cr.	09/11/01	61° 36' 22.9'	124° 48' 28.8"	EF	BLTR	67	3	Juvenile	-
111	47333	Funeral Cr.	09/11/01	61° 36' 22.9'	124° 48' 28.8"	EF	BLTR	61	2	Juvenile	Stomach - aquatic insects
112	47334	Funeral Cr.	09/11/01	61° 36' 22.9'	124° 48' 28.8"	EF	BLTR	35	1	Juvenile	-
113	47335	Funeral Cr.	09/11/01	61° 36' 22.9'	124° 48' 28.8"	EF	BLTR	38	1	Juvenile	-
114	47336	Funeral Cr.	09/11/01	61° 36' 22.9'	124° 48' 28.8"	EF	BLTR	99	14	Juvenile	Stomach - aquatic insects
115	47337	Funeral Cr.	09/11/01	61° 36' 22.9'	124° 48' 28.8"	EF	BLTR	139	28	Juvenile	Stomach - insects & fish
116	FT0852	Funeral Cr.	09/13/01	61° 36' 37.5"	124° 44' 12.3"	ANG	BLTR	284	250	Adult	Spawning BLTR (female)
117	FT0853	Funeral Cr.	09/13/01	61° 36' 37.5"	124° 44' 12.3"	ANG	BLTR	299	180	Adult	-
118	FT0854	Funeral Cr.	09/13/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	268	200	Adult	Spawning BLTR (female)
119	-	Funeral Cr.	09/13/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	150	34	Juvenile	-
120	-	Funeral Cr.	09/13/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	84	4	Juvenile	-
121	-	Funeral Cr.	09/13/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	143	27	Juvenile	-
122	-	Funeral Cr.	09/13/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	112	14	Juvenile	-
123	-	Funeral Cr.	09/13/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	148	33	Juvenile	-
124	-	Funeral Cr.	09/13/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	134	28	Juvenile	-
125	-	Funeral Cr.	09/13/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	174	50	Juvenile	-
126	-	Funeral Cr.	09/13/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	154	37	Juvenile	-
127	-	Funeral Cr.	09/13/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	150	31	Juvenile	-

Table A1.6. (Continued).

No.	Fish ID[1]	Location[2]	Date M/D/Y	Latitude (N)	Longitude (W)	Method[3]	Species	FL (mm)	Wt (g)	Life Stage Assigned	Notes[4]
128	-	Funeral Cr.	09/13/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	149	34	Juvenile	-
129	-	Funeral Cr.	09/13/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	129	24	Juvenile	-
130	-	Funeral Cr.	09/13/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	145	25	Juvenile	-
131	-	Funeral Cr.	09/13/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	147	32.5	Juvenile	-
132	-	Funeral Cr.	09/13/01	61° 36' 37.5"	124° 44' 12.3"	EF	BLTR	65	1	Juvenile	-
133	FT0855	Prairie Cr.	09/13/01	61° 36' 29.3"	124° 49' 13.9"	EF	BLTR	430	245	Adult	-
134	-	Prairie Cr.	09/13/01	61° 36' 29.3"	124° 49' 13.9"	EF	BLTR	175	48	Juvenile	-
135	-	Marengo Cr.	09/14/01	61° 35' 32.1"	125° 48' 02.6"	EF	MTWH	119	13	-	-
136	-	Marengo Cr.	09/14/01	61° 35' 32.1"	125° 48' 02.6"	EF	ARGR	276	190	-	-
137	-	Marengo Cr.	09/14/01	61° 35' 32.1"	125° 48' 02.6"	EF	ARGR	181	54	-	-
138	-	Marengo Cr.	09/14/01	61° 35' 32.1"	125° 48' 02.6"	EF	ARGR	206	83	-	-
139	-	Marengo Cr.	09/14/01	61° 35' 32.1"	125° 48' 02.6"	EF	ARGR	300	255	-	-
140	47596	Irvine Cr.	09/15/01	61° 18' 08.7"	124° 25' 24.1"	EF	BLTR	934	456	Adult	Stomach - small terrestrial insects, lesion LS
141	47338	Irvine Cr.	09/15/01	61° 18' 08.7"	124° 25' 24.1"	ANG	BLTR	626	2870	Adult	Stomach - fish (2) - ARGR?
142	-	Irvine Cr.	09/15/01	61° 18' 08.7"	124° 25' 24.1"	ANG	ARGR	-	-	Adult	Captured + ~ 20 ARGR (~300-500 mm)
143	-	Sheaf Cr.	09/16/01	-	-	EF	SLSC	-	-	-	Captured additional ~ 6 SLSC (~30 - 70 mm)
144	47329	Keele R.	09/20/01	-	-	ANG	BLTR	529	1268	Adult	Fish angled by local resident
145	-	Dodo Cr.	09/22/01	64° 50' 41.7"	127° 14' 46.4"	EF	SLSC	-	-	-	Captured additional ~10 SLSC
146	-	Dodo Cr.	09/22/01	64° 50' 41.7"	127° 14' 46.4"	EF	ARGR	-	-	-	Observed 1 ARGR
147	-	Dodo Cr.	09/22/01	64° 53' 07.4"	127° 13' 30.0"	EF	ARGR	-	-	Adult	Captured 1 ARGR (~ 300 mm)
148	-	Dodo Cr.	09/22/01	64° 52' 59.3"	127° 13' 39.5"	EF	ARGR	-	-	-	Captured additional ~ 20 ARGR in small pool
149	-	Unnamed Cr.[B]	09/23/01	64° 14' 32.6"	125° 59' 19.5"	EF	ARGR	-	-	Juvenile	Captured 2 YOY ARGR
150	-	Unnamed Cr.[B]	09/23/01	64° 13' 34.9'	126° 05' 08.5"	EF	ARGR	-	-	Adult	Captured 1 ARGR (~ 300 mm)
151	-	Unnamed Cr.[B]	09/23/01	64° 13' 34.9'	126° 05' 08.5"	EF	MTWH	-	-	-	Captured 1 MTWH (~120 mm)
152	-	Unnamed Cr.[B]	09/23/01	64° 13' 34.9'	126° 05' 08.5"	EF	SLSC	-	-	-	Captured 2 SLSC
153	-	Unnamed Cr.[B]	09/23/01	64° 10' 56.6"	126° 09' 54.6"	EF	ARGR	-	-	-	Captured additional ~ 40 ARGR

Table A1.6. (Continued).

No.	Fish ID[1]	Location[2]	Date M/D/Y	Latitude (N)	Longitude (W)	Method[3]	Species	FL (mm)	Wt (g)	Life Stage Assigned	Notes[4]
154	-	Unnamed Cr.[B]	09/23/01	64° 10' 56.6"	126° 09' 54.6"	EF	MTWH	-	-	-	Captured 3 MTWH
155	-	Unnamed Cr.[B]	09/23/01	64° 08' 32.6"	126 09' 06.5"	EF	ARGR	-	-	-	Captured 4 ARGR (~150 - 350 mm)
156	-	Unnamed Cr.[B]	09/23/01	64° 08' 32.6"	126 09' 06.5"	EF	SLSC	-	-	-	Captured 1 SLSC
157	-	Saline Cr.	09/24/01	64° 18' 55.4"	124° 24' 13.6"	EF	ARGR	-	-	-	Captured additional ~ 30 ARGR (~200 - 400 mm)
158	-	Saline Cr.	09/24/01	64° 18' 55.4"	124° 24' 13.6"	EF	SLSC	-	-	-	Captured 2 SLSC
159	FT0856	Drum Lake outlet	09/25/01	63° 49' 04.3"	126° 11' 08.4"	ANG	BLTR	544	1650	Adult	-
160	FT0857	Drum Lake outlet	09/25/01	63° 49' 04.3"	126° 11' 08.4"	ANG	BLTR	504	1600	Adult	-
161	FT0858	Drum Lake outlet	09/25/01	63° 49' 04.3"	126° 11' 08.4"	ANG	BLTR	662	2970	Adult	-
162	FT0859	Drum Lake outlet	09/25/01	63° 49' 04.3"	126° 11' 08.4"	ANG	BLTR	574	2000	Adult	-
163	FT0860	Drum Lake outlet	09/25/01	63° 49' 04.3"	126° 11' 08.4"	ANG	BLTR	671	3250	Adult	-
164	FT0861	Drum Lake outlet	09/25/01	63° 49' 04.3"	126° 11' 08.4"	ANG	BLTR	589	2250	Adult	-
165	FT0862	Drum Lake outlet	09/25/01	63° 49' 04.3"	126° 11' 08.4"	ANG	BLTR	611	2350	Adult	-
166	FT0863	Drum Lake outlet	09/25/01	63° 49' 04.3"	126° 11' 08.4"	ANG	BLTR	586	2250	Adult	-
167	FT0864	Drum Lake outlet	09/25/01	63° 49' 04.3"	126° 11' 08.4"	ANG	BLTR	444	850	Adult	-
168	FT0865	Drum Lake outlet	09/25/01	63° 49' 04.3"	126° 11' 08.4"	ANG	BLTR	636	2620	Adult	-
169	FT0866	Drum Lake outlet	09/25/01	63° 49' 04.3"	126° 11' 08.4"	ANG	BLTR	590	1950	Adult	-
170	47119	Drum Lake outlet	09/25/01	63° 49' 04.3"	126° 11' 08.4"	ANG	BLTR	610	2360	Adult	Female (resting)
171	47339	Drum Lake outlet	09/25/01	63° 49' 04.3"	126° 11' 08.4"	EF	BLTR	711	423	Adult	Stomach - fish (ARGR?), insects, lesion RS
172	47340	Drum Lake outlet	09/25/01	63° 49' 04.3"	126° 11' 08.4"	EF	BLTR	604	1917	Adult	-
173	47341	Drum Lake outlet	09/25/01	63° 49' 04.3"	126° 11' 08.4"	EF	BLTR	568	1823	Adult	Stomach - small larval insects
174	47342	Drum Lake outlet	09/25/01	63° 49' 04.3"	126° 11' 08.4"	EF	BLTR	528	1561	Adult	Stomach - insects, fish (unidentifiable)
175	47343	Drum Lake outlet	09/25/01	63° 49' 04.3"	126° 11' 08.4"	EF	BLTR	639	2771	Adult	Stomach - insects, fish (unidentifiable)
176	47344	Drum Lake outlet	09/25/01	63° 49' 04.3"	126° 11' 08.4"	EF	BLTR	661	3379	Adult	Stomach empty
177	47345	Drum Lake outlet	09/25/01	63° 49' 04.3"	126° 11' 08.4"	EF	BLTR	642	3144	Adult	Stomach - small larval insects

Table A1.6. (Continued).

No.	Fish ID[1]	Location[2]	Date M/D/Y	Latitude (N)	Longitude (W)	Method[3]	Species	FL (mm)	Wt (g)	Life Stage Assigned	Notes[4]
178	47346	Drum Lake outlet	09/25/01	63° 49' 04.3"	126° 11' 08.4"	EF	BLTR	561	1875	Adult	Stomach - insects, fish (unidentifiable)
179	47347	Drum Lake outlet	09/25/01	63° 49' 04.3"	126° 11' 08.4"	EF	BLTR	550	1735	Adult	Stomach empty
180	47348	Drum Lake outlet	09/25/01	63° 49' 04.3"	126° 11' 08.4"	EF	BLTR	558	1954	Adult	Stomach empty
181	47349	Drum Lake outlet	09/25/01	63° 49' 04.3"	126° 11' 08.4"	EF	BLTR	635	2480	Adult	Stomach - insects, fish (2 LNSC)
182	47350	Unnamed Cr.[C]	09/27/01	63° 48' 01.0"	126° 09' 40.1"	EF	BLTR	49	0.9	Juvenile	-
183	47351	Unnamed Cr.[C]	09/27/01	63° 48' 01.0"	126° 09' 40.1"	EF	BLTR	57	1.8	Juvenile	-
184	-	Unnamed Cr.[C]	09/27/01	63° 48' 01.0"	126° 09' 40.1"	EF	ARGR	-	-	Juvenile	Captured additional ~ 75-100 YOY/Juvenile ARGR
185	-	Unnamed Cr.[C]	09/27/01	63° 48' 01.0"	126° 09' 40.1"	EF	SLSC	-	-	-	Captured additional ~ 20 SLSC
186	-	Unnamed Cr.[C]	09/27/01	63° 48' 01.0"	126° 09' 40.1"	EF	LKCH	-	-	-	Captured additional ~ 5 LKCH
187	-	Drum Lake outlet	09/27/01	63° 49' 04.3"	126° 11' 08.4"	EF	LNSC	-	-	-	-
188	-	Drum Lake outlet	09/27/01	63° 49' 04.3"	126° 11' 08.4"	EF	LKCH	-	-	-	-
189	-	Drum Lake outlet	09/27/01	63° 49' 04.3"	126° 11' 08.4"	EF	BURB	-	-	Adult	-
190	-	Bluefish Cr.	09/27/01	63° 47' 48.0"	126° 09' 12.3"	EF	ARGR	-	-	Juvenile	Captured additional ~300 ARGR including YOY
191	-	Bluefish Cr.	09/27/01	63° 47' 48.0"	126° 09' 12.3"	EF	BURB	-	-	-	Captured additional ~20 BURB
191	-	Bluefish Cr.	09/27/01	63° 47' 48.0"	126° 09' 12.3"	EF	SLSC	-	-	-	Captured additional ~20 SLSC

1. MC### & FT### = Floy-tag codes; five digit codes (e.g., 47257) are ID numbers assigned to dead-sampled fish at the Department of Fisheries and Oceans, Wpg; and 48.### = codes for fish with radio-transmitters.

2. A - Unnamed Creek flowing into Kotaneelee River system, B - Unnamed Creek flowing into Keele River system, C - Unnamed Creek flowing into Drum Lake outlet.

3. ANG = angling, EF = electrofishing, GN = gillnetting.

4. LS = left side, RS = right side, YOY = young-of-the-year.

Table A1.7. Biological data collected from both live- and dead-sampled bull trout captured in streams and rivers from the Northwest Territories in 2000 and 2001.

Fish ID[1]	Date M/D/Y	No.	Location[2]	FL (mm)	Wt (g)	Sex	Mat.[3]	Gonad Wt (g)	Age	Fish[4] fate	Adipose[5] fin clip (Y/N)	Life[6] history	Life[7] stage	Notes
47267	08/13/01	1	Funeral Cr.	168	53	1	06	-	4	DS	-	SR	J	Stomach contents - Aquatic and terrestrial insects/larvae
47268	08/13/01	2	Funeral Cr.	266	204	2	02	0.7	7	DS	-	SR	A	Stomach contents - Aquatic and terrestrial insects/larvae
47269	08/13/01	3	Funeral Cr.	354	495	2	05	8.0		DS	-	SR	A	Eggs retained from previous year
47270	08/13/01	4	Funeral Cr.	185	72	1	06		5	DS	-	SR	J	Stomach contents - Aquatic and terrestrial insects/larvae
47263	08/14/01	5	Funeral Cr.	71	2.8	-	-	-	1	DS	-	SR	J	-
47264	08/14/01	6	Funeral Cr.	64	2.3	-	-	-	1	DS	-	SR	J	-
47265	08/14/01	7	Funeral Cr.	323	387	1	07	5.2	11	DS	-	SR	J	Stomach contents - Aquatic and terrestrial insects/larvae
47266	08/14/01	8	Funeral Cr.	289	281	1	07	3.8	9	DS	-	SR	J	Stomach - Aquatic and terrestrial insects(grasshopper)/larvae
47257	07/24/00	9	Unnamed Cr.[A]	289	235	2	01	1.0	8	DS	-	SR	A	-
47258	07/24/00	10	Unnamed Cr.[A]	355	479	-	-	-	8	DS	-	SR	A	-
47259	08/05/00	11	Keele R.	512	1435	1	10	1.0	10	DS	-	F	A	-
47260	08/05/00	12	Keele R.	533	1341	1	10	4.3	10	DS	-	F	A	-
47326	08/10/01	13	Unnamed Cr.[A]	270	200	2	05	0.8	8	DS	-	SR	A	Stomach - terrestrial (grasshopper) and larval insects
47327	08/10/01	14	Unnamed Cr.[A]	276	253	1	06	1.5	7	DS	-	SR	A	Stomach contents - sculpin (SLSC)
47328	08/10/01	15	Unnamed Cr.[A]	400	736	1	10	8.9	9	DS	-	SR	A	Stomach - terrestrial (small worms) and aquatic insects
47325	08/15/01	16	South Nahanni R.	281	236	1	10	-	11	DS	-	SR	A	Stomach contents - small larval insects
47330	09/11/01	17	Funeral Cr.	272	246	2	02	1.5	11	DS	-	SR	A	Stomach - Ants, wasp, insect larvae, small BLTR # 47331
47331	09/11/01	18	Funeral Cr.	101	10	-	00	-	2	DS	-	SR	J	Stomach contents - small larval insects
47332	09/11/01	19	Funeral Cr.	67	3	-	00	-	1	DS	-	SR	J	Too small & rotten to sex
47333	09/11/01	20	Funeral Cr.	61	2	2	01	-	1	DS	-	SR	J	Stomach contents - aquatic insects
47334	09/11/01	21	Funeral Cr.	35	1	2	01	-	0	DS	-	SR	YOY	-
47335	09/11/01	22	Funeral Cr.	38	1	-	00	-	0	DS	-	SR	YOY	-
47336	09/11/01	23	Funeral Cr.	99	14	2	01	0.1	2	DS	-	SR	J	Recapture - adipose fin clip from Aug
47337	09/11/01	24	Funeral Cr.	139	28	2	01	1.0	3	DS	-	SR	J	Stomach - aquatic and terrestrial insects, fish (unidentifiable)

Table A1.7. (Continued).

Fish ID[1]	Date M/D/Y	No.	Location[2]	FL (mm)	Wt (g)	Sex	Mat.[3]	Gonad Wt (g)	Age	Fish[4] fate	Adipose[5] fin clip (Y/N)	Life[6] history	Life[7] stage	Notes
47261	09/13/00	25	Drum L. outlet	561	1806	2	05	9.3	9	DS	-	AF	A	Observed 3 other BLTR and (>10) ARGR
47262	09/13/00	26	Drum L. outlet	583	2161	2	05	9.8	14	DS	-	AF	A	-
47596	09/15/01	27	Irvine Cr.	626	2870	2	05	17.2	12	DS	-	F	A	Stomach contents - fish (2) - ARGR possible?
47338	09/15/01	28	Irvine Cr.	934	456	2	05	4.6	10	DS	-	F	A	Stomach - fish, aquatic and terrestrial insects, lesion RS
47329	09/20/01	29	Keele R.	529	1268	2	05	-	9	DS	-	F	A	Fish angled by local resident
47339	09/25/01	30	Drum L. outlet	423	711	1	10	0.3	9	DS	-	AF	A	Stomach - fish, aquatic and terrestrial insects, lesion
47340	09/25/01	31	Drum L. outlet	604	1917	1	09	3.9	18	DS	-	AF	A	-
47341	09/25/01	32	Drum L. outlet	568	1823	1	10	1.1	10	DS	-	AF	A	Stomach contents - small larval insects
47342	09/25/01	33	Drum L. outlet	528	1561	1	09	3.0	10	DS	-	AF	A	Stomach - aquatic and terrestrial insects, fish (unidentifiable)
47343	09/25/01	34	Drum L. outlet	639	2771	2	05	23.3	-	DS	-	AF	A	Stomach - aquatic and terrestrial insects, fish (unidentifiable)
47344	09/25/01	35	Drum L. outlet	661	3379	2	05	20.2	16	DS	-	AF	A	Stomach contents – empty
47345	09/25/01	36	Drum L. outlet	642	3144	1	09	1.6	11	DS	-	AF	A	Stomach contents - small larval insects
47346	09/25/01	37	Drum L. outlet	561	1875	1	10	1.0	10	DS	-	AF	A	Stomach - aquatic and terrestrial insects, fish (unidentifiable)
47347	09/25/01	38	Drum L. outlet	550	1735	1	10	0.9	13	DS	-	AF	A	Stomach contents – empty
47348	09/25/01	39	Drum L. outlet	558	1954	2	05	8.8	11	DS	-	AF	A	Stomach contents – empty
47349	09/25/01	40	Drum L. outlet	635	2480	2	05	15.3	11	DS	-	AF	A	Stomach - aquatic and terrestrial (ants) insects, fish (LNSC)
47119	09/27/01	41	Drum L. outlet	610	2360	2	05	-	12	DS	-	AF	A	Female (resting)
47350	09/27/01	42	Unnamed Cr.[B]	49	0.9	-	-	-	1	DS	-	AF	J	-
47351	09/27/01	43	Unnamed Cr.[B]	57	1.8	1	06	-	1	DS	-	AF	J	-
-	08/10/01	44	Unnamed Cr.[A]	204	130	-	-	-	-	RNT	N	SR	-	Released same day at capture site
-	08/13/01	45	Funeral Cr.	180	60	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	08/13/01	46	Funeral Cr.	142	30	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	08/13/01	47	Funeral Cr.	179	50	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	08/13/01	48	Funeral Cr.	155	40	-	-	-	-	RNT	Y	SR	J	Released same day at capture site

Table A1.7. (Continued).

Fish ID[1]	Date M/D/Y	No.	Location[2]	FL (mm)	Wt (g)	Sex	Mat.[3]	Gonad Wt (g)	Age	Fish[4] fate	Adipose[5] fin clip (Y/N)	Life[6] history	Life[7] stage	Notes
-	08/13/01	49	Funeral Cr.	180	70	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	08/13/01	50	Funeral Cr.	170	50	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	08/14/01	51	Funeral Cr.	70	1	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	08/14/01	52	Funeral Cr.	78	0.9	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	08/14/01	53	Funeral Cr.	70	0.9	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	08/14/01	54	Funeral Cr.	70	0.7	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	08/14/01	55	Funeral Cr.	75	0.5	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	08/14/01	56	Funeral Cr.	75	0.9	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	08/14/01	57	Funeral Cr.	80	0.9	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	08/14/01	58	Funeral Cr.	75	0.8	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	08/14/01	59	Funeral Cr.	80	1	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	09/11/01	60	Funeral Cr.	168	50	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	09/11/01	61	Funeral Cr.	82	6.5	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	09/11/01	62	Funeral Cr.	117	18	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	09/11/01	63	Funeral Cr.	81	5	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	09/11/01	64	Funeral Cr.	80	5	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	09/11/01	65	Funeral Cr.	76	4	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	09/11/01	66	Funeral Cr.	80	6	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	09/11/01	67	Funeral Cr.	78	5.5	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	09/11/01	68	Funeral Cr.	64	3	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	09/11/01	69	Funeral Cr.	73	4	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	09/11/01	70	Funeral Cr.	76	3.9	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	09/11/01	71	Funeral Cr.	83	6	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	09/11/01	72	Funeral Cr.	74	5	-	-	-	-	RNT	Y	SR	J	Released same day at capture site

Table A1.7. (Continued).

Fish ID[1]	Date M/D/Y	No.	Location[2]	FL (mm)	Wt (g)	Sex	Mat.[3]	Gonad Wt (g)	Age	Fish[4] fate	Adipose[5] fin clip (Y/N)	Life[6] history	Life[7] stage	Notes
-	09/11/01	73	Funeral Cr.	70	3.8	-	-	-	-	RNT	N	SR	J	Released same day at capture site
-	09/11/01	74	Funeral Cr.	77	3.5	-	-	-	-	RNT	N	SR	J	Released same day at capture site
-	09/11/01	75	Funeral Cr.	79	5	-	-	-	-	RNT	N	SR	J	Released same day at capture site
-	09/11/01	76	Funeral Cr.	77	4	-	-	-	-	RNT	N	SR	J	Released same day at capture site
-	09/11/01	77	Funeral Cr.	75	4	-	-	-	-	RNT	N	SR	J	Released same day at capture site
-	09/13/01	78	Funeral Cr.	150	34	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	09/13/01	79	Funeral Cr.	84	4	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	09/13/01	80	Funeral Cr.	143	27	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	09/13/01	81	Funeral Cr.	112	14	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	09/13/01	82	Funeral Cr.	148	33	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	09/13/01	83	Funeral Cr.	134	28	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	09/13/01	84	Funeral Cr.	174	50	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	09/13/01	85	Funeral Cr.	154	37	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	09/13/01	86	Funeral Cr.	150	31	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	09/13/01	87	Funeral Cr.	149	34	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	09/13/01	88	Funeral Cr.	129	24	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	09/13/01	89	Funeral Cr.	145	25	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	09/13/01	90	Funeral Cr.	147	32.5	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	09/13/01	91	Funeral Cr.	65	1	-	-	-	-	RNT	Y	SR	J	Released same day at capture site
-	09/13/01	92	Prairie Cr.	175	48	-	-	-	-	RNT	Y	SR	-	Released same day at capture site
MC0018	08/10/01	93	Unnamed Cr.[A]	202	200	-	-	-	-	T	Y	SR	A	Released same day at capture site
MC0019	08/10/01	94	Unnamed Cr.[A]	284	240	-	-	-	-	T	Y	SR	A	Released same day at capture site
MC0017	08/13/01	95	Funeral Cr.	208	100	-	-	-	-	T	Y	SR	A	Released same day at capture site
MC0026	08/13/01	96	Funeral Cr.	281	360	-	-	-	-	T	Y	SR	A	Released same day at capture site

Table A1.7. (Continued).

Fish ID[1]	Date M/D/Y	No.	Location[2]	FL (mm)	Wt (g)	Sex	Mat.[3]	Gonad Wt (g)	Age	Fish[4] fate	Adipose[5] fin clip (Y/N)	Life[6] history	Life[7] stage	Notes
MC0029	08/13/01	97	Funeral Cr.	292	280	-	-	-	-	T	Y	SR	A	Released same day at capture site
MC0030	08/13/01	98	Funeral Cr.	329	360	-	-	-	-	T	Y	SR	A	Released same day at capture site
MC0031	08/13/01	99	Funeral Cr.	302	370	-	-	-	-	T	Y	SR	A	Released same day at capture site
MC0032	08/14/01	100	Funeral Cr.	272	220	-	-	-	-	T	Y	SR	A	Released same day at capture site
MC0033	08/14/01	101	Funeral Cr.	307	315	-	-	-	-	T	Y	SR	A	Released same day at capture site
MC0034	08/14/01	102	Funeral Cr.	370	500	-	-	-	-	T	Y	SR	A	Released same day at capture site
MC0035	08/14/01	103	Galena Cr.	321	350	-	-	-	-	T	Y	SR	A	Released same day at capture site
MC0037	08/15/01	104	South Nahanni R.	330	250	-	-	-	-	T	Y	-	A	Released same day at capture site
MC0038	08/15/01	105	South Nahanni R.	402	750	-	-	-	-	T	Y	-	A	Released same day at capture site
MC0040	08/16/01	106	Jorgenson Cr.	245	145	-	-	-	-	T	Y	SR	A	Released same day at capture site
MC0041	08/16/01	107	Jorgenson Cr.	320	455	-	-	-	-	T	Y	SR	A	Released same day at capture site
MC0042	08/16/01	108	Jorgenson Cr.	336	355	-	-	-	-	T	Y	SR	A	Released same day at capture site
MC0043	08/17/01	109	South Nahanni R.	510	1250	-	-	-	-	T	Y	F	A	Released same day at capture site
MC0044	08/17/01	110	Marengo Cr.	359	475	-	-	-	-	T	Y	-	A	Released same day at capture site
MC0031	09/11/01	111	Funeral Cr.	302	260	-	-	-	-	T	Y	SR	A	Recapture - fish tagged in Funeral Creek, Aug 2001
MC0029	09/11/01	112	Funeral Cr.	278	240	-	-	-	-	T	Y	SR	A	Recapture - fish tagged in Funeral Creek, Aug 2001
MC0032	09/11/01	113	Funeral Cr.	250	200	-	-	-	-	T	Y	SR	A	Recapture - fish tagged in Funeral Creek, Aug 2001
FT0851	09/11/01	114	Funeral Cr.	258	230	-	-	-	-	T	Y	SR	A	Released same day at capture site
FT0852	09/13/01	115	Funeral Cr.	284	250	-	-	-	-	T	Y	SR	A	Spawning (female) BLTR, Released same day at capture site
FT0853	09/13/01	116	Funeral Cr.	299	180	-	-	-	-	T	Y	SR	A	Juvenile BLTR, Released same day at capture site
FT0854	09/13/01	117	Funeral Cr.	268	200	-	-	-	-	T	Y	SR	A	Spawning (female) BLTR, Released same day at capture site
FT0855	09/13/01	118	Prairie Cr.	245	430	-	-	-	-	T	Y	SR	A	Released same day at capture site
FT0856	09/25/01	119	Drum L. outlet	544	1650	-	-	-	-	T	Y	AF	A	Released same day at capture site
FT0857	09/25/01	120	Drum L. outlet	504	1600	-	-	-	-	T	Y	AF	A	Released same day at capture site

Table A1.7. (Continued).

Fish ID[1]	Date M/D/Y	No.	Location[2]	FL (mm)	Wt (g)	Sex	Mat.[3]	Gonad Wt (g)	Age	Fish[4] fate	Adipose[5] fin clip (Y/N)	Life[6] history	Life[7] stage	Notes
FT0858	09/25/01	121	Drum L. outlet	662	2970	-	-	-	-	T	Y	AF	A	Released same day at capture site
FT0859	09/25/01	122	Drum L. outlet	574	2000	-	-	-	-	T	Y	AF	A	Released same day at capture site
FT0860	09/25/01	123	Drum L. outlet	671	3250	-	-	-	-	T	Y	AF	A	Released same day at capture site
FT0861	09/25/01	124	Drum L. outlet	589	2250	-	-	-	-	T	Y	AF	A	Released same day at capture site
FT0862	09/25/01	125	Drum L. outlet	611	2350	-	-	-	-	T	Y	AF	A	Released same day at capture site
FT0863	09/25/01	126	Drum L. outlet	586	2250	-	-	-	-	T	Y	AF	A	Released same day at capture site
FT0864	09/25/01	127	Drum L. outlet	444	850	-	-	-	-	T	Y	AF	A	Released same day at capture site
FT0865	09/25/01	128	Drum L. outlet	636	2620	-	-	-	-	T	Y	AF	A	Released same day at capture site
FT0866	09/25/01	129	Drum L. outlet	590	1950	-	-	-	-	T	Y	AF	A	Released same day at capture site
MC001	07/22/00	130	Unnamed Cr.[A]	350	400	-	-	-	-	T	Y	SR	A	Released same day at capture site
MC002	07/22/00	131	Unnamed Cr.[A]	380	460	-	-	-	-	T	Y	SR	A	Released same day at capture site
MC003	07/23/00	132	Unnamed Cr.[A]	228	130	-	-	-	-	T	Y	SR	A	Released same day at capture site
MC004	07/23/00	133	Unnamed Cr.[A]	286	450	-	-	-	-	T	Y	SR	A	Released same day at capture site
MC005	07/23/00	134	Unnamed Cr.[A]	300	590	-	-	-	-	T	Y	SR	A	Released same day at capture site
MC006	07/23/00	135	Unnamed Cr.[A]	240	190	-	-	-	-	T	Y	SR	A	Released same day at capture site
MC007	07/23/00	136	Unnamed Cr.[A]	234	100	-	-	-	-	T	Y	SR	A	Released same day at capture site
MC008	07/23/00	137	Unnamed Cr.[A]	265	180	-	-	-	-	T	Y	SR	A	Released same day at capture site
MC009	07/23/00	138	Unnamed Cr.[A]	344	380	-	-	-	-	T	Y	SR	A	Released same day at capture site
MC0010	07/24/00	139	Unnamed Cr.[A]	312	290	-	-	-	-	T	Y	SR	A	Released same day at capture site
MC0011	08/03/00	140	Keele R.	636	1220	-	-	-	-	T	Y	F	A	Released same day at capture site
*48.835	08/03/00	141	Keele R.	604	2000	-	-	-	-	T	Y	F	A	Released same day at capture site
*48.814	08/03/00	142	Keele R.	577	1790	-	-	-	-	T	Y	F	A	Released same day at capture site
*48.872	08/03/00	143	Keele R.	583	1410	-	-	-	-	T	Y	F	A	Released same day at capture site
*48.695	08/03/00	144	Keele R.	522	1230	-	-	-	-	T	Y	F	A	Released same day at capture site

Table A1.7. (Continued).

Fish ID[1]	Date M/D/Y	No.	Location[2]	FL (mm)	Wt (g)	Sex	Mat.[3]	Gonad Wt (g)	Age	Fish[4] fate	Adipose[5] fin clip (Y/N)	Life[6] history	Life[7] stage	Notes
*48.854	08/03/00	145	Keele R.	535	1300	-	-	-	-	T	Y	F	A	Released same day at capture site
*48.774	08/03/00	146	Keele R.	485	1000	-	-	-	-	T	Y	F	A	Released same day at capture site
*48.754	08/03/00	147	Keele R.	474	1000	-	-	-	-	T	Y	F	A	Released same day at capture site
MC0012	08/03/00	148	Keele R.	432	730	-	-	-	-	T	Y	F	A	Released same day at capture site
*48.715	08/04/00	149	Keele R.	513	1150	-	-	-	-	T	Y	F	A	Released same day at capture site
*48.795	08/05/00	150	Keele R.	548	1540	-	-	-	-	T	Y	F	A	Released same day at capture site

1. MC### & FT### = Floy-tag codes; five digit codes (e.g., 47257) are ID numbers assigned to dead-sampled fish at the Department of Fisheries and Oceans, Wpg; and numbers with (*) are radio transmitter tags.
2. A - Unnamed Creek flowing into Kotaneelee River system, B - Unnamed Creek flowing into Drum Lake outlet.
3. Maturity (see methods for codes).
4. DS = dead-sampled, RNT = released with no tag, T = released with tag.
5. Y = yes, N = no.
6. AF = adfluvial, F = fluvial, SR = stream-resident.
7. A = adult, J = juvenile.

Table A1.8. Qualitative, quantitative, and genetic identification of bull trout dead-sampled from the Northwest Territories in 2000 and 2001.

Fish ID code	Location	Standard length (mm)	Upper jaw length (mm)	ARC[1]	BRC[2]	LDF[3]	Age (yrs)	Eye[4] position	Upper jaw shape	Upper jaw length	Head shape	Head size	mt DNA[5]	rDNA[6]	ID[7]
47257	Unnamed Cr.	267.0	29.9	10	26	0.5052	8	top	decurved	well past eye	flat, triangular	large	BLTR	BLTR	BLTR
47258	Unnamed Cr.	335.0	38.3	12	26	0.9567	8	top	decurved	well past eye	flat, triangular	large	BLTR	HY	BLTR
47259	Keele R.	461.0	53.1	10	28	1.8911	10	top	decurved	well past eye	flat, triangular	large	BLTR	HY	BLTR
47260	Keele R.	478.0	58.3	10	26	0.8877	10	top	decurved	well past eye	flat, triangular	large	BLTR	BLTR	BLTR
47261	Drum Lake	508.0	54.2	10	28	1.5720	9	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47262	Drum Lake	536.0	62.5	9	28	1.7659	14	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47325	South Nahanni R.	281.0	30.7	9	27	0.8625	11	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47326	Unnamed Cr.	266.0	28.0	10	28	1.5166	8	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47327	Unnamed Cr.	246.0	27.1	9	28	1.5181	7	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47328	Unnamed Cr.	349.0	45.5	10	28	2.4509	9	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47329	Keele R.	465.0	57.9	10	29	2.8635	9	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47330	Funeral Cr.	244.0	30.7	10	26	1.0207	11	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47331	Funeral Cr.	90.0	9.1	8	27	0.3836	2	top	decurved	just past eye	-	-	BLTR	BLTR	BLTR
47332	Funeral Cr.	60.0	6.3	8	26	-0.1107	1	top	decurved	just past eye	-	-	BLTR	-	BLTR
47333	Funeral Cr.	54.0	6.1	7	28	1.2381	1	top	decurved	just past eye	-	-	BLTR	-	BLTR
47334	Funeral Cr.	32.0	3.5	8	26	0.0471	0	top	decurved	just past eye	-	-	BLTR	BLTR	BLTR
47335	Funeral Cr.	36.0	2.9	7	26	-1.2152	0	top	decurved	just past eye	-	-	BLTR	-	BLTR
47336	Funeral Cr.	96.0	10.6	9	29	2.1626	2	top	decurved	just past eye	-	-	BLTR	-	BLTR
47337	Funeral Cr.	120.0	12.5	10	27	0.8495	3	top	decurved	just past eye	-	-	BLTR	-	BLTR
47338	Irvine Cr.	400.0	44.5	10	28	1.7399	10	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47339	Drum Lake	368.0	41.7	9	28	1.6387	9	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47340	Drum Lake	528.0	71.7	10	27	2.0267	18	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47341	Drum Lake	491.0	60.9	9	26	0.7829	10	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47342	Drum Lake	465.0	55.0	9	29	2.4576	10	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR

Table A1.8. (Continued).

Fish ID code	Location	Standard length (mm)	Upper jaw length (mm)	ARC[1]	BRC[2]	LDF[3]	Age (yrs)	Eye[4] position	Upper jaw shape	Upper jaw length	Head shape	Head size	mt DNA[5]	rDNA[6]	ID[7]
47343	Drum Lake	560.0	64.9	10	27	1.2890	10	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47344	Drum Lake	576.0	68.0	9	29	2.4489	16	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47345	Drum Lake	550.0	68.6	9	28	2.0669	11	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47346	Drum Lake	491.0	50.7	9	27	0.6345	10	top	decurved	well past eye	flat, triangular	large	BLTR	BLTR	BLTR
47347	Drum Lake	478.0	51.5	9	27	0.8071	13	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47348	Drum Lake	492.0	57.8	9	29	2.4239	11	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47349	Drum Lake	559.0	70.6	10	27	1.6725	11	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47350	Drum Lake	44.0	5.7	10	26	1.1928	1	top	decurved	well past eye	-	-	BLTR	-	BLTR
47351	Drum Lake	51.0	6.5	9	26	0.9258	0	top	decurved	just past eye	-	-	BLTR	BLTR	BLTR
47596	Irvine Cr.	560.0	67.4	10	29	2.7122	15	top	decurved	well past eye	flat, triangular	large	BLTR	BLTR	BLTR
47263	Funeral Cr.	72.0	5.8	7	26	-1.1945	1	top	decurved	just past eye	-	-	BLTR	-	BLTR
47264	Funeral Cr.	65.0	5.2	6	26	-1.3702	1	top	decurved	just past eye	-	-	BLTR	HY	BLTR
47265	Funeral Cr.	287.0	37.0	9	28	2.2240	11	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47266	Funeral Cr.	259.0	34.9	9	27	1.8096	9	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47267	Funeral Cr.	150.0	14.9	9	28	1.1201	4	top	decurved	just past eye	flat, triangular	large	BLTR	-	BLTR
47268	Funeral Cr.	233.0	27.0	9	27	1.1117	7	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47269	Funeral Cr.	312.0	38.3	10	28	2.1732	-	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47270	Funeral Cr.	166.0	17.5	9	28	1.3473	5	top	decurved	just past eye	flat, triangular	large	BLTR	-	BLTR

1. ARC = principal anal ray count.
2. BRC = total branchiostegal ray count.
3. Linear discriminant function (LDF) score as computed following Haas and McPhail (1991): LDF Score = 0.629(total branchiostegal ray count) + 0.178(principal anal ray count) + 37.310(upper jaw length/standard length) – 21.8.
4. Eye position relative to dorsal surface of head.
5. Identification for individual fish is based on mitochondrial DNA (mtDNA) analyses; BLTR = bull trout, DVCH = Dolly Varden, HY = Hybrid, UK = unknown.
6. Identification for individual fish is based on ribosomal DNA (rDNA) analyses.
7. Identification for individual fish is based on the LDF score, genetic results, and morphometric characteristics.

Table A1.9. Population estimates of bull trout captured from Funeral Creek in 2001.

	All Life Stages		Juveniles	
Pass	N (reach 1)	N (reach 2)	N (reach 1)	N (reach 2)
1	13	14	12	14
2	3	5	4	6
3	1	2	1	3
Total catch	17	21	17	23
Population estimate	17	21	17	24
Standard error	0.531	1.002	0.686	1.943
upper 95% CI	18.126	23.090	18.454	28.020
lower 95% CI	15.874	18.190	15.546	19.980
Mean wetted width	3.02	3.50	3.05	3.60
Reach length	200	200	100	100
Sampling area	604	700	305	360
number of fish/100m^2	2.81	3.00	5.57	6.67
upper 95% CI	3.00	3.30	6.05	7.78
lower 95% CI	2.63	2.60	5.10	5.55

Table A1.10. Physical habitat characteristics of study locations where habitat use of bull trout was measured in the Northwest Territories during 2000 and 2001.

Location	Site	Stream order (map scale 1:50, 000)	Average wetted width (m)	Average temp (°C)	Month sampled	Elevation (m) (map scale 1:50 000)	Depth (cm)[1]	Velocity (m/s)[1]	Dominant substrate[2]	Dominant cover[2]
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)	3	2
	2	1	4.45	4.0	Sept	800	19.1(3-66)	0.18(0.01-0.70)	3	5
	3	2	16.4	6.4	Sept	800	149(54-282)	0.32(0.12-0.49)	0	3
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)	4	6
	2	1	2.56	7.5	Aug	1100	29.5(9-93)	0.26(0.0-0.93)	4	6
	3	1	1.72	4.6	Sept	1100	22.2(9-80)	0.30(0.1-1.33)	4	6
	4	1	1.70	4.1	Sept	1100	29.1(7-90)	0.22(0.01-0.91)	4	6
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)	4	6
	2	2	4.86	7.8	Sept	600	31.8(10-72)	0.68(0.01-1.46)	4	6
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)	6	6
	2	2	2.82	-	-	600	31.5(12-88)	0.37(0.01-1.72)	5	6
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)	4	6
	2	3	13.8	5.6	Sept	400	46.8(12-122)	0.41(0.0-1.25)	4	6
	3	2	5.17	3.6	Sept	600	35.9(12-66)	0.35(0.01-1.02)	4	6
	4	2	10.1	4.0	Sept	600	45.0(12-130)	0.42(0.0-1.46)	4	6
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)	1	2
	2	1	6.90	10.3	Aug	2000	55.3(8-135)	0.47(0.0-1.21)	4	7
	3	1	5.80	7.8	Aug	2000	49.1(8-140)	0.51(0.0-1.40)	4	4
	4	1	7.20	8.5	Aug	2000	52.5(18-104)	0.48(0.0-1.55)	5	4

1. Depth and velocities are mean values with ranges in parentheses, 2. Substrate and cover codes are described in methods.

APPENDIX 2

IDENTIFICATION OF CHAR CAPTURED FROM RIVERS IN THE SOUTHERN AND CENTRAL NORTHWEST TERRITORIES, 2000 AND 2001.

INTRODUCTION

Bull trout (*Salvelinus confluentus*) is one of four chars native to northwestern Canada. Other char found in the region include Arctic char, *S. alpinus*, lake trout *S. namayacush*, and the char most closely related to bull trout, Dolly Varden, *S. malma* (Lee et al. 1980; Nelson and Paetz 1992). Bull trout were described in 1860 by George Suckley; however, were placed in synonymy with Dolly Varden (Walbaum). In 1978, bull trout were recognized as a full biological species, thus distinct from Dolly Varden (Cavender 1978). Further meristic and morphometric work (Haas and McPhail 1991) combined with genetic confirmation of the two char in sympatry (Baxter et al. 1997; Leary and Allendorf 1997) provided compelling evidence that bull trout and Dolly Varden were distinct biological species. However, despite meristic, morphometric, and osteological differences between the two species, their similar morphological appearance made in-field identification difficult for non-experts.

A linear discriminant function (LDF) proven to be 100 % effective in distinguishing Dolly Varden from bull trout was developed (Haas and McPhail 1991). The LDF is based on meristic and morphometric measurements, and is generally accepted as an accurate identification tool for the two species; however, a recent study shows that this discriminant function possesses an inherent bias by design. The LDF is more likely to inaccurately identify bull trout as Dolly Varden, as a result of missed counts, since all counts or measurements are higher for bull trout (Haas and McPhail 2001). Missed counts are likely more prevalent for juvenile life stages as ray counts can be difficult to accurately determine, especially by individuals with limited training. Furthermore, for young-of-the-year bull trout, meristic traits may not be fully developed altering counts, which would result in lower counts and could result in identification as hybrids or Dolly Varden. The LDF was employed in this study to aid in identification of unknown chars found throughout the Northwest Territories (NWT). A second objective of the study was to examine the accuracy of the LDF by comparing the results to genetic and morphological data from char specimens acquired in watersheds across the NWT during the study.

METHODS

Forty-two char were captured in the summer and fall of 2000 and 2001 from nine tributaries in the Northwest Territories (NWT). These fish were sacrificed for biological processing, which included morphometric and meristic measurements (Reist et al. 1997), age determination from sectioned and whole otoliths, sex and maturity determination, and gonad weight where possible. Char were captured by electrofishing and angling. The hypothesized identity of each fish was determined by examining key morphological characteristics used to discriminate between Dolly Varden and bull trout in the literature (Cavender 1978; Nelson and Paetz 1992; Reist et al. 2002). The LDF, developed by Haas and McPhail (1991), was used to confirm or refute initial identifications that were based on morphological features. The measurements used in the LDF, total anal fin ray number, total branchiostegal ray number, standard length and maxillary length (Haas and McPhail 1991), were counted and measured on each fish by the same observer during two separate occasions. The following equation was used to confirm the identity of char captured (Haas and McPhail 1991):

$$LDF = 0.629N_b + 0.178N_a + 37.310\ L_j/L_s - 21.8$$

Where:

LDF	=	Linear Discriminant Function;
N_b	=	Total number of branchiostegal rays;
N_a	=	Total number of anal fin rays;
L_j	=	Total length of upper jaw; and
L_s	=	Standard length of fish

All fish with LDF values greater than zero are bull trout, and those less than zero are Dolly Varden.

Genetic analyses were also completed to confirm the identity of the samples obtained. Mitochondrial DNA (mtDNA) analyses (Baxter et al. 1997) were run on tissue samples from 114 char specimens, which included the 42 samples used in the LDF analyses, by individuals from the fish genetics laboratory at the Freshwater Institute in Winnipeg. Ribosomal DNA (rDNA) analyses (Baxter et al. 1997) were run on ten tissue samples, which were also included in both mtDNA and LDF analyses, by individuals from the genetics laboratory at the University of British Columbia.

RESULTS

The meristic and morphometric data for char captured during the study are shown in Table A2.1. The LDF values given for char captured from all locations, except Funeral Creek, suggest that 100% of the specimens are bull trout. The LDF values for char captured from Funeral Creek (n = 16) suggest that 56.3% are bull trout and 43.7% are Dolly Varden. However, most fish assigned values < 0 were all juvenile fish (age 0 – 3) and those with relatively low LDF values (i.e., 0 – 1) were not sexually mature (Table A2.1).

Haas and McPhail (1991) suggested that total branchiostegal ray number is the best meristic trait to distinguish between Dolly Varden and bull trout. However, this character cannot be used exclusively as a definitive characteristic to identify the two species. Reported values for median branchiostegal ray counts are 22 (range 17 to 23) for Dolly Varden and 27 (range 26 - 31) for bull trout (Haas and McPhail 1991). The median branchiostegal ray count of char captured during this study was 27 (range 26 to 29) and the median anal ray count was 9 (range 9 – 12). The median branchiostegal ray count for char with negative LDF values (i.e., putative Dolly Varden) was 26 (range 24 – 26) and the median anal ray count was 7 (range 6 – 8).

The mtDNA results show that all specimens analyzed were bull trout. The rDNA results indicate that char no. 47258, 47259, and 47264 were hybrids. However, char no. 47258 and 47259 also show evidence that these individuals are bull trout at the FOK marker. Char no. 47264 shows that it is a hybrid only at the MTB marker but reveals nothing at the FOK and GH markers.

DISCUSSION

All char captured were identified as bull trout based on morphological characteristics. However, the LDF values show that four fish from Funeral Creek were possibly Dolly Varden. All of the fish with negative LDF values were young-of-the year (YOY) and juveniles. Juvenile fish, especially YOY, may not have fully developed all bony structures (e.g., branchiostegal rays) or reflect the same proportional characteristics (i.e., standard length; upper jaw length) as older, further-developed fish might. Meristic and morphometric traits that have not fully developed could be a plausible explanation for negative LDF scores.

Although a more likely explanation for misidentification is an inherent bias in the design of the LDF. Since bull trout always have higher counts or measurements they are more susceptible to error, which leads to misidentification of bull trout more often than Dolly Varden (Haas and McPhail 2001). This implies that if errors are made in counts for bull trout they are likely to result in misidentification of bull trout as Dolly Varden or hybrids. Other char captured had low LDF values but showed distinct morphological characteristics of bull trout, which may be an indication that this LDF is not appropriate for this particular geographic region. However, the LDF was designed and tested on 1580 char from all life stages, captured at 310 sites, covering the majority of the known bull trout range (Haas and McPhail 1991). Furthermore, it has been thoroughly reassessed and supported by numerous data since its introduction (Dr. Gordon Haas, Professor, University of Alaska Fairbanks, School of Fisheries and Ocean Sciences, Fairbanks, Alaska, personal communication 2002). The LDF is very sensitive to subtle variation in branchiostegal counts which are easily missed especially for small fish. However, no char captured had branchiostegal ray counts in the range of Dolly Varden, even very small fish with low or negative LDF values.

The data suggest that juveniles with negative LDF values from Funeral Creek may have been hybrids, but more likely were bull trout as no confirmed Dolly Varden have been captured in this area. Although ribosomal DNA analyses suggest that char no. 47264 was a hybrid, this was only evident at one enzyme marker (MTB), which is inconclusive. Most char captured appear to be bull trout and have LDF values to support this. Furthermore, the mtDNA show that all char captured were bull trout, which suggests that fish with low or negative LDF values are likely incorrectly identified. The misidentification of these char are likely due to errors in meristic counts (e.g., branchiostegal rays) which are difficult to count accurately, especially for young-of-the-year fish by inexperienced personnel.

CONCLUSIONS

Despite low LDF scores for some fish, all char captured have been demonstrated to be bull trout based on morphometric and/or genetic analyses. The results indicate that no Dolly Varden char were captured in the study area. Evidence of bull trout/Dolly Varden hybrids were documented in two areas during the study. However, the small sample size and faint genetic signals discovered for these samples preclude their identity as known hybrids. The mitochodrial DNA and morphological analyses also suggest that these specimens were bull trout. The LDF is an effective method for distinguishing larger bull trout from Dolly Varden in the NWT; however, care must be taken to accurately count and measure voucher specimens, especially juvenile and young-of-the-year fish. Furthermore, the co-retention of a few voucher specimens and their deposition in appropriate fish collections should be encouraged for studies conducted in the area, providing this does not compromise the local populations.

ACKNOWLEDGMENTS

This project was directly supported through funding received from Fisheries and Oceans Canada and the Habitat Stewardship Program for Species at Risk, sponsored by the Government of Canada. Funding and in-kind support was also provided by Parks Canada Agency, Fisheries and Oceans Canada, the Northern Scientific Training Program, Manitoba Wildlife Federation, Government of the Northwest Territories, Department of Resources, Wildlife and Economic Development, Tulita Renewable Resource Council, Nahanni Butte Renewable Resource Council, and the Natural Resources Institute. Robert Bajno and Anna Elz are thanked for preparing and analyzing the samples for the genetic component of this project. E. Taylor and J. Reist are thanked for providing the resources to analyze the samples at the University of British Columbia and Freshwater Institute. L. Bataille, K. Bourassa, K. Cott, P. Cott, J. Demers, K. Ditz, K. Hickling, M. Low, A. Nande, G. Sibbeston, D. Tate, B. Vital, M. Vital, and S. Weaver are thanked for their assistance in the field.

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Table A2.1. Qualitative, quantitative, and genetic identification of bull trout dead-sampled from the Northwest Territories in 2000 and 2001.

Fish ID code	Location	Standard length (mm)	Upper jaw length (mm)	ARC[1]	BRC[2]	LDF[3]	Age (yrs)	Eye[4] position	Upper jaw shape	Upper jaw length	Head shape	Head size	mt DNA[5]	rDNA[6]	ID[7]
47257	Unnamed Cr.	267.0	29.9	10	26	0.5052	8	top	decurved	well past eye	flat, triangular	large	BLTR	BLTR	BLTR
47258	Unnamed Cr.	335.0	38.3	12	26	0.9567	8	top	decurved	well past eye	flat, triangular	large	BLTR	HY	BLTR
47259	Keele R.	461.0	53.1	10	28	1.8911	10	top	decurved	well past eye	flat, triangular	large	BLTR	HY	BLTR
47260	Keele R.	478.0	58.3	10	26	0.8877	10	top	decurved	well past eye	flat, triangular	large	BLTR	BLTR	BLTR
47261	Drum Lake	508.0	54.2	10	28	1.5720	9	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47262	Drum Lake	536.0	62.5	9	28	1.7659	14	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47325	South Nahanni R.	281.0	30.7	9	27	0.8625	11	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47326	Unnamed Cr.	266.0	28.0	10	28	1.5166	8	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47327	Unnamed Cr.	246.0	27.1	9	28	1.5181	7	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47328	Unnamed Cr.	349.0	45.5	10	28	2.4509	9	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47329	Keele R.	465.0	57.9	10	29	2.8635	9	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47330	Funeral Cr.	244.0	30.7	10	26	1.0207	11	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47331	Funeral Cr.	90.0	9.1	8	27	0.3836	2	top	decurved	just past eye	-	-	BLTR	BLTR	BLTR
47332	Funeral Cr.	60.0	6.3	8	26	-0.1107	1	top	decurved	just past eye	-	-	BLTR	-	BLTR
47333	Funeral Cr.	54.0	6.1	7	28	1.2381	1	top	decurved	just past eye	-	-	BLTR	-	BLTR
47334	Funeral Cr.	32.0	3.5	8	26	0.0471	0	top	decurved	just past eye	-	-	BLTR	BLTR	BLTR
47335	Funeral Cr.	36.0	2.9	7	26	-1.2152	0	top	decurved	just past eye	-	-	BLTR	-	BLTR
47336	Funeral Cr.	96.0	10.6	9	29	2.1626	2	top	decurved	just past eye	-	-	BLTR	-	BLTR
47337	Funeral Cr.	120.0	12.5	10	27	0.8495	3	top	decurved	just past eye	-	-	BLTR	-	BLTR
47338	Irvine Cr.	400.0	44.5	10	28	1.7399	10	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47339	Drum Lake	368.0	41.7	9	28	1.6387	9	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47340	Drum Lake	528.0	71.7	10	27	2.0267	18	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47341	Drum Lake	491.0	60.9	9	26	0.7829	10	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47342	Drum Lake	465.0	55.0	9	29	2.4576	10	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR

Table A2.1. (Continued).

Fish ID code	Location	Standard length (mm)	Upper jaw length (mm)	ARC[1]	BRC[2]	LDF[3]	Age (yrs)	Eye[4] position	Upper jaw shape	Upper jaw length	Head shape	Head size	mt DNA[5]	rDNA[6]	ID[7]
47343	Drum Lake	560.0	64.9	10	27	1.2890	10	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47344	Drum Lake	576.0	68.0	9	29	2.4489	16	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47345	Drum Lake	550.0	68.6	9	28	2.0669	11	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47346	Drum Lake	491.0	50.7	9	27	0.6345	10	top	decurved	well past eye	flat, triangular	large	BLTR	BLTR	BLTR
47347	Drum Lake	478.0	51.5	9	27	0.8071	13	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47348	Drum Lake	492.0	57.8	9	29	2.4239	11	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47349	Drum Lake	559.0	70.6	10	27	1.6725	11	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47350	Drum Lake	44.0	5.7	10	26	1.1928	1	top	decurved	well past eye	-	-	BLTR	-	BLTR
47351	Drum Lake	51.0	6.5	9	26	0.9258	0	top	decurved	just past eye	-	-	BLTR	BLTR	BLTR
47596	Irvine Cr.	560.0	67.4	10	29	2.7122	15	top	decurved	well past eye	flat, triangular	large	BLTR	BLTR	BLTR
47263	Funeral Cr.	72.0	5.8	7	26	-1.1945	1	top	decurved	just past eye	-	-	BLTR	-	BLTR
47264	Funeral Cr.	65.0	5.2	6	26	-1.3702	1	top	decurved	just past eye	-	-	BLTR	HY	BLTR
47265	Funeral Cr.	287.0	37.0	9	28	2.2240	11	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47266	Funeral Cr.	259.0	34.9	9	27	1.8096	9	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47267	Funeral Cr.	150.0	14.9	9	28	1.1201	4	top	decurved	just past eye	flat, triangular	large	BLTR	-	BLTR
47268	Funeral Cr.	233.0	27.0	9	27	1.1117	7	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47269	Funeral Cr.	312.0	38.3	10	28	2.1732	-	top	decurved	well past eye	flat, triangular	large	BLTR	-	BLTR
47270	Funeral Cr.	166.0	17.5	9	28	1.3473	5	top	decurved	just past eye	flat, triangular	large	BLTR	-	BLTR

1. ARC = principal anal ray count.
2. BRC = total branchiostegal ray count.
3. Linear discriminant function (LDF) score as computed following Haas and McPhail (1991): LDF Score = 0.629(total branchiostegal ray count) + 0.178(principal anal ray count) + 37.310(upper jaw length/standard length) – 21.8.
4. Eye position relative to dorsal surface of head.
5. Identification for individual fish is based on mitochondrial DNA (mtDNA) analyses; BLTR = bull trout, DVCH = Dolly Varden, HY = Hybrid, UK = unknown.
6. Identification for individual fish is based on ribosomal DNA (rDNA) analyses.
7. Identification for individual fish is based on the LDF score, genetic results, and morphometric characteristics.