Bull Trout

Salvelinus confluentus

Original[1] prepared by Jay Hammond

Species Information

Taxonomy

As a member of the genus *Salvelinus,* Bull Trout (family Salmonidae) are not a true trout, but rather a char. Bull Trout have a complicated taxonomic history, in part due to Bull Trout and Dolly Varden (*Salvelinus malma*) being considered for a time as the same species, until Cavender (1978) identified a number of morphological characteristics of the skull and distribution patterns that suggested the two species were actually distinct. Haas and McPhail (1991) also concluded that Bull Trout and Dolly Varden are separate species, based on principal component analyses of meristic and morphometric data. In addition, genetic studies of the genus *Salvelinus*, using ribosomal DNA (Phillips et al. 1992; Phillips et al. 1994) and mitochondrial DNA (Grewe et al. 1990), supported the findings of the morphological studies. In fact, in each of these genetic studies, Bull Trout and Dolly Varden were not as closely related to each other as they were to other char species. This separation between the two species has been recognized by the American Fisheries Society since 1980 (Robins et al. 1980).

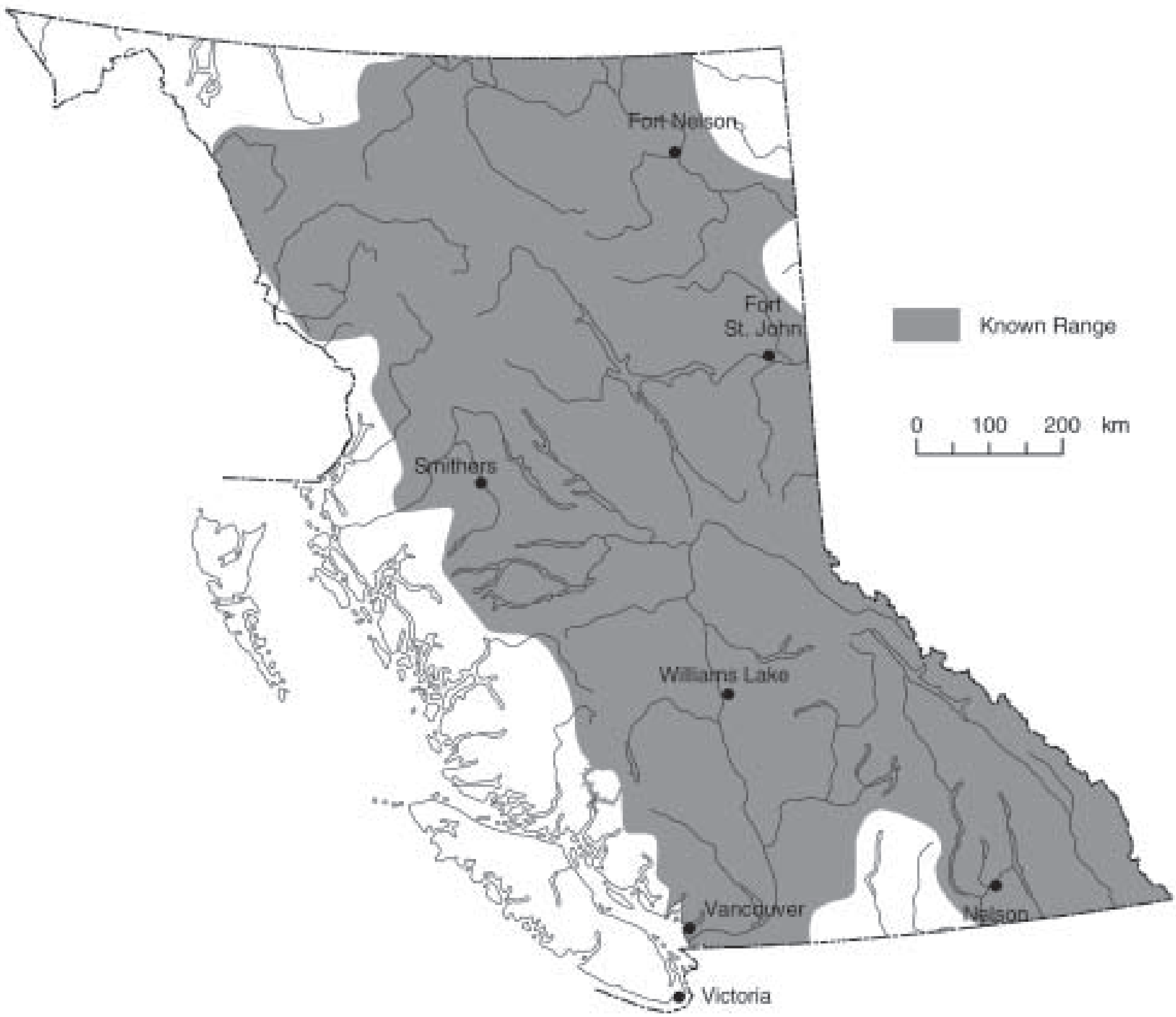
The taxonomic history is also complicated by records of hybridization between Bull Trout and Dolly Varden, where these species occur in sympatry (McPhail and Taylor 1995; Baxter et al. 1997). However, Hagen (2000) undertook a detailed study in the Thutade watershed, where Bull Trout and Dolly Varden ranges overlap, and concluded that ecological factors and niche selection were supporting reproductive isolation between the two species and that the hybrids were generally not as fit as either parent species in this environment. Taylor et al. (2001) noted that, despite the gene flow brought about by hybridization, Bull Trout and Dolly Varden are clearly distinct gene pools. The maintenance of this distinction, in sympatry and in the face of gene flow, was considered conclusive in meeting the test of biological species.

There are no recognized subspecies of Bull Trout. However, Taylor et al. (1999) identified two evolutionarily distinct units—coastal and interior—based on range-wide mitochondrial DNA studies. In British Columbia, the coastal unit is concentrated in the lower Fraser (downstream of Hell's Gate) and other south coast rivers such as the Squamish. This group likely invaded British Columbia from the Chehalis refuge and may extend farther north up the coast; however, sample coverage was poor in that area. The interior unit, occupying the remainder of the species' range in British Columbia, likely invaded British Columbia from the Columbia refuge.

Taylor et al. (1999) also noted that genetic diversity in Bull Trout was principally found between (rather than within) populations and stressed the importance of maintaining as many populations as possible to conserve the species. Costello et al. (2003) used microsatellite DNA to examine genetic structure at the basin level. Their results supported the earlier work and demonstrated high levels of population subdivision within basins. Importantly, above-barrier populations were found to contain locally rare alleles, suggesting the possibility of distinct founding events. These results suggest that recolonization of extirpated populations from neighbouring watersheds may not be sufficient to maintain the species diversity.

1 Volume 1 account prepared by J. Ptolemy.

Bull Trout
(Salvelinus confluentus)



Note: This map represents a broad view of the distribution of habitat used by this species. The map is based on current knowledge of the species' distribution. This species may or may not occur in all areas indicated.

Description

Bull Trout have a large head and jaws in relation to their long, slender body (Post and Johnston 2002). Cavender (1978) reported that Bull Trout have a larger, broader, and flatter head, and a more ventrally flattened body, than Dolly Varden. Bull Trout colouration ranges from green to greyish-blue, with lake-resident fish often displaying silvery sides (Nelson and Paetz 1992; Berry 1994). The dorsum and flanks are spotted with pale yellowish-orange spots. The absence of black spots on the dorsal fin distinguishes Bull Trout from other species of char and trout that are native to western Canada (Berry 1994). The pelvic and anal fins of mature male Bull Trout develop a tri-colour sequence beginning with white leading edges progressing to a black band fading to grey and ending with a bright orange trailing edge. Mature female Bull Trout exhibit a similar pelvic and anal fin colouration, though the colour contrast is not as pronounced as that of male fish (McPhail and Murray 1979).

Bull Trout are large fish relative to other char and trout species (Ford et al. 1995). Stream-resident populations often reach maturity and maximum length at 20–33 cm (Robinson and McCart 1974; Craig and Bruce 1982; Pollard and Down 2001). The maximum size of mature Bull Trout has been reported to vary from 20 to 40 cm in some habitats (Bjornn 1961; McPhail and Murray 1979). However, Pollard and Down (2001) also reported that the mean size of mature Bull Trout in a selection of large lakes, reservoirs, and rivers in British Columbia ranged from 60 to 66 cm for females and from 65 to 73 cm for males. The minimum size for spawners typically exceeded 50 cm. The largest recorded Bull Trout captured, from Pend Oreille Lake, Idaho, was 100 cm long and weighed 15 kg (Goetz 1989).

Sexual dimorphism exists in Bull Trout and male fish are often larger than females (McPhail and Murray 1979; Carl et al. 1989). Spawning males often develop a pronounced hook, or kype, on the lower jaw (McPhail and Baxter 1996).

Distribution

Global

Bull trout are endemic to western Canada and the U.S. Pacific Northwest (Federal Register 1998). Historically they were found in most of the large river systems from about 41° N (i.e., McCloud River drainage in northern California and the Jarbridge River in Nevada) to about 60° N (i.e., headwaters of the Yukon River) (Federal Register 1998). Although mostly located west of the Continental Divide, Bull Trout are also found in certain headwater systems of the Saskatchewan and McKenzie river systems of Alberta and British Columbia (Federal Register 1998). In British Columbia and Washington, Bull Trout have been primarily considered to be an interior species, found mostly east of the Coast (Cascade) Mountains (McPhail and Baxter 1996). However, as the ability of fisheries biologists to discriminate between Bull Trout and Dolly Varden has improved, coastal populations have been recognized (e.g., Olympic Peninsula; lower Fraser and Squamish rivers), with some individuals even making forays into salt water (T. Down, pers. comm.). Through the years, the distribution of Bull Trout has diminished throughout its range; most of this reduction has occurred at its southern fringe.

British Columbia

In British Columbia, Bull Trout are found in practically every major mainland drainage, including those major coastal drainages which penetrate the Coast Mountains into the interior of the province (e.g., Fraser, Homathko, Klenaklini, Bella Coola, Dean, Skeena and Nass rivers). In addition, some coastal populations of Bull Trout have been recognized (e.g., Squamish River).

Drainages/locations where they do *not* occur include Vancouver Island and the Queen Charlotte Islands; the lowermost reaches of some of the major drainages penetrating the Coast Mountains; the Petitot and Hay river systems in the north-east; most of the headwaters of the Yukon River system, except for Swan Lake in the Teslin drainage; and the Alsek system on the north coast (McPhail and Carveth 1993; McPhail and Baxter 1996).

Note that, at the current time, Dolly Varden rather than Bull Trout are identified as the species present in the majority of the coastal drainages that do not penetrate into the interior of the province.

Forest regions and districts

Coast: Chilliwack, North Island (mainland portion), Squamish

Northern Interior: Fort Nelson (absent in Petitot and Hay River drainages), Fort St. James, Kalum, Mackenzie, Nadina, Peace, Prince George, Skeena Stikine (absent in Alsek drainage and all upper Yukon drainage except for Swan Lake in Teslin system), Vanderhoof

Southern Interior: Arrow Boundary (absent in Kettle River), Cascades, Central Cariboo, Chilcotin, Columbia, Headwaters, Kamloops, Kootenay Lake, Okanagan Shuswap (absent in Similkameen and Okanagan rivers), Quesnel, Rocky Mountain

Ecoprovinces and ecosections

BOP: CLH*, HAP, KIP, PEL

CEI: BUB, BUR, CAB, CAP, CCR, CHP, FRB, NAU, NEU, QUL, WCR, WCU

COM: CBR*, CPR*, CRU, EPR, KIM, MEM*, NAB, NAM*, NBR*, NWC, SBR*, SPR*

GED: FRL

NBM: CAR, EMR, HYH, KEM, LIP, MUF, NOM, SBP, SIU, STP, TEP*, THH*, TUR*, WMR

SBI: BAU, ESM, HAF, MAP, MCP, MIR, NEL, NHR, NSM, PAT, PEF, SHR, SOM, SSM

SIM: BBT, BOV, CAM, CCM, COC, CPK, EKT, ELV, EPM, FLV, FRR, MCR, NKM, NPK, QUH, SCM, SFH*, SHH, SPK, SPM, UCV, UFT

SOI: GUU, HOR*, LPR, NIB, NOH*, NTU, PAR, SCR, SHB, STU*, THB, TRU

TAP: ETP*, FNL*, MAU*, MUP

* = presence in portion of ecosection only

Broad ecosystem units

FS, IN, LL, LS, OW, RE, SP

Elevation

The occurrence of Bull Trout is strongly associated with elevational (Rieman and McIntyre 1995) and thermal (Pratt 1984) gradients in streams, and with thermal gradients in individual habitats (Bonneau and Scarnnechia 1996). There are anecdotal observations that Bull Trout do not occur, or are much less frequently observed, above certain threshold temperatures (e.g., Fraley and Shepard 1989; Rieman and McIntyre 1993; Parkinson and Haas 1996). In Washington State, on the west side of the Cascades, 94% of known spawning occurred above 210 m elevation. On the east side of the Cascades, 94% of known spawning occurred above 610 m elevation (Washington State Internet site). Note that these elevation data are mostly from the United States where higher temperatures have often limited Bull Trout distribution to headwater areas. In a study on B.C. populations, Parkinson and Haas (1996) considered temperature to be more important in determining Bull Trout distribution than other physical factors.

Life History

Diet and foraging behaviour

In general, Bull trout fry tend to stay near the substrate to avoid being swept downstream (Ford et al. 1995). Juvenile Bull Trout predominantly feed on aquatic insects and amphipods from benthic, pelagic, and littoral zones (Connor et al. 1997). Boag (1987) reported that juveniles in western Alberta preferentially feed on plecopterans, trichopterans, ephemeropterans, and coleopterans. Juveniles in the Flathead Basin in Montana feed on dipterans and ephemeropterans (Shepard et al. 1984).

The three life history strategies of Bull Trout largely influence diet and foraging behaviour. Steam-resident Bull Trout are often smaller than migratory fish. Of the migratory strategies, adfluvial (spawn in tributary streams and reside in lakes or reservoirs) populations tend to experience greater growth than fluvial (spawn in tributaries, but live in mainstem rivers) fish (Berry 1994; Ratcliff et al. 1996). The growth rate of Bull Trout rapidly increases in populations that enter rivers and lakes with plentiful fish prey (McPhail and Murray 1979). Adfluvial fish are predominantly piscivorous (Berry 1994; Connor et al. 1997; Mushens and Post 2000), which plays a large role in the more rapid growth rate of adfluvial fish over fluvial or resident populations.

Reproduction

Bull trout often reach sexual maturity at 5–7 years of age, but the range is 3–8 years (McPhail and Murray 1979; Fraley and Shepard 1989; Rieman and McIntyre 1996). The body size of mature Bull Trout varies according to their life history strategy (Post and Johnston 2002). Fecundity of females is proportional to body size; small, resident females may produce 500 eggs, while the much larger migratory fish will produce 2000–5000 eggs (McPhail and Murray 1979; Berry 1994).

Bull trout spawn between mid-August and late October (McPhail and Murray 1979; Rieman and McIntyre 1996). Pollard and Down (2001) noted that spawning windows for northern Bull Trout populations were generally earlier than for southern populations and may be affected by annual climatic conditions. Distance covered during spawning migrations and timing of migration varies and depends upon life history strategy (Post and Johnston 2002). Resident populations tend to migrate short distances to spawning grounds, while migratory populations may travel up to or over 250 km (McLeod and Clayton 1997; Burrows et al. 2001). McPhail and Murray (1979) and Weaver and White (1985) reported that 9°C appears to be the temperature threshold below which Bull Trout begin their spawning activities.

Females select redd sites and excavate the nest. Courtship and spawning are carried out at the redd and a complete round of spawning requires several days to complete (McPhail and Baxter 1996).

Site fidelity

Approximately 50% of radio-tagged Bull Trout in a study by Carson (2001) exhibited signs of spawning migration and post-spawning homing behaviour. The results of Carson's study suggest that Bull Trout in the McLeod system in west-central Alberta occupy a small home range and exhibit strong fidelity to their range. Swanberg (1997) also reported strong post-spawning homing behaviour suggesting some degree of site fidelity. Burrows et al. (2001) reported mixed fidelity to summer and fall habitat for feeding and spawning in the Halfway River system in north-eastern British Columbia; some radio-tagged Bull Trout had returned to locations where they had been previously located, but other fish remained in streams where they had not been previously observed.

The homing ability of Bull Trout appears to be variable and is perhaps an adaptive trait that is subject to natural selection (McPhail and Baxter 1996). McPhail and Baxter (1996) speculate that the degree of homing may be related to stream size and stability. Baxter (1995) reported that different females will select previously used redd locations in different years suggesting some degree of spawning site fidelity.

Home range

Bull Trout home range is highly variable depending upon life history strategy. The home range for resident populations is much smaller than that of migratory fluvial or adfluvial populations, which can have very large home ranges, usually because resident populations are restricted to stream reaches located above barriers to migration. Burrows et al. (2001) reported annual movement of up to 275 km in the Halfway River system. Carson (2001) reported small, discrete home ranges for Bull Trout tracked in the McLeod River system in Alberta.

Movements and dispersal

Bull Trout populations may move long or short distances to and from feeding, spawning, and overwintering sites depending upon their life history strategy. Timing of the spawning migration depends on a number of variables that include water temperature, habitat, genetic stock, and possibly daylight (photoperiod regulates endocrine control of these types of behaviour in other salmonids) (Ford et al. 1995). Mature fish from fluvial populations make spawning migrations from large to smaller rivers in mid- to late summer when the water temperatures are relatively high and water levels are typically declining (Oliver 1979; Fraley and Shepard 1989; Hagen and Baxter 1992). Many of the juvenile fish from fluvial populations migrate from their natal areas during their third summer, but some do not emigrate until their fourth summer (Oliver 1979; Pratt 1992; Sexauer 1994). Juvenile migrations begin in spring and continue through summer months (Oliver 1979).

Fluvial forms in the Peace River system make long distance migrations to and from spawning locations (Pattenden 1992; McPhail and Baxter 1996; Burrows et al. 2001), as do populations in the Columbia River system (O'Brien 1996). Adfluvial populations exhibit similar migratory patterns as the fluvial form where mature Bull Trout migrate from lakes to spawning streams (McPhail and Murray 1979; Fraley and Shepard 1989). Juvenile fish (fry, 1+, 2+, and 3+) emigrate from natal streams to lakes or reservoirs through summer months (McPhail and Murray 1979).

Habitat

Structural stage

Forest health and the maintenance of riparian forests are very important in maintaining the integrity of fish habitat. In addition, the forest structural stage surrounding streams may also play an important role. Generally, mature structural stages (5–7) produce more large woody debris than younger seral stages (Robison and Beschta 1990); more sediment trapping and storage (Bragg et al. 2000); more nutrient cycling (Bilby and Likens 1980); and more fish habitat structure (Bragg et al. 2000).

Important habitats and habitat features

Bull Trout are cold water specialists which Rieman and McIntyre (1993) identified as having more specific habitat requirements than other salmonids. These authors reviewed five habitat features that consistently influence Bull Trout distribution and abundance: channel and hydraulic stability; substrate; cover; temperature; and the presence of migration corridors. The influence and temporal importance of each of these features can be modified depending on the life history strategy (fluvial, adfluvial, or resident) and life history stage.

Spawning

Bull Trout spawn in flowing water (references cited in McPhail and Baxter 1996) and show a preference for gravel and cobble sections in smaller, lower order rivers and streams. Bull Trout tend to be very selective when choosing spawning locations. Spawning sites are characterized by low gradients (~1.0–1.5%); clean gravel <20 mm; water velocities of 0.03–0.80 m/s; and cover in the form of undercut banks, debris jams, pools, and overhanging vegetation (references cited in McPhail and Baxter 1996).

Water temperature plays an important role in Bull Trout spawning success. A threshold temperature of 9°C has been suggested as the temperature below which spawning is initiated (McPhail and Murray 1979; Weaver and White 1985), at least for more southern stream systems. More recent data on temperature/spawning timing in northern B.C. systems suggest that temperature thresholds are lower or that temperature is not as important a cue because mean stream temperatures at spawning locations rarely exceed 9° at any time of the year (T. Zimmerman, pers. comm.).

The stability of the temperature environment in natal streams is likely a much more critical feature of high quality spawning locations. There may also be a lower temperature threshold below which spawning is suspended. Allan (1987) reported that Bull Trout in Line Creek in the east Kootenay region of British Columbia stopped spawning when water temperatures dropped below 5°C. Egg incubation requires temperatures <8°C and an optimal range of 2–4°C (Berry 1994; Fairless et al. 1994).

Groundwater interaction with surface water likely creates thermal stability at spawning sites that can act to minimize winter hazards for incubating eggs (Baxter and McPhail 1999). During the winter, stream temperatures in parts of British Columbia are at or very near 0°C; therefore, anchor ice formation is a constant threat to incubating eggs. A stable winter environment would be a spawning site that (1) could be predicted to be anchor ice free for most winters, or (2) demonstrates a stable thermal signature above 0°C year over year (T. Zimmerman, pers. comm.).

Rearing and foraging

In general, all Bull Trout (regardless of the life stage or life history strategy) are cold water specialists. Bull Trout are seldom found in systems where water temperature is above 15°C for prolonged periods (references cited in McPhail and Baxter 1996). Adults are primarily piscivorous and depend on an adequate forage base to support growth and reproduction. Bull Trout appear to be primarily ambush predators and are highly dependent on cover, usually in the form of deep pools, woody debris jams and undercut banks (T. Down, pers. comm.).

Bull Trout fry are often associated with shallow water, low-velocity side channels, and abundant instream cover in the form of cobble and boulders (Environmental Management Associates 1993; Baxter 1994, 1995). Bull Trout fry focus their feeding on aquatic insects near or on the bottom of the stream (Nakano et al. 1992).

Most juveniles rear in streams and appear to prefer pools over riffles, runs, or pocket water (Fraley and Shepard 1989; Nakano et al. 1992). Adequate instream cover is an important component of juvenile habitat. Juveniles in Line Creek in the east Kootenay region of southeastern British Columbia were associated with large woody debris (LWD), undercut banks, and coarse substrate (Allan 1987). Juveniles are benthic and drift foragers (Nakano et al. 1992) that feed on aquatic insects until the fish reach about 11 cm, at which time they usually switch to preying on other fish (Pratt 1992).

Overwintering

Juvenile overwintering in streams is more closely associated with cover than during summer months (Sexauer 1994). Overhead cover, deep, low-velocity water, and the absence of anchor ice are important overwintering habitat features for juveniles (Thurow 1997).

Stream-resident populations of Bull Trout, particularly those in northern latitudes, require suitable ice-free overwintering sites and this is a critical component in maintaining viable populations (McPhail and Baxter 1996). In the fall, fish will move from small tributaries into larger streams or rivers (Craig and Bruce 1982; Stewart et al. 1982). In the Sukunka River in northeastern British Columbia, Bull Trout overwinter in deep pools (Stuart and Chislett 1979). As for juveniles, adult overwintering habitat requirements are low velocity water with sufficient depth to provide ice-free refuges and overhead and instream cover (Rhude and Rhem 1995). Adults often undergo extensive downstream migrations to overwintering habitat (e.g., Burrows et al. 2001).

Conservation and Management

Status

The Bull Trout is on the provincial *Blue List* in British Columbia. Its status in Canada has not been determined (COSEWIC 2002).

Summary of ABI status in BC and adjacent jurisdictions (NatureServe Explorer 2002)

BC	AB	ID	AK	MT	OR	WA	YK	Canada	Global
S3	S3	S3	S?	S3	S3	S3	S?	N3	G3

Trends

Population trends

Generally, Bull Trout populations are considered to be declining in abundance throughout their native range in Canada and the United States (references cited in Post and Johnston 2002). For the most part, this range reduction is comprised of localized extinctions, although in at least one system (the McCloud in California) they no longer exist (McPhail and Baxter 1996). In Alberta, Bull Trout populations have been in decline since the beginning of the 1900s.

In British Columbia, the general trend for Bull Trout populations is stable to diminishing (Pollard and Down 2001) – stable if adequate protection measures are implemented and enforced, but diminishing if forest practices and road development activities (including petroleum development roads in northeastern British Columbia) continue to degrade and exclude suitable Bull Trout habitat. Population trends for Bull Trout in British Columbia are shown in Figure 1 (note that there are minor inconsistencies between the Bull Trout distributions shown in Figure 1 and the Bull Trout distributions noted earlier in this account).

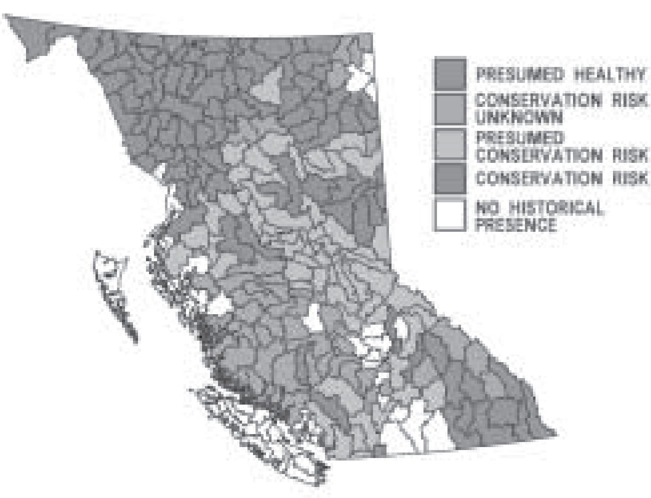


Figure 1. Status of Bull Trout in British Columbia by watershed group. Conservation risk means that the population is known to be in decline (B.C. MWLAP 2002).

Habitat trends

Given the broad distribution of Bull Trout in British Columbia, no studies have attempted to quantify trends in Bull Trout habitat across the provincial landscape. In this situation, it is appropriate to use indicators of general habitat condition; one such indicator is road density in watershed groups (B.C. MWLAP 2002), with road density being a surrogate measure of the amount of development in a given watershed. Cross and Everest (1997) examined the link between changes in habitat attributes for Bull Trout in "managed" watersheds (roaded and subject to logging and/or mining activity) and unroaded/unlogged watersheds. They noted, among other findings, a reduction in pool depth and volume in managed watersheds, which were considered to be key impacts to Bull Trout habitat. In British Columbia, road length increased by 45% between 1988 and 1999 (B.C. MWLAP 2002). This finding suggests a general decline in the quality of Bull Trout habitat in British Columbia.

Threats

Population threats

In British Columbia, a primary threat to Bull Trout is the fragmentation of populations through the disruption of migration patterns. Except for populations upstream of migration barriers, subpopulations that occur in the same watershed most likely exchange genetic material and are able to recolonize streams following catastrophic events. Studies on these clusters of subpopulations or "metapopulations" indicate that the likelihood of persistence decreases as local populations become isolated from each other through the creation of barriers to migration. Obstructions to Bull Trout movement can be fairly obvious (e.g., perched culvert outlets or water velocity through a culvert) or more subtle, such as sections of degraded habitat (e.g., stream channel instability, increasing water temperatures, sedimentation of substrate, or lack of cover). Once fragmented, the components of a metapopulation are much more prone to extirpation from both stochastic and deterministic risks.

A second primary threat to Bull Trout is their sensitivity to angling pressure. The significant increase in the number of roads, and other linear developments such as seismic trails, pipelines, and power line corridors, in previously unroaded watersheds, especially in northeastern British Columbia, is a major concern for Bull Trout populations because it allows anglers and poachers unprecedented access to streams that were previously protected by their remoteness. Poaching and non-compliance with conservative regulations for Bull Trout is a serious problem in previously more remote regions of the province.

Other threats to Bull Trout populations include disease and competition with other species.

Habitat threats

Of all the salmonid species, Bull Trout have the most specific habitat requirements (Rieman and McIntyre 1993) and are very sensitive to habitat degradation. Their specialization as a cold water species makes them highly susceptible to activities such as riparian timber harvesting. Loss of stream shading can lead to elevated water temperatures (both daily mean and peak temperatures), which can be problematic for a species that is seldom found in streams or lakes where temperatures rise above 15°C. Increasing water temperatures can lead to population fragmentation and increase the risk of invasion by other species that may displace Bull Trout and lead to further decreases in their abundance (Parkinson and Haas 1996).

Bull Trout require clean, well-oxygenated water; as a result, the distribution and abundance of all Bull Trout are strongly influenced by channel and hydrologic stability. The eggs and young of this fall-spawning species are vulnerable to winter and early spring conditions such as low flows, which can strand eggs and embryos or lead to freezing within the substrate. These life stages are also susceptible to flooding and scouring. Success of embryo survival, fry emergence, and overwinter survival of juveniles is related to low sedimentation levels, because increased sediment leads to losses in pool depth and frequency; reductions in interstitial spaces; channel braiding; and potential instabilities in the supply and temperature of groundwater inputs (Rieman and McIntyre 1993).

Forest harvesting, petroleum and mining development, and associated access; livestock grazing; and urban development are all anthropogenic threats to the integrity of Bull Trout habitat. The effects of these threats can be separated into three general categories: (1) elimination of habitat or restriction of fish access; (2) sedimentation and erosion; and (3) alteration or loss of required habitat characteristics.

Elimination or restriction

Pre-Forest Practices Code forest harvesting and forestry road development, and petroleum exploration and development access construction, have contributed to the decline in Bull Trout populations around the province by disrupting migration corridors. Perched culverts, debris, channelization, increased water temperatures, and increased water velocities are all capable of influencing access to important habitats utilized by adfluvial, fluvial, and resident Bull Trout populations. Construction of dams and reservoirs in the Peace River and Columbia River watersheds eliminated significant amounts of stream habitat through inundation and also created barriers that, in some cases, have altered historical migration patterns. The resultant isolation and restriction of populations related to these access barriers may reduce the gene flow within and between populations and negatively affect the long-term success of distinct Bull Trout populations throughout the province.

Sedimentation and erosion

Significant changes in unit area peak flows, unit area storm volumes, and response time to storm events are known to be associated with increased development within a watershed (e.g., forest harvest; grazing; petroleum resource, mining, and urban development). As the area of a clearcut increases, a corresponding increase in storm volume occurs. Road development leads to earlier, higher peak flows and can also alter groundwater flows. In addition to influencing peak flows, roads may act as sediment sources.

An increase in sediments and erosion (above natural background levels) are undesirable as they can degrade spawning and rearing habitat, and cause direct injury to fish, by:

- infilling gravel spawning substrate;
- infilling pool and riffle habitat;
- impairing feeding ability, through increased turbidity;
- reducing food availability for juvenile fish and lowering stream productivity, through smothering of aquatic insects; and
- clogging and abrading of fish gills.

Alteration of habitat characteristics

The presence of riparian vegetation is a critical factor in the maintenance of many important habitat features required by Bull Trout and other fish species. However, riparian vegetation is frequently removed as a result of development activities within a watershed, and this loss has significant negative impacts on fish habitat. Riparian vegetation:

- Provides a source of short- and long-term LWD recruitment, which is a key component in the creation of optimal salmonid habitat such as pools and cover (Chilibeck et al. 1992);
- Maintains lower water temperatures by shading the channel—a critical habitat factor for Bull Trout (Scruton et al. 1998; Maloney et al. 1999);
- Increases bank stability and maintains integrity of channel morphology (Robison and Beschta 1990; Chilibeck et al. 1992; Bragg et al. 2000);
- Provides a substrate for many terrestrial insects, which are in turn an important aquatic food source, and provides organic matter (in the form of leaf litter) that supports the aquatic food chain (Chilibeck et al. 1992; Wipfli 1997); and
- Acts as a buffer zone to intercept runoff and filter for sediment and pollutants (Chilibeck et al. 1992).

As for other fish and aquatic organisms, climate change and associated global warming are predicted to reduce Bull Trout habitat by leading to increased water temperatures and leaving even more areas unsuitable for all life stages of this cold water specialist (Kelehar and Rahel 1992; Mullan et al. 1992).

Legal Protection and Habitat Conservation

Bull Trout in British Columbia are protected under the provincial *Wildlife Act*, the provincial *Fish Protection Act*, and the federal *Fisheries Act*. The *Wildlife Act* enables provincial authorities to license anglers and angling guides, and to supply scientific fish collection permits, and the *Fish Protection Act* provides the legislative authority for water managers to consider impacts on fish and fish habitats before approving new water licences or amendments to existing licences, or issuing approvals for works in and about streams. However, the *Fish Protection Act* cannot be used to supercede activities authorized under the provincial *Forest Act*, or where the Forest Practices Code or its successor, the *Forest and Range Practices Act*, applies (see Section 7(7), *Fish Protection Act*).

The federal *Fisheries Act* delegates authority to the Province to establish and enforce fishing regulations under the British Columbia Sport Fishing Regulations. These Regulations incorporate a variety of measures to protect fish stocks, including stream and lake closures, catch and release fisheries, size and catch limits, and gear restrictions.

In addition, Section 35(1) of the federal *Fisheries Act* prohibits activities that may result "in the harmful alteration, disruption, or destruction of fish habitat." Similarly, Section 36(3) of the Act prohibits the deposition of a "deleterious substance of any type" into waters frequented by fish.

Also of note is the fish habitat policy of the federal Department of Fisheries and Oceans, which includes a goal of "… no net loss of the productive capacity of fish habitat", which is designed to maintain the maximum natural fisheries capacity of streams (Chilibeck et al. 1992).

The provincial system of parks and protected areas, and the federal system of parks, provide some level of protection for certain populations, or portions of populations, of Bull Trout. However, given the wide distribution of this species, most of its habitat in British Columbia does not lie within the boundaries of a protected area.

Provisions enabled under the Forest Practices Code (FPC) or its successor, the *Forest and Range Practices Act* (FRPA), that may help maintain habitat for this species include: ungulate winter range areas; old growth management areas; riparian management areas; community watersheds; coarse woody debris retention, visual quality objectives; and the wildlife habitat feature designation. All of these, except community watersheds, have the ability to protect relatively small portions of streamside vegetation (i.e., a few hundred hectares) along a stream; community watersheds have the potential to protect an entire population of a stream resident form.

However, for Bull Trout, these provision are considered to be coarse filters only and thus inadequate to conserve Bull Trout, as this species is more sensitive to habitat disturbances than most other fish species. For example, one potential problem with these provisions is that the current Riparian Management Area (RMA) guidelines do not require retention of a reserve zone on S4 streams (small, fish-bearing; <1.5 m wide), only a 30 m management zone (MOF and MOELP 1995). Given Bull Trout's preference for cool water systems and their use of smaller headwater systems, these guidelines may be inconsistent with the goal of protecting Bull Trout critical habitat.

Provisions exist within FRPA to allow watersheds to be designated as having significant fisheries values, and streams to be designated as being temperature sensitive. The former designation could lead to requirements to consider cumulative hydrologic impacts, while the latter could have implications with regard to riparian retention on S4 and S5 streams. However, notwithstanding that significant fisheries watersheds are as yet undefined, both provisions will require a proactive designation by MWLAP before the provisions would be available to protect and conserve Bull Trout habitat.

The data necessary for such value judgments by the Ministry is not widely available. Furthermore, the impact to the overall temperature regime of individual watersheds, and thus on any downstream fisheries values, as a result of logging small headwater tributaries to their stream banks is poorly understood.

Identified Wildlife Provisions

Sustainable resource management and planning recommendations

Due to the wide distribution of Bull Trout in the province, the varying migratory patterns of the species, and the species' use of a variety of sparsely distributed habitats, wildlife habitat areas (WHAs) cannot address all aspects of the Bull Trout's life history requirements. In addition, as this species is especially sensitive to habitat degradation, its requirements must be addressed at the landscape level, in order to effectively manage for the maintenance of populations.

In sub-basins where Bull Trout are present, and where forest development is planned for the next 5-year period, any of the following are recommended as supplementary triggers for the watershed assessment procedure (WAP):

- more than 10% of the watershed has been logged in the 20 years prior to the start of the proposed development plan, or will be logged in the 25 years prior to the end of the proposed development plan;
- a "significant" number of mass-wasting events are known to have occurred in the watershed (i.e., more than one event/km^2 and more than two events reaching the mainstem);
- the presence in the watershed of either high stream channel density (i.e., more than 1 km of channel/km^2), high road density (i.e., more than 150 m of road length/km^2), or a siginificant number of stream crossings (i.e., more than 0.6/km^2 in the interior or more than 1.4 km^2 on the coast); or
- evidence of significant stream channel stability problems.

The objective of the WAP is to avoid cumulative hydrologic impacts that may affect channel stability or structure. If the WAP determines that the watershed is sensitive to disturbance (a rating of Medium or High in the Hazard Category), Bull Trout populations are at risk. In such sensitive watersheds, the following conservation measures, based on the metapopulation concept, should be demonstrated by strategic and operational planning processes, and reflected in the temporal and spatial layout of cutblocks, road layout and design, and hydrologic green-up and recovery standards:

- Minimization of upstream and upslope disturbances to prevent siltation, temperature, and hydrologic impacts (including disruptions of groundwater flows) in areas influencing critical reaches of Bull Trout habitat;
- Minimization of road networks, total road length, and number of stream crossings, and avoidance of linear road developments adjacent to stream channels, where practical from an engineering perspective;
- Maintenance of riparian habitats in a properly functioning condition, to ensure LWD recruitment is based on life expectancy and decay periods of naturally occurring adjacent tree species;
- Minimization of obstructions to movements, and isolation of populations (e.g., ensure stream crossings will pass migrating Bull Trout at all flows and life history stages, etc.);
- Minimize road construction within 0.5 km of known Bull Trout congregations; and
- Maintain riparian reserves on S4 streams with or suspected to have Bull Trout, or S5 and S6 streams that are tributary to streams with Bull Trout, where local managers deem necessary to protect natural stream processes and limit erosion and sedimentation.

General wildlife measures

Apply general wildlife measure to "identified fisheries sensitive watersheds," as defined by MWLAP, where Bull Trout were part of the rationale for the designation *or* at and above S4 streams with Bull Trout congregations. A congregation is defined as a significant portion of a run. A significant portion will generally be >20% of the adult population of a run, depending on professional judgement. True congregations will be intuitively obvious at critical times of the year. They should be based on a ground survey or aerial redd count that identifies a significant portion of the run accumulating at a specific location/habitat that will be reasonably stable over several years.

Goals

1. Prevent or minimize access to Bull Trout congregations.
2. Prevent or minimize detrimental alterations to Bull Trout habitat, including sedimentation.
3. Maintain important habitat features including cover, substrate quality, pool depth and volume, groundwater flow, water quality, temperature, channel structure, and hydrologic characteristics of the site.
4. Ensure large woody debris recruitment based on life expectancy and decay periods of naturally occurring adjacent tree species.
5. Maintain migration corridors and prevent isolation of Bull Trout population.
6. Maintain or rehabilitate to a properly functioning condition.

Measures

Access

- Do not construct roads and excavated or bladed trails. Where there is no alternative to road or trail development, close to public during staging and spawning times and rehabilitate as soon as possible. Ensure that roads do not impact stream channel integrity, water quality, groundwater flow, substrate composition, cover, and natural temperature regimes.
- Avoid stream crossings at Bull Trout concentrations. Stream crossings should be built to the highest standards to minimize the risk of sediment input or impacts to the channel.

Harvesting and silviculture

- Plan harvest to meet goals of maintaining stream channel integrity, water quality, groundwater flow, and substrate composition; and to minimizing disturbance.

Range

- Do not place livestock attractants within 500 m of known congregations.

Recreation

- Do not develop recreational trails, facilities, or structures within 500 m of known congregations.

Additional Management Considerations

Place roads as far as practicable from critical Bull Trout habitat.

Avoid development of recreational trails, facilities, or structures immediately adjacent to WHAs.

Information Needs

1. Biology, ecology, and limiting factors of the anadromous form of Bull Trout in British Columbia (e.g., factors limiting juvenile recruitment, juvenile migratory patterns and habitat use, dispersal mechanisms, and rates).
2. Knowledge of distribution and stock status is inadequate in most areas of the province.
3. Effects of sustained forest harvesting on the quality and quantity of groundwater supplies in Bull Trout watersheds.

Cross References

Grizzly Bear, "Westslope" Cutthroat Trout

References Cited

Allan, J.H. 1987. Fisheries investigations in Line Creek – 1987. Prepared for Line Creek Resources Ltd., Sparwood, B.C. 67 p.

Baxter, J.S. 1994. Juvenile bull trout (*Salvelinus confluentus*) assessment and inventory in the Chowade River: preliminary surveys (1994). Report prepared for B.C. Min. Environ., Lands and Parks, Fisheries Br., Fort St. John, B.C. 8 p.

_______. 1995. Chowade River bull trout studies 1995: habitat and population assessment. Report prepared for B.C. Min. Environ., Lands and Parks, Fish. Br., Fort St. John, B.C. 108 p.

Baxter, J.S. and J.D. McPhail. 1999. The influence of redd site selection, groundwater upwelling, and over-winter incubation temperature on survival of bull trout (*Salvelinus confluentus*) from egg to alevin. Can. J. Ecology 77:1233–1239.

Baxter, J.S., E.B. Taylor, R.H. Devlin, J. Hagen, and J.D. McPhail. 1997. Evidence of natural hybridiz-ation between dolly varden (*Salvelinus malma*) and bull trout (*Salvelinus confluentus*) in a northcentral British Columbia watershed. Can. J. Fish. Aquatic Sci. 54:421-429.

Berry, D.K. 1994. Alberta's bull trout management and recovery plan. Alta. Environ. Prot., Fish and Wildl. Serv., Fish. Manage. Div., Edmonton, Alta. 22 p.

Bilby, R. and G. Likens 1980. Importance of organic debris dams in the structure and function of stream ecosystems. Ecology 61:1107–1113.

Bjornn, T.C. 1961. Harvest, age structure and growth of game fish populations from Priest and upper Priest lakes. Trans. Am. Fish. Soc. 90:27–31.

Boag, T.D. 1987. Food habits of bull char, *Salvelinus confluentus*, and rainbow trout, *Salmo gairdneri*, coexisting in a foothills stream in northern Alberta. Can. Field-Nat. 101:56–62.

Bonneau, J.L. and D.L. Scarnecchia. 1996. Distribution of juvenile bull trout in a thermal gradient of a plunge pool in Granite Creek, Idaho. Trans. Am. Fish. Soc. 125:628–630.

Bragg, D., J. Kershner, and D. Roberts. 2000. Modeling large woody debris recruitment for small streams of Central Rocky Mountains. U.S. Dep. Agric. For. Serv., Rocky Mtn. Res. Stn. Gen. Tech. Rep. 55.

B.C. Ministry of Water, Land and Air Protection (B.C. MWLAP). 2002. State of the Environment Reporting. Available from: http://wlapwww.gov.bc.ca/soerpt/4fish/trout.htm (Bull Trout).

Burrows J., T. Euchner, and N. Baccante. 2001. Bull trout movement patterns: Halfway River and Peace River progress. *In* Bull Trout II Conf. Proc. M.K. Brewin, A.J. Paul, and M. Monita (editors). Trout Unlimited Canada, Calgary, Alta., pp. 153–157.

Carl, L.M., M. Kraft, and L. Rhude. 1989. Growth and taxonomy of bull charr, *Salvelinus confluentus*, in Pinto Lake, Alberta. Environ. Biol. Fish. 26:239–246.

Carson, R.J. 2001. Bull trout spawning movements and homing behaviour back to pre-spawning locations in the McLeod River, Alberta. *In* Bull Trout II Conf. Proc. M.K. Brewin and M. Monita (editors). Trout Unlimited Canada, Calgary, Alta., pp. 137–140.

Cavender, T.M. 1978. Taxonomy and distribution of the bull trout, *Salvelinus confluentus*, from the American Northwest. Calif. Fish and Game 64:139–174.

Chilibeck, B., G. Chislett, and G. Norris. 1992. Land Development Guidelines for the Protection of Aquatic Habitat. Dept. Fish. Oceans Can. and B.C. Min. Environ., Lands and Parks, Victoria, B.C. 128 p.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2002. Canadian species at risk. Available from: http://www.speciesatrisk.gc.ca

Connor, E., D. Reiser, K. Binkley, D. Paige, and K. Lynch. 1997. Abundance and distribution of an unexploited bull trout population in the Cedar River watershed, Washington, USA. *In* Friends of the Bull Trout Conf. Proc. W.C. Mackay, M.K. Brewin, and M. Monita (editors). Bull Trout Task Force (Alberta), Trout Unlimited Canada, Calgary, Alta., pp. 403–412.

Costello, A.B., T.E. Down, T.S.M. Pollard, C.J. Pacas, and E.B. Taylor. 2003. The influence of history and contemporary stream hydrology on the evolution of genetic diversity within species: an examination of microsatellite DNA variation in bull trout, *Salvelinue confluentus* (Pisces: Salmonidae). Evol. 57(2):328–344.

Cross, D. and L. Everest. 1997. Fish habitat attributes of reference and managed watersheds, with special reference to the location of Bull Trout *(Salvelinus confluentus)* spawning sites in the upper Spokane River ecosystem, northern Idaho. *In* Friends of the Bull Trout Conf. Proc. W.C. Mackay, M.K. Brewin, and M. Monita (editors). Bull Trout Task Force (Alberta), Trout Unlimited Canada, Calgary, Alta., pp. 381-385.

Craig, P.C. and K.A. Bruce.. 1982. Fish resources in the upper Liard River drainage. *In* Fish resources and proposed hydroelectric development in the upper Liard drainage. A.D. Sekerak (editor). Report submitted to British Columbia Hydro and Power Authority. 184 p.

Environmental Management Associates. 1993. Bull trout juvenile and spawning habitat preference criteria, Smith-Dorrien Creek, Alberta. Report to Alta. Environ. Prot., Fish and Wildl. Div., Edmonton, Alta. 26 p. Unpubl.

Fairless, D.M., S.J. Herman, and P.J. Rhem. 1994. Characteristics of bull trout (*Salvelinus confluentus*) spawning sites in five tributaries of the Upper Clearwater River, Alberta. Alta. Environ. Prot., Fish and Wildl. Serv., Rocky Mountain House, Alta. 49 p.

Federal Register. 1998. Rules and regulations. Endangered and threatened wildlife and plants: Determination of threatened status for the Klamath River and Columbia River distinct population segments of bull trout. Vol. 63, No. 111/June 10, 1998.

Ford, B.S., P.S. Higgins, A.F. Lewis, K.L. Cooper, T.A. Watson, C.M. Gee, G.L. Ennis, and R.L. Sweeting. 1995. Literature reviews of the life history, habitat requirements and mitigation/ compensation strategies for selected fish species in the Peace, Liard and Columbia River drainages of British Columbia. Report prepared for the Dep. of Fish. and Oceans and B.C. Ministry of Environment, Lands and Parks, Victoria, B.C. 23 p.

Fraley, J.J. and B.B. Shepard. 1989. Life history, ecology and population status of migratory bull trout (*Salvelinus confluentus*) in the Flathead Lake and river system, Montana. Northwest Sci. 63:133–143.

Goetz, F. 1989. Biology of the bull trout, a literature review. U.S. Dep. Agric. For. Serv., Willamette National Forest, Eugene, Oreg. 53 p.

Grewe, P.M., N. Billington, and P.D.N. Hebert. 1990. Phylogenetic relationships among members of *Salvelinue* inferred from mitochondrial DNA divergence. Can. J. Fish. Aquat. Sci. 47:984–991.

Haas, G.R. and J.D. McPhail. 1991. Systematics and distributions of Dolly Varden (*Salvelinus malma*) and bull trout (*Salvelinus confluentus*) in North America. Can. J. Fish. Aquat. Sci. 48:2191–2211.

Hagen, J. 2000. Reproductive isolation between Dolly Varden (*Salvelinus malma*) and bull trout (*S. confluentus*) in sympatry: the role of ecological factors. MSc thesis. Univ. B.C., Vancouver, B.C.

Hagen, J. and J.S. Baxter. 1992. Bull trout populations of the North Thompson River Basin, British Columbia: initial assessment of a biological wilderness. Report to B.C. Min. Environ., Lands and Parks, Fish. Br., Kamloops, B.C. 37 p.

Kelehar, C. and F. Rahel. 1992. Potential effect of climatic warming on salmonid distributions in Wyoming. West. Div. Am. Fish. Soc. Ann. Meet., July 13–16, 1992, Fort Collins, Colo.

Maloney, S.B., A.R. Tiedemann, D.A. Higgins, T.M. Quigley, and D.B. Marx. 1999. Influence of stream characteristics and grazing intensity on stream temperatures in eastern Oregon. General Technical Report PNW-GTR-459. USDA USFS Pacific Northwest Research Station, Portland, Oregon. 19p.

McLeod, C.L. and T.B. Clayton. 1997. Use of radio telemetry to monitor movements and obtain critical habitat data for a fluvial bull trout population in the Athabasca River, Alberta. *In* Friends of the Bull Trout Conf. Proc. W.C. Mackay, M.K. Brewin, and M. Monita (editors). Bull Trout Task Force (Alberta), Trout Unlimited Canada, Calgary, Alta., pp. 413–420.

McPhail, J.D. and J.S. Baxter. 1996. A review of bull trout (*Salvelinus confluentus*) life-history and habitat use in relation to compensation and improvement opportunities. B.C. Min. Environ., Lands and Parks, Fish. Br., Victoria, B.C. Fish. Manage. Rep. No. 104.

McPhail, J.D. and R. Carveth. 1993. Field key to the freshwater fishes of British Columbia. Draft for 1993 Field Testing. Resour. Inv. Comm., Aquat. Inv. Task Force, Victoria, B.C.

McPhail, J.D. and C.B. Murray. 1979. The early life-history and ecology of Dolly Varden (*Salvelinus malma*) in the upper Arrow Lakes. Submitted to BC Hydro and Power Authority and Kootenay Region Fish and Wildlife. 113 p.

McPhail, J.D. and E.B. Taylor. 1995. Skagit Char Project (Project 94-1). Final report to Skagit Environmental Endowment Commission. 39 p.

Mullan, J., K. Williams, G. Rhodus, T. Hilliman, and J. McIntyre. 1992. Production and habitat of salmonids in mid-Columbia River tributary streams. U.S. Dept. Interior U.S. Fish Wildl. Serv., Monogr. 1. 60 p.

Mushens, C. and J.R. Post. 2000. Population dynamics of the Lower Kananaskis Lake bull trout: 1999 progress report. Prepared for Alberta Conserv. Assoc. and TransAlta Utilities. Univ. Calgary, Calgary, Alta. 65 p. + appendices.

Nakano, S., K.D. Fausch, T. Furukawa-Tanaka, K. Maekawa, and H. Kawanabe 1992. Resource utilization by bull char and cutthroat trout in a mountain stream in Montana, USA. Jap. J. Ichthyol. 39:211–217.

NatureServe Explorer. 2002. An online encyclopedia of life [Web application]. Version 1.6. Arlington, Va. Available from: http://www.natureserve.org/explorer

Nelson, J.S. and M.J. Paetz 1992. The fishes of Alberta. 2nd ed. Univ. Alberta Press and Univ. Calgary Press, Edmonton, Alta. 437 p.

O'Brien, D.S. 1996. Findings of the 1995 Duncan bull trout radio telemetry project. Report submitted to Columbia Basin Fish and Wildlife Compensation Program, Nelson, B.C. 82 p.

Oliver, G.G. 1979. A final report on the present fisheries use of the Wigwam River with an emphasis on the migration, life-history and spawning behaviour of Dolly Varden char, *Salvelinus malma* (Walbaum). Fish and Wildl. Br., Kootenay Region, Cranbrook, B.C. 82 p.

Parkinson, E. and G. Haas. 1996. The role of macrohabitat variables and temperature in defining the range of Bull Trout. B.C. Min. Environ., Lands and Parks. Fish. Proj. Rep. No. 51. 13 p.

Pattenden, R. 1992. Peace River Site C hydroelectric development pre-construction fisheries studies. Data summary report 1991. Prepared for BC Hydro Environmental Resources Div. by RL&L Environmental Services Ltd., Edmonton, Alta. 23 p.

Phillips, R.B., S.A. Manley, and T.J. Daniels. 1994. Systematics of the salmonid genus *Salvelinus* inferred from ribosomal DNA sequences. Can. J. Fish. Aquat. Sci. 51:198–204.

Phillips, R.B., K.A. Pleyte, and M.R. Brown. 1992. Salmonid phylogeny inferred from ribosomal DNA restriction maps. Can. J. Fish. Aquat. Sci. 49:2345–2353.

Pollard, S.M. and T. Down. 2001. Bull Trout in British Columbia - A provincial perspective on status, management and protection. *In* Bull Trout II Conf. Proc. M.K. Brewin, A.J. Paul, and M. Monita (editors). Trout Unlimited Canada, Calgary, Alta., pp. 207-214.

Post, J.R. and F.D. Johnston. 2002. Status of the Bull Trout (*Salvelinus confluentus*) in Alberta. Alberta Wildl. Status Rep. No. 39. 40 p.

Pratt, K.L. 1984. Pend Oreille trout and char life history study. Idaho Dep. Fish and Game, Boise, Idaho.

_______. 1992. A review of bull trout life history. *In* Proc. Gearhart Mountain bull trout workshop. P.J. Howell and D.V. Buchanan (editors). Oreg. Chapter of the Am. Fish. Soc., Corvallis, Oreg., pp. 5–9.

Ratcliff, D.E., S.L. Thiesfeld, W.G. Weber, A.M. Stuart, M.D. Riehle, and D.V. Buchanan. 1996. Distribution, life history, abundance, harvest, habitat, and limiting factors of bull trout in the Metolius River and Lake Billy Chinook, Oregon, 1983-1994. Oreg. Dep. Fish and Wildl., Fish Div., Info. Rep. No. 96–97. 44 p.

Rhude, L.A. and P.J. Rhem. 1995. Bull trout population status, spawning and seasonal movement in the Upper Clearwater drainage, Alberta 1992 and 1993. Alberta Environ. Prot., Natural Resour. Serv., Fish and Wildl., Rocky Mountain House, Alta. 166 p.

Rieman, B.E. and J.D. McIntyre. 1993. Demographic and habitat requirements for the conservation of bull trout, *Salvelinus confluentus*. U.S. Dep. Agric. For. Serv., Intermtn. Res. Stn., Gen. Tech. Rep. INT-302, Ogden, Utah.

_______. 1995. Occurrence of Bull Trout in naturally fragmented habitat patches of varied size. Trans. Am. Fish. Soc. 124:285–296.

_______. 1996. Spatial and temporal variability in bull trout. N. Am. J. Fish. Manage. 16:132–141.

Robins, C.R., R.M. Bailey, C.E. Bond, J.R. Brooker, E.H. Lachner, R.N. Lea, and W.B. Scott. 1980. A list of common and scientific names of fishes from the United States and Canada. Am. Fish. Soc. Spec. Publ. 12, Bethesda, Md.

Robinson, D.J. and P.J. McCart. 1974. Fisheries investigations along the route of Inland Natural Gas Co. Ltd. East Kootenay Link Pipeline, Oasis to Yahk, B.C. *In* Environmental Assessment Report of the 12-inch East Kootenay Link Pipeline. Section B – Salmo to Yahk, British Columbia. William Brothers Canada Ltd., Calgary, Alta.

Robison, E.G. and R.L. Beschta. 1990. Identifying trees in riparian areas that can provide coarse woody debris to streams. Forest Science 36(3):790-801.

Sexauer, H.S. 1994. Life history aspects of bull trout, *Salvelinus confluentus*, in the eastern Cascades, Washington. M.Sc. thesis. Central Wash. Univ., Ellensburg, Wash.

Scruton, D., K. Clarke, and L. Cole. 1998. Water temperature dynamics in small forested headwater streams of Newfoundland, Canada: Quantification of thermal brook trout habitat to address initial effects of forest harvesting. *In* Proc. Forest-Fish Conf.: land management practices affecting aquatic ecosystems, May 1–4, 1996. M. Brewin and D. Monita (editors). Can. For. Serv., Edmonton, Alta., NOR-X-356, pp. 325–336.

Shepard, B., K. Pratt, and J. Graham. 1984. Life histories of westslope cutthroat trout and bull trout in the upper Flathead River Basin, Montana. Montana Dep. Fish, Wildl. and Parks. Kalispell, Mont. 85 p. + 3 appendices.

Stewart, R.J., R.E. McLenehan, J.D. Morgan, and W.R. Olmsted. 1982. Ecological studies of arctic grayling, *Thymallus arcticus*, Dolly Varden, *Salvelinus malma*, and mountain whitefish, *Prosopium williamsoni*, in the Liard River drainage, B.C. Report to Westcoast Transmission Company and Foothills Pipe Lines Ltd. by EVS Consulting, North Vancouver, B.C.

Stuart, K.M. and G.R. Chislett. 1979. Aspects of the life history of arctic grayling in the Sukunka drainage. B.C. Fish and Wildl. Br., Prince George, B.C. 111 p.

Swanberg, T.R. 1997. Movements of and habitat use by fluvial bull trout in the Blackfoot River, Montana. Trans. Am. Fish. Soc. 126:735–746.

Taylor, E.B., S. Pollard, and D. Louie. 1999. Mitochondrial DNA variation in bull trout (*Salvelinus confluentus*) from northwestern North America: implications for zoogeography and conservation. Molecular Ecology 8:1155–1170.

Taylor, E.B., Z. Redenback, A.B. Costello, S.M. Pollard, and C.J. Pacas. 2001. Nested analysis of genetic diversity in northwestern North American char, Dolly Varden (*Salvelinus malma*) and bull trout (*Salvelinus confluentus*). Can. J. Fish. Aquatic Sci. 58(2):406–420.

Thurow, R.F. 1997. Habitat utilization and diel behaviour of juvenile bull trout (*Salvelinus confluentus*) at the onset of winter. Ecol. Freshwater Fish. 6:1–7.

Washington State Department of Ecology. Protection of spawning and early tributary rearing of char. Last updated July 2003. Available at http://www.ecy.wa.gov/programs/wq/swqs/bull_trout/early_trib-identification.html

Weaver, T.M. and R.G. White. 1985. Coal Creek fisheries monitoring study, No. III. Final report. Montana Coop. Fish. Res. Unit, Boseman, Mont.

Wipfli, M.S. 1997. Terrestrial invertebrates as salmonid prey and nitrogen source in streams: Contrasting old-growth and young-growth riparian forests in south-eastern Alaska, USA. Can. J. Fish. Aquat. Sci. 54:1259–1269.

Personal Communications

Down, T. 2003. Min. Water, Land and Air Protection, Victoria, B.C.

Zimmerman, T. 2003. Min. Water, Land and Air Protection, Prince George, B.C.