King County
Department of Natural Resources

Literature Review and Recommended Sampling Protocol for Bull Trout in King County

Final Draft

June 12, 2000

… … … … … … … Salvelinus confluentus

Prepared for:

King County Department of Natural Resources
Pam Bissonnette, Director

Water and Land Resources Division
Nancy Hansen, Manager

Watershed Coordination Unit
Steve Nicholas, Manager

Bull Trout Project Team:
David St. John, Project Manager
Robert Fuerstenberg, Senior Ecologist
Wendy Gable, Communications Specialist
Sandy Kraus, Communications Specialist
Gino Lucchetti, Senior Ecologist
William Mavros, Senior Ecologist
Kate O'Laughlin, Senior Ecologist
Laurel Preston, Communications Specialist

Prepared by:

R2 Resource Consultants, Inc., Redmond, WA
Edward Connor, Project Manager

Historical Research by:

Historical Research Associates, Inc., Seattle, WA
Lisa Mighetto, Historian/Project Manager

This report should be cited as following:

King County Department of Natural Resources. Literature Review and Recommended Sampling Protocol for Bull Trout in King County. Seattle, WA. June, 2000.

ACKNOWLEDGEMENTS

Contributions of time, knowledge and expertise from numerous people were essential to the compilation of the information in this report. The efforts of those listed below to assemble and provide technical reports, participate in interviews, review drafts of this report and provide guidance regarding the most efficient manner to gather and present this information have been invaluable. Their spirit of openness and generosity has resulted in a product that will benefit many taking action to ensure the health of bull trout and other salmonids native to the Puget Sound Basin. The Project Team extends many thanks to them.

Kurt Beardslee, Washington Trout
David Beauchamp, University of Washington
Hal Boynton, Trout Unlimited
Jeff Chan, USFWS
Scott Craig, USFWS
Fred Goetz, ACOE
Curt Kraemer, WDFW
Keith Kurko, Seattle Public Utilities
Dwayne Paige, Seattle Public Utilities
Bob Pfeifer, Parametrix
Al Solonsky, Seattle City Light
Shelley Spalding, USFWS
Paul Spruell, University of Montana
Eric Warner, Muckleshoot Indian Tribe

The Project Team also extends its thanks to those who attended the January 12, 2000, meeting in King Street Center to discuss the draft report and proposed sampling program. The insights and ideas shared there greatly improved this report. Those attending included:

Kerry Bauman, King County DNR
Kurt Beardslee, Washington Trout
Hans Berge, King County DNR
Keith Binkley, Seattle Public Utilities
Melissa Boles, King County DNR (WRIA 7)
Jim Brennan, King County DNR (Nearshore)
Scott Brewer, King County DNR (WRIA 8)
Jeff Chan, USFWS
Peter Christensen, Duke Engineering Services
Richard Ereth, WDFW
Howard Haemmerle, King County DOT
Kollin Higgins, King County DNR
Don Jarrett, Duke Engineering Services
Curt Kraemer, WDFW
Keith Kurko, Seattle Public Utilities
David Low, USFWS
Tom Nelson, King County DNR (WRIA 9)
Dwayne Paige, Seattle Public Utilities
Bob Pfeifer, Parametrix
Jennifer Rice, King County DNR (WRIA 9)
James Schroeder, King County DNR
Fran Solomon, King County DNR (WRIA 7)
Al Solonsky, Seattle City Light
Erick Thompson, King County DOT
Jim Uehara, WDFW
Sewall Young, WDFW

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

EXECUTIVE SUMMARY

This report comprises a summary of available information regarding the distribution, abundance and life history strategies of bull trout/native char in King County watershed areas and a proposed pilot sampling program to fill gaps in data in these subject areas. For purposes of this report, the term "bull trout" is used when presenting life history or habitat information known to pertain specifically to that species or when describing efforts to gather data pertaining specifically to that species. The term "native char" is used when presenting information that pertains to that species complex broadly and *could* apply to a specific group within that complex (e.g., bull trout) but the information necessary to make that connection is not available. It is also used when describing sampling efforts that first target this species complex to facilitate further, more specific analytical measures targeting bull trout.

The literature summary provides information on the life history characteristics and habitat factors that may have the greatest influence on the distribution and abundance of bull trout in King County. Bull trout in the Coastal / Puget Sound Distinct Population Segment (DPS) were proposed for listing as a threatened species under the Endangered Species Act (ESA) by the U.S. Fish and Wildlife Service (USFWS) on June 10, 1998 (*Federal Register* 63[111]:31693-31710). Following the requisite one-year review period, bull trout in the Coastal / Puget Sound DPS were listed as a threatened species by the USFWS on November 1, 1999 (*Federal Register* 64[210]:58910-58933). These char require very cold, clean water in relatively pristine streams for the spawning and rearing phases of their life history, thus limiting the distribution of this species during these phases largely to higher elevations. Bull trout possess complex behavioral and migrational traits, and exhibit several different life history strategies including anadromous, stream-resident, fluvial, and adfluvial. During their migrational phases they may exhibit a higher tolerance for higher water temperatures over short timeframes, facilitating their mobility.

Fifteen subpopulations of native char occur in the Puget Sound region (including subpopulations in the Nisqually, Puyallup, Green, Snohomish, Stillaguamish, Skagit, and Nooksack rivers, and the Lake Washington Basin). A subpopulation is a group whose specific spawning and rearing areas are known and are distinct from those of other groups. Within King County, self-

sustaining populations of native char have been found in the South Fork Skykomish River (upper Snohomish River drainage), the upper Cedar River drainage (including the Cedar and Rex rivers and Chester Morse Lake), and the White River drainage. Recent surveys have documented bull trout in the Green River, Chester Morse Reservoir, and Snohomish River-Skykomish River subpopulations. Incidental observations of native char in recent years have been recorded in the forks of the Tolt River, Issaquah Creek (tributary to Lake Sammamish), the lower and middle Cedar River, Lake Washington, Lake Sammamish, Shilshole Bay and the lower Green River. These isolated observations of native char do not conclusively indicate the presence of self-sustaining populations in each of these areas. Rather, these sightings may suggest that fish occasionally migrate into lakes or a number of lower river drainages from headwater areas, or via the Puget Sound. Anadromous bull trout may have migratory patterns that are similar to anadromous Dolly Varden, which migrate to the ocean during the spring and then randomly enter other stream systems to possibly forage.

Surveys to detect the presence of bull trout/native char have been conducted in various locations in King County, including the upper Skykomish River, the upper and middle Cedar River, and the upper Green River. However, a systematic and formal sampling program for bull trout/native char has not been implemented within geographic King County. Moreover, the USFWS and WDFW do not have conclusive data on the distribution and status of bull trout/native char subpopulations within King County. For this reason, the King County Department of Natural Resources (KCDNR) is proposing a two-phase pilot sampling program to generate data describing the presence of bull trout/native char in drainages where the presence or absence of native char subpopulations has not been confirmed. Information obtained from this proposed sampling program will be valuable to those completing Biological Assessments that are part of the Section 7 project review process and to those developing and implementing multi-species recovery strategies in King County watershed areas in response to ESA listings.

The objective of Phase 1 of the sampling program is to identify the presence of native char in those King County drainages where habitat characteristics are highly suitable for bull trout spawning and rearing but where the presence of self-sustaining populations has not been demonstrated. Phase 2 sampling will be conducted in those areas within King County where

habitat characteristics are less suitable for bull trout spawning and rearing but provide some measure of habitat function that would support bull trout during a portion of their life history. At this time the recommended candidate areas for Phase 1 sampling within King County are:

1) Snoqualmie River above Snoqualmie Falls;
2) Upper Tolt River drainage;
3) Upper Issaquah Creek including Holder Creek, Carey Creek, and smaller tributaries in higher elevation areas which are accessible to migrating fish;
4) Rock Creek in the lower Cedar River drainage above the Landsburg Diversion Dam,
5) headwater tributaries in the upper Green River drainage; and
6) tributaries of the White River within King County.

To increase the likelihood that this proposed sampling program is implemented and the information it generates is shared among those most interested in it, King County will seek the direct involvement of those stakeholders with direct (e.g. land ownership or land management responsibility) interests within the recommended sampling areas.

1.0 Introduction

This technical report was prepared to provide guidance for the development of sampling, monitoring, and recovery plans for bull trout (*Salvelinus confluentus*) populations in King County, Washington. The intended audience of this report is primarily technical staff involved in salmonid conservation planning efforts within King County, although the information presented will be of interest to citizens, and public and private organizations within the Puget Sound basin generally. For purposes of this report, the term "bull trout" is used when presenting life history or habitat information known to pertain specifically to that species or when describing efforts to gather data pertaining specifically to that species. The term "native char" is used when presenting information that pertains to that species complex broadly and *could* apply to a specific group within that complex (e.g., bull trout) but the information necessary to make that connection is not available. It is also used when describing sampling efforts that first target this species complex to facilitate further, more specific analytical measures targeting bull trout.

A summary of literature and data on the current status, life history, and habitat requirements of bull trout/native char is first presented in this report. This literature summary is intended to provide information on the life history characteristics and habitat factors that likely have the greatest influence on the distribution and abundance of bull trout in King County. It should be noted that a number of excellent literature reviews have been prepared on the biology, life history, and habitat requirements of bull trout in the western United States and Canada, including those by Goetz (1989), the Washington Department of Wildlife (WDW 1992), Pratt (1992), Rieman and McIntyre (1993), and McPhail and Baxter (1996). A review of the known distribution of bull trout is then provided for the major river drainages in King County, including the Snohomish River Basin, the Lake Washington Basin, the Green River Basin, and the White River Basin. Finally, based upon the findings of this literature and data review, recommendations for a pilot bull trout sampling and monitoring program for King County are provided.

2.0 Literature Summary with Emphasis on King County

2.1 Regulatory Status

Bull trout in the Coastal / Puget Sound Distinct Population Segment (DPS) were proposed for listing as a threatened species under the Endangered Species Act (ESA) by the U.S. Fish and Wildlife Service (USFWS) on June 10, 1998 (*Federal Register* 63[111]:31693-31710). Following a one-year review period, bull trout in the Coastal / Puget Sound DPS were listed as a threatened species by the USFWS on November 1, 1999 (*Federal Register* 64[210]:58910-58933).

In the final listing document, the USFWS stated that the listing of bull trout was warranted because: 1) available data suggest that populations of this species have substantially declined from historic levels; 2) remaining populations are severely fragmented, increasing the probability of local extinction; 3) bull trout habitat has been degraded over time by land-use activities, urbanization, and hydropower development; 4) populations have been, and continue to be, impacted by fishing and poaching; 5) conservation and recovery efforts implemented to date have been insufficient to improve population levels and restore at least some of the previous distribution of this species; and 6) many populations continue to be impacted by introductions of non-native fish, especially brook trout.

2.2 Systematics

The systematics of native char in the Puget Sound region continue to be the subject of controversy, which is true in general of the taxonomy of char in North America (Benke 1984; Crane et al. 1994). Two species of native char are present in the Coastal / Puget Sound DPS: bull trout and Dolly Varden (WDFW 1998). Cavender (1978) provided the necessary evidence regarding the morphological, osteological, and developmental differences between bull trout and Dolly Varden (*Salvelinus malma*) to determine that these native char are distinct species. Prior to this publication, bull trout were considered to be an inland form of Dolly Varden. It is interesting to note that bull trout were originally described as a species from specimens collected in the Puyallup River (Suckley 1858).

The information to date on hybridization of bull trout and Dolly Varden in the Puget Sound region is contradictory. The results of a genetics study conducted on the Olympic Peninsula and in the Puget Sound region suggest that bull trout and Dolly Varden are separate species, with no evidence for hybridization or introgression (Leary and Allendorf 1997). This is an important finding, since widespread hybridization of bull trout and Dolly Varden would make it difficult to differentiate these two species in those rivers where they coexist, and could suggest that they are the same species. Leary and Allendorf (1997) found that two Puget Sound rivers (Skokomish and Sauk rivers) contained only bull trout, while a third Puget Sound river (Canyon Creek) contained only Dolly Varden, indicating that these two species are distinct, and that hybridization is not common.

Contrary to this finding, meristic studies conducted by the Washington Department of Fish and Wildlife (WDFW) have found fish having morphological characteristics (relative head size, number of anal fin rays, number of branchiostegal rays) intermediate to that of bull trout and Dolly Varden in the Puget Sound region (WDW 1992). WDFW biologists have suggested that the widespread hybridization of bull trout and Dolly Varden in northern Puget Sound rivers provides evidence that bull trout and Dolly Varden are the same species. These intermediate forms were observed to be abundant in northern Puget Sound rivers including the Skykomish, Stillaguamish, and Skagit rivers (Mongilla 1993; Kraemer 1994). Bull trout / Dolly Varden hybrids have recently been observed in British Columbia, although these two species appear to maintain distinct populations despite apparent introgression (Baxter et al. 1997). Dolly Varden are mainly found along coastal areas of northern Washington, British Columbia, and Alaska. Bull trout are more widely distributed than Dolly Varden, and are found in interior areas of Washington, Oregon, Idaho, Montana, British Columbia, and Alberta (Cavender 1978). Bull trout are the only native char species found in the Klamath River Basin in Oregon, and within the Columbia River Basin in Washington, Oregon, Idaho, and Montana (Leary et al. 1993).

It is currently unclear if bull trout is the dominant native char species in the Puget Sound region, since bull trout and Dolly Varden have been found to coexist in many river drainages including the Skagit, Stillaguamish, and Skykomish rivers (WDFW 1998). Recent studies suggest that bull

trout is the dominant native char species in the Cedar River and White River drainages. The upper Cedar River contains the only native char population in King County which has been determined to contain only bull trout. Meristic analysis of char in the upper Cedar River drainage using a discriminant function developed by Haas and McPhail (1991) found that these fish were bull trout (Connor et al. 1997). This population remains isolated upstream of Lower Cedar Falls (RM 34.2), which is an impassable barrier to upstream migration. Recent genetic studies of native char in the White River found that all but one fish analyzed were bull trout (Fred Goetz, pers. comm.). Results of meristic analysis of the native char using the Haas discriminant method suggest that both bull trout and Dolly Varden are present in the Skykomish River system (Kraemer 1994), though this has not yet been verified using genetic methods.

Until a more comprehensive genetic analysis of bull trout and Dolly Varden has been completed in the Puget Sound region, the WDFW stated it would consider these as the same species for management and regulatory purposes (WDFW 1998). Bull trout and Dolly Varden have similar morphological characteristics, which makes them difficult to distinguish by physical appearance alone. The methodologies used to differentiate these species (e.g., Haas discriminant function; Haas and McPhail 1991) have not been widely applied in the Olympic Peninsula and northern Puget Sound where these species occur sympatrically. Even in cases in which a reliable methodology is applied, confidence in identification can be reduced by improper application of the methodology (Haas and McPhail 2000). Further, these species are similar in their life history traits, habitat requirements, and management concerns and approaches (WDFW 1998). Consequently, WDFW currently manages these two species together as "native char", and does not distinguish between these species in its current stock status review (WDFW 1998). However, some researchers have stated that sufficient genetic evidence exists to conclude that bull trout and Dolly Varden are indeed separate species in the Puget Sound area, and that WDFW's decision to manage these as one species may be inappropriate (Leary and Allendorf 1997).

The USFWS has determined at this time that Dolly Varden would not be protected as a threatened species based upon their similarity of appearance to bull trout (*Federal Register* 64[210]:58910-58933), although Section 4(e) of the ESA provides for the listing of a non-

threatened species based on similarity of appearance to a listed species. There is presently no evidence to suggest that the restricted harvest of Dolly Varden threatens bull trout populations in those areas where these two species occur sympatrically. However, the USFWS may consider proposing Dolly Varden for listing in the future based upon similarity of appearance should WDFW decide to manage them as distinct species (*Federal Register* 64[210]:58910-58933).

2.3 Life History

Bull trout possess complex behavioral and migrational traits, and consequently exhibit several different life history forms (Goetz 1989; WDW 1992; Rieman and McIntyre 1993; McPhail and Baxter 1996). Three life history patterns have been observed in this species: stream-resident, fluvial, and adfluvial (McPhail and Baxter 1996). Anadromy, a fourth life history pattern, has been observed among native char but to date has not been definitively proven as a life history pattern for bull trout. Stream-resident forms of bull trout complete their entire life cycle in headwater streams. The streams where resident bull trout are found are typically cold and relatively unproductive. Consequently, stream-resident forms are often small in size, rarely exceeding 300 mm in length (McPhail and Baxter 1996). Fluvial forms spawn and rear in small, headwater steams, but migrate to larger rivers where they mature as adults. Fluvial bull trout are often much larger than stream-resident forms because of the higher productivity of mainstem rivers (Goetz 1989). Adfluvial forms spawn and rear in headwater streams like fluvial fish, but migrate to lakes and reservoirs to mature. Due to the high productivity of many lakes, adfluvial bull trout can attain lengths exceeding 700 mm (Goetz 1989; Ratliff et al. 1996). Fluvial and anadromous native char in the Snohomish and Skagit river basins often exceed 700 mm in length (Curt Kraemer, pers. comm.).

Anadromous forms of native char have been observed in coastal regions of British Columbia and western Washington. In the Puget Sound Region, anadromous native char have been reported to be present in the Skagit and Skykomish basins (WDFW 1998). Native char have occasionally been observed at the mouths of some Puget Sound rivers (e.g., Duwamish and Puyallup) suggesting that these fish may be anadromous. Native char tagged in the Skagit River have been captured in the Snohomish River, providing evidence for the presence of anadromous native char

in the Puget Sound region (Curt Kraemer, pers. comm.). Although the species identity of these anadromous forms has yet to be confirmed, recent genetic testing suggests that most native char in the Snohomish River system are bull trout (Curt Kraemer, pers. comm.).

Individual populations of native char may possess all four life history forms (WDW 1992; Rieman and McIntyre 1993; McPhail and Baxter 1996), as is thought to be the case in the Puget Sound region (WDFW 1998; WDFW 1999). Fluvial, anadromous, and resident forms have been observed in the Skykomish River drainage (Kraemer 1994), and in the White River drainage (WDFW 1998). The sightings of native char in the lower Cedar and Green rivers may also be anadromous forms, or fish which have migrated downstream from the upper watersheds of these rivers. The population of bull trout in the upper Cedar River watershed consists largely of adfluvial fish, since mature adults have not been observed in the tributaries of Chester Morse Lake except during their spawning period (Connor et al. 1997). Results of aging determinations indicated that most bull trout in tributaries of Chester Morse Lake are one to three years in age. Analysis of gonads of bull trout in Chester Morse Lake indicated that these fish do not become sexually mature until 5 to 6 years of age (Connor et al. 1997).

Spawning of most native char populations in the Puget Sound region occurs in September and October (WDFW 1998), though it may occur in August at higher elevations (above 3,000 ft) in the Cascades (Wissmar and Craig 1997), and as late as November in lower drainages (e.g., upper Cedar River, see Reiser et al. 1997) and coastal streams (Goetz 1989). Spawning of bull trout appears to be triggered when water temperatures decline below 9°C (Goetz 1989; McPhail and Baxter 1996). Bull trout in Gold Creek, Washington (near Snoqualmie Pass) were found to commence their spawning migration from Keechelus Lake in the early summer (Wissmar and Craig 1997). Bull trout spawned in the upper reaches of this stream during September when temperatures ranged from 9 to 11°C. Spawning in the Skykomish River commences from mid-September to early November when water temperatures drop below 8°C, and begins in most years during early October (Kraemer 1994). Most bull trout in Chester Morse Lake migrate into the Cedar and Rex rivers immediately prior to spawning, which occurs from late September through late November (Reiser et al. 1997). Water temperatures in the Cedar and Rex rivers are typically 9°C or less when bull trout are spawning (as determined by thermograph records),

although some spawning activity has been observed at temperatures at 10°C and slightly higher (Dwayne Paige, pers. comm.).

Bull trout eggs hatch between 51 days (at 10°C) and 126 days (at 2°C) (McPhail and Baxter 1996). The optimal temperatures for egg development are between 2°C and 4°C, based upon high survival rates observed at these temperatures. Emergence from the streambed typically occurs in late winter and early spring (Pratt 1992). The emergence period of bull trout fry in the upper Cedar River drainage was found to extend from late March through late May, with peak emergence observed during April (Reiser et al. 1997). Water temperatures typically range from 3 to 7°C during the period of peak fry emergence the upper Cedar River drainage (Dwayne Paige, pers. comm.).

Fluvial, adfluvial, and anadromous native char typically remain in tributary streams as juveniles for two to three years (Goetz 1989; Ratliff et al. 1996; McPhail and Baxter 1996). They then migrate downstream to mainstem river sections (fluvial forms) or lakes (adfluvial forms). This is consistent with the observation of bull trout in the upper Cedar River drainage, which were determined to be two to three years of age prior to migrating to Chester Morse Lake to mature (Connor et al. 1997).

Bull trout become sexually mature between five and seven years of age (Goetz 1989; McPhail and Baxter 1996, WDW 1992). Most adult bull trout in the upper Cedar River watershed were found to become sexually mature at five years of age (Connor et al. 1997). Their late age of maturity exposes bull trout generally to greater risks of not reaching reproductive capacity due to fishing pressure, competition from non-native fish such as brook trout, and natural and man-made disturbances relative to that of other salmonids.

2.4 Habitat Requirements

2.4.1 Water Temperature

Bull trout are generally regarded as requiring cold, clean water in relatively pristine streams (Goetz 1989; McPhail and Baxter 1996; WDFW 1998; USFWS 1998). The geographic extents

of bull trout distribution follows a pattern exhibiting a general relationship to water temperature parameters. Water temperature is probably the most important habitat feature limiting the distribution and abundance of this species, and for this reason self-sustaining bull trout populations are most likely to be found in colder, higher elevation watersheds (Reiser et al. 1997). Bull trout, like other native char species including Dolly Varden and arctic char in western United States and Canada, are endemic to the northern regions of the continent (Cavender 1978; Haas and McPhail 1991). Bull trout are most abundant in the northern portion of their distribution (i.e., Yukon Territory and British Columbia), and progressively decline to isolated, remnant populations through the southern limit of their distribution in the Klamath River Basin of Oregon, and the Jarbidge River Basin in Nevada. The current distribution of this species in their southern range is limited to systems (e.g., Klamath and Metolius river drainages in Oregon) which are dominated by cold springs (Goetz 1989; Ratliff et al. 1996). Bull trout have been declining in abundance and distribution through the southern portion of their range since the Pleistocene (Cavender 1978; Haas and McPhail 1991). The range of this species will likely continue to move northward as a result of long-term warming trends, including possible global warming (Ratliff et al. 1996).

Specific data regarding higher temperature as a limiting factor for the distribution of juvenile and adult bull trout include a range of values which vary from 13° C to 19°C (McPhail and Baxter 1996). Many field studies conducted to date suggest that juvenile and adult bull trout are uncommon in streams and rivers where water temperatures exceed 15°C for extended periods (Fraley and Shepard 1989; Goetz 1989; Donald and Alger 1993; Rieman and McIntyre 1993; Ratliff et al. 1996; McPhail and Baxter 1996) (Table 2.1). There is currently little information on how frequently water temperatures can exceed this value before limiting the distribution of bull trout. These findings are largely consistent among bull trout populations located in the Pacific Northwest, and suggest that this temperature value may represent the upper physiological tolerance limit for bull trout juveniles although additional available information makes such generalizations problematic. A study of the distribution of juvenile bull trout in the Cascade Mountain streams in Oregon (Deschutes and upper Willamette drainages) and Washington (upper Cedar River and upper Yakima River drainages) found that this species was not present in streams where summer water temperatures exceeded 14°C (Goetz 1997a). In another bull trout

study conducted in the Tuccannon and Asotin rivers of Washington, the warmest stream temperature where young-of-year (YOY) bull trout were observed was 13°C, and the warmest temperature where age 1+ and older juvenile bull trout were observed in these drainages was 16°C (Martin et al. 1992). Adult bull trout are more likely to tolerate warm water temperatures than juveniles, though observations of adults in water warmer than 19°C are rare (McPhail and Baxter 1996).

Bull trout require cold water for spawning and incubation. The threshold temperature below which spawning appears to occur in bull trout is approximately 9°C (Goetz 1989; McPhail and Baxter 1996). Bull trout have been observed to spawn in slightly warmer water (10°C to 11°C) in Gold Creek, Washington (Wissmar and Craig 1997). The distribution of spawning areas in the Puget Sound region may be limited to those having temperatures that drop below 10°C during the fall spawning period. Stream temperatures during the egg incubation period may also limit the distribution of bull trout spawning areas. The optimal range of temperatures for bull trout incubation ranges from 2°C to 4°C (McPhail and Baxter 1996). Successful incubation of bull trout eggs may require water temperatures below 5°C during the winter incubation period (WDFW 1999). Low survival rates of bull trout eggs and embryos (0 to 20 percent) were observed at temperatures between 8°C to 10°C (McPhail and Baxter 1996). Cold water temperatures during the winter incubation period may ultimately determine the range of bull trout spawning areas in the Puget Sound region (Curt Kraemer, pers. comm.).

Table 2.1 Temperature requirements of bull trout at various life stages (multiple sources cited in report).

Life Stage	Optimal Range (°C)	Upper Limiting Temperature (°C)
Spawning	5-9[a]	10[a]
Incubation	2-4[b]	10[b]
Juvenile	7-8[c]	16[d]
Adult	7-12[e]	19[f]

a – Fraley and Shepard 1989
b – McPhail and Baxter 1996
c – Goetz 1989
d – Goetz 1989; Rieman and Baxter 1993; McPhail and Baxter 1996

c – Shepard et al. 1984; Goetz 1989
f – Shepard et al. 1984; McPhail and Baxter 1996; Adams and Bjorrn 1997

2.4.2 Spawning and Incubation

Bull trout generally spawn in a limited number of reaches within a given river drainage (Fraley and Shepard 1989; McPhail and Baxter 1996). Spawning fish typically use the same reaches during consecutive spawning seasons. Groundwater influence and proximity to cover were reported as important factors in spawning site selection (Fraley and Shepard 1989). Studies conducted throughout the range of this species indicate that spawning activity is often concentrated in reaches fed by cold headwater streams, or reaches having large groundwater inflows (Pratt 1992; McPhail and Baxter 1996). Spawning sites are characterized by low gradient sections of streams having abundant gravel, relatively low water velocities, depths from 10 cm to 1 m, and proximity to cover (Fraley and Shepard 1989; WDW 1992; McPhail and Baxter 1996). Bull trout in the upper Cedar River drainage were found to spawn in river sections possessing abundant gravels at depths between 12 and 48 cm, and velocities between 12 and 60 cm/sec (Reiser et al. 1997).

Hydrologic factors, especially low flows during the late summer and early fall, were found to be the most important factors limiting the distribution and survival of a remnant population of bull trout in Gold Creek, which is located at Snoqualmie Pass (Wissmar and Craig 1997). Low flows during the late summer isolated portions of this stream, preventing adults from migrating into preferred holding and spawning habitats in the upper reaches of this drainage, and resulted in high levels of mortality to spawning fish.

2.4.3 Rearing

Sediment is one of the most important physical habitat factors influencing the distribution and abundance of juvenile bull trout in streams and rivers. Juvenile and adult bull trout have been found to be closely associated with coarse substrates such as large gravels, cobbles, and boulders in streams (Goetz 1989; WDW 1992; McPhail and Baxter 1996; Watson and Hillman 1997). Sedimentation, by filling in the interstitial spaces within the substrate matrix, can substantially reduce the amount of habitat cover that would otherwise be provided by coarse substrates. This

can limit the distribution of juvenile fish. Sedimentation and the resulting loss of cover along and within the stream bottom likely results in increased mortality rates of juvenile native char during the winter, when these substrates would provide critical refuge habitat from high flows and cover from predators.

Bull trout fry are usually found in shallow, slow, backwater side-channels and eddies, in close proximity to instream cover (Goetz 1989; Pratt 1992). Young-of-the-year bull trout are found primarily in lateral stream habitats such as side channel areas and along stream margins, especially in areas possessing low velocities (Fraley and Shepard 1989). Older juveniles and adults are primarily bottom dwellers, and are often associated with coarse substrates such as large cobbles and boulders (Fraley and Shepard 1989; Pratt 1992). The association with bottom substrates was found to be greatest during the winter (Bonneau and Scarnecchia 1998). Older juveniles and adults have been found to congregate in deeper pools in many drainages in the Pacific Northwest (Fraley and Shepard 1989; Watson and Hillman 1997; Bonneau and Scarnecchia 1998), particularly those which possess large woody debris or undercut banks. Juvenile bull trout were found to generally use shallow channel margins and backwater areas of riffles in streams located in the Yakima and Wenatchee river drainages (Sexauer and James 1997). Juvenile bull trout in the upper Cedar River were found to occupy habitats exhibiting a variety of physical features, including pools with abundant woody debris cover, and riffles and runs with abundant substrate and pocket-water cover (Connor et al. 1997). Off-channel habitats, including small ground-water fed tributaries and wetland areas, have been found to provide important rearing habitat to juvenile bull trout in the upper Cedar River system (Dwayne Paige, pers. comm.).

2.5 Metapopulation Concepts

Bull trout are typically found in isolated habitat areas or "patches" within a river drainage, which is a consequence of the narrower range of habitat conditions tolerated by this species in relation to other salmonids (Rieman and McIntyre 1993). It has been argued that habitat disturbances such as logging and natural flood events will result in the increasing likelihood of local extinction of this species, provided that subpopulations are further fragmented and isolated by

dams, debris flows, river sections possessing low-quality habitat, and other barriers to migration (Rieman and McIntyre 1993).

The metapopulation concept suggests that populations often become extinct within subdrainages of a watershed degraded by natural or man-made disturbances. The subdrainages where fish have been extirpated, however, can be recolonized later by the same species provided that individuals disperse and migrate from existing populations into the extirpated drainage. The patchy nature of bull trout populations has been thought to be consistent with the metapopulation concept (Rieman and McIntyre 1993), in which local populations found in individual streams are partially or completely isolated from other populations. This increases the risk of extinction of a subpopulation caused by natural or manmade disturbance, as well as from the loss of genetic diversity and the resulting inability of the population to adapt to changes in environmental conditions. Increasing population fragmentation and disruption of habitat increases the risk of extinction to all bull trout subpopulations within a river drainage (Rieman and McIntyre 1993). Providing and maintaining the interconnectivity among subpopulations is important from a management standpoint for protecting and restoring healthy bull trout populations over time. Based upon the results of metapopulation simulation modeling conducted by Rieman and McIntyre (1993), the USFWS has proposed minimum population targets for bull trout subpopulations throughout their range, above which the risks of extinction would be minimized (*Federal Register* 63[111]:31693-31710).

Recent studies, however, suggest that bull trout populations may not be structured in a way that is consistent with all aspects of metapopulation theory. First, bull trout have been recently found to possess little genetic variation within subpopulations, but with substantial genetic differences among populations in the Flathead River Basin (Kanda 1998) and Pend Oreille Lake Basin (Paul Spruell, pers. comm.). These findings suggest that there may be little gene flow between subpopulations, which contradicts a major assumption of metapopulation theory that there is dispersion and migration among subpopulations. Second, bull trout in tributaries to Pend Oreille Lake have been found to persist in numbers considerably lower than those predicted by metapopulation models as necessary to support a viable population over time. This recent finding suggests that subpopulations of bull trout may be more resilient than previously thought

to localized habitat perturbations. Never-the-less, it is still prudent, from a management perspective, to protect and restore as many remaining bull trout subpopulations as possible, since the abundance and distribution of this species is considerably smaller than that occurring historically. Although some populations are persisting at very low numbers, these small populations are still at an increased risk to extirpation because of stochastic events. These small numbers are more likely a reflection of impacts of past management practices than they are a reflection of original population levels.

2.6 Historical Information on Bull Trout/Native Char in King County

The first scientific description of native char in King County was in 1856 (Suckley and Cooper 1860). This species was referred to as the "red-spotted salmon trout", and was assigned the scientific name *Salmo spectablis* (renamed *Salmo campbelli* by Suckley in 1874). Suckley first observed native char in the Duwamish and Nisqually rivers, as well as "other rivers emptying into the Puget Sound" during June 1856. These fish were found in relatively low numbers until October, when fish were observed to enter the mouths of rivers in "vast numbers" and continued to be captured until "near Christmas" (Suckley and Cooper 1860). The largest individual was observed in the Duwamish River and was about two feet in length. Another specimen was captured 35 miles up the Green River in June 1856. Suckley observed native char in the Puyallup River during September 1856, and referred to this species as *Salmo confluentus*. This same species was also observed in the Black River in December 1858 (Suckley 1874). He also described a third native char species present in the Nisqually River as *Fario stellatus*, which was also described as being present in some "affluents of Puget Sound" (Suckley and Cooper 1860). This latter species was described as being similar in physical features to the other species except for the lack of red spots along the side of the fish. The confusion in the differentiation among these presumed char species may have been caused by differences in physical size and coloration between fish which are presently defined as Dolly Varden and bull trout, among individuals having different life histories (e.g., fluvial versus adfluvial), and among individuals possessing varying degrees of spawning coloration.

Native char in the Puget Sound had limited commercial value during the later part of the 1800s,

and were sold at market in small numbers relative to that of salmon ($1,000 value for steelhead and Dolly Varden combined versus $222,000 for salmon in 1895 [Crawford 1896]). Commercial fishing for native char continued in the Puget Sound through the 1920s, with the total catch of "Dolly Varden trout" varying between 9 and 2,348 (average 537) pounds per year from 1921 through 1930 (WDF 1938). Records of fishing catches of native char were not published following 1930. Native char were described as being abundant but of "slight commercial value" along the west coast of Washington and Oregon during the 1930's (Schultz and DeLacy 1935).

Given their minor commercial and sport fishing value, efforts to describe the distribution and abundance of native char in King County rivers, streams, and lakes have been minor compared to that expended toward salmon, steelhead, and other trout species throughout most of the twentieth century. Until recently, native char were typically regarded as a nuisance species by fish management agencies and sport fishermen. The low regard for this species stems from the piscivorous nature of native char; large individuals have been known to consume substantial numbers of salmon, steelhead, and trout fry. For example, Dolly Varden were described to be the "worst enemy of other fish" in biological surveys conducted in the northern Puget Sound streams (Darwin 1921).

2.7 Current Distribution in King County

The distribution and abundance of native char in western Washington is poorly understood due to the lack of comprehensive survey data. Reliable long-term trend data are available for only a small number of drainages (WDFW 1998). A total of 34 subpopulations of native char have been identified in the Coastal-Puget Sound DPS (*Federal Register* 64[210]:58911-58933). Bull trout were found to be present in 12 of 15 subpopulations analyzed to date using genetic and morphometric-meristic tests. This suggests that bull trout are present in most systems known to contain native char (i.e., bull trout and Dolly Varden). Of the 33 subpopulations of native char identified to date in the Coastal-Puget Sound DPS, 10 occur in the coastal area of Washington (including Chehalis, Hoh, Quinault, Queets, and Quillayute rivers), 5 are present in the Strait of Juan de Fuca area (including Elwha and Dungeness rivers), 3 are present in the Hood Canal area

(Skokomish River), and 15 occur in the Puget Sound area (including subpopulations in the Nisqually, Puyallup, Green, Snohomish, Stillaguamish, Skagit, and Nooksack rivers, and Lake Washington).

Within King County, self-sustaining populations of native char have only been found to date in the South Fork Skykomish River (upper Snohomish River drainage), the upper Cedar River drainage (including the Cedar and Rex rivers and Chester Morse Lake), and the White River drainage (WDFW 1998) (Figure 2.1). A self-sustaining population is defined as one which possesses both spawning adults and rearing juveniles in numbers which are sufficient to support the population over time. Incidental observations of native char have been recorded in Issaquah Creek (tributary to Lake Sammamish), the lower and middle Cedar River, and the lower Green River in recent years. If these were indeed bull trout, these isolated observations may suggest that they have complex migratory patterns within King County, and that individual fish may opportunistically move into drainages where self-sustaining populations may not have been found historically or are not currently present. These could also be remnant populations. Anadromous bull trout may have migratory patterns that are similar to anadromous Dolly Varden, which migrate to the ocean during the spring and then randomly enter other stream systems (Armstrong 1984). The isolated observations of native char in certain King County rivers do not conclusively indicate the presence of self-sustaining populations, but rather, may suggest that fish occasionally migrate into a number of lower river drainages from headwater areas, or via the Puget Sound.

2.7.1 Snohomish River Basin

Self-sustaining populations of native char have been documented in the upper Skykomish River basin by WDFW biologists (WDFW 1998; WDFW 1999), and by presence/absence surveys conducted for the U.S. Forest Service (USFS) within the North Fork Skykomish River during the summer of 1998 (R2 Resource Consultants 1999). Recent surveys have documented bull trout within the Snohomish River-Skykomish River native char subpopulation (*Federal Register* 64[210]:58910-58933). Native char have been found in the mainstem of the upper North Fork Skykomish River and its tributaries between Bear Creek Falls and Deer Creek Falls (WDFW

Figure 2.1 Current known distribution of self-sustaining native char subpopulations, and isolated observations of native char in King County (multiple sources, cited in report).

1998), in the lower sections of West Cady and Goblin creeks, and in Salmon Creek (WDFW 1999). Native char have also been found within the South Fork Skykomish River, with most fish in this drainage spawning in the lower sections of the East Fork Foss River (WDFW 1998; WDFW 1999). The population of native char in the South Fork Skykomish River was established following the construction of a trap-and-haul facility at Sunset Falls in 1958 (WDFW 1998). Native char were not observed in the South Fork Skykomish River prior to the construction of this fish passage facility, but migrated into the South Fork from the North Fork following the completion of this facility (WDFW 1999). The native char present in the South Fork Skykomish River are not considered to be separate from those in the North Fork Skykomish (WDFW 1998). The most likely streams to support bull trout in the South Fork Skykomish are the Foss River, Tye River, Miller River, and Deception Creek (WDFW 1998).

Three life history forms of native char are present in the Skykomish River system (including the North and South forks): anadromous, fluvial, and resident (Kraemer 1994). Anadromous and fluvial adults enter tributaries prior to spawning, between late May into September (WDFW 1998; WDFW 1999). Spawning within this drainage occurs from late August to early November, with peak spawning occurring during October and early November. Spawning activity in this drainage commences when temperatures drop below 8°C (WDFW 1998). Fluvial fish have been found to return to the same holding areas in mainstem river sections following spawning in higher tributaries. Sub-adult anadromous forms migrate from the marine environment into the lower Snohomish River, or other nearby systems in the fall or early winter, to overwinter in freshwater (WDFW 1999). These fish remain in the lower river during the winter, and rarely migrate more than 30 miles upstream.

Habitat conditions are generally considered to be favorable for native char spawning and juvenile rearing in the reaches of the North Fork Skykomish River and its tributaries (WDFW 1998). The East Fork Foss River, which is situated largely within the Alpine Lakes Wilderness, provides suitable habitat for native char (WDFW 1998). Most bull trout spawning and rearing areas in the Skykomish River drainage are found in headwater areas possessing cold water temperatures. Streams most likely to support spawning and early juvenile rearing are those draining large snowfields, which maintain water temperatures below the thermal maximum of this species,

throughout the year (WDFW 1998). The downstream limit of successful native char spawning in the Skykomish drainage is upstream of the winter snow line (WDFW 1999).

An adult native char was observed in the North Fork Tolt River at River Mile 2.2 during the fall of 1999 (Kurt Beardslee, pers. comm.) This fish was about 17 inches in length. Native char have also been observed in the canyon reach of the North Fork Tolt River in previous years. A large redd was observed in the upper North Fork Tolt River during the fall 1997, and was possibly constructed by a native char. Adult native char have also been observed in the South Fork Tolt River between River Miles 3.2 and 5.2 (i.e., below Tolt Reservoir) in the past five years during fall snorkel surveys conducted by Washington Trout (Kurt Beardslee pers. comm.). An average of one native char has been observed in the South Fork Tolt per year during these surveys. Native char were not found during fish studies conducted in the Tolt Reservoir (sampled using gill nets) and in its upstream tributaries (sampled by electrofishing) (Tappel and Tappel 1995).

Native char have not been found above anadromous fish barriers in the Snohomish River Basin, with the exception of Sunset Falls and Troublesome Creek in the South Fork Skykomish River (WDFW 1999). Native char have not been found above Snoqualmie Falls, above Spada Lake on the Sultan River, above Deer Falls on the North Skykomish River, or above Alpine Falls on the Tye River (WDFW 1999). Water temperatures in this drainage may be too warm during the summer to support native char spawning and rearing (WDFW 1998). A local fishing guide (Jones 1979) states that "Dolly Varden" may be found in small numbers in the North Fork Snoqualmie River drainage. However, an extensive two-year survey of the river, its tributaries, sloughs and beaver ponds using electrofishing, snorkeling, angling, and creel surveys (Sweeney et al. 1981) did not detect the presence of any char except brook trout. Native char have not been observed by WDFW biologists above Snoqualmie Falls within the past 10 years during stream and creel surveys (Kurt Kraemer, pers. comm.). Native char were not observed during fish surveys conducted above Snoqualmie Falls by the USFS and the Army Corps of Engineers during the early and mid-1990s (Fred Goetz, pers. comm.).

2.7.2 Lake Washington Basin

A self-sustaining population of native char in the Lake Washington basin is known to occur in the Cedar River drainage above Lower Cedar Falls at RM 34.2 (WDFW 1998). Recent surveys have documented bull trout within the Chester Morse Reservoir native char subpopulation (*Federal Register* 64[210]:58910-58933). A small number of native char have been observed in recent years in Lake Washington and one of its tributaries, Issaquah Creek. No native char were observed during a one-year survey of Lake Sammamish conducted in 1980, and one native char was captured in Lake Washington by an angler in April 1981 (Bradbury and Pfeiffer 1992, as cited in WDFW 1998). These surveys were conducted primarily to describe the distribution of fish species in this system and not to detect the presence of native char species. These surveys do not offer conclusive evidence for the presence or absence of bull trout in the Lake Washington system outside of the known upper Cedar River subpopulation. A lake sampling program undertaken from 1983 through 1985 confirmed the presence of native char at several points in Lake Washington, although the sampling design did not specifically target bull trout, or native char, specifically (David Beauchamp, pers. comm.). The information regarding native char generated through this effort may provide some clues about the distribution and life history strategies of native char, and potentially bull trout, in the Lake Washington Basin (Table 2.2).

Table 2.2 Occurrence of native char in UW lake sampling effort on Lake Washington (source: Beauchamp, unpublished data).

Date	Site Collected	Specimen Details	Location Details
4/27/84	Cedar River Delta	Adult male; 635 mm FL; smelt in gut	5-10 m depth
8/9/84	Mid-lake between the SR 520 and I-90 bridges	300 mm FL	60 m depth
3/8/85	Cedar River Delta	Juvenile; 333 mm FL; 384 g; 1 smelt and 6 sockeye in gut	5-10 m depth
3/29/85	Cedar River Delta	Juvenile; 371 mm FL; 521 g; neomysis in gut	5-10 m depth

Two char were observed holding in Carey Creek, a tributary to upper Issaquah Creek, during the

fall of 1993 (Robert Fuerstenberg, pers. comm.). A single native char was observed in Lake Sammamish during April 1981 (WDFW 1998). Dolly Varden have complex migration patterns, and have been observed to migrate into lakes from the ocean during the spring (Armstrong 1984). The two fish observed in Carey Creek, however, could have been spawners, since these fish were observed holding together during the fall spawning period of native char. The 1994 master plan for the Ballard Locks mentions the presence of native char, suggesting that they pass through the locks from Puget Sound to Lake Washington. However, there are no data on the number of char passing through this facility from and to Lake Washington (Fred Goetz, pers. comm.). Eric Warner with the Muckleshoot Indian Tribe observed native char in the viewing chamber of the locks on June 21, 1996 (Jeff Chan, pers. comm.). Bill Mavros (King County DNR) and Brian Footen (Muckleshoot Indian Tribe) caught and released a native char on May 3, 2000 during a beach seine in Shilshole Bay near the outlet of the Ballard Locks (Bill Mavros, pers. comm.). Native char have been known to congregate in Shilshole Bay and in other estuarine areas to feed on smolts during the spring outmigration period (Curt Kraemer, pers. comm.; Steve Foley, pers. comm.).

A small number of native char have also been observed in the lower Cedar River below the Landsburg Diversion Dam. A single native char (225 mm total length) was also captured during a beach seine survey in the lower Cedar River during July 1998 (Fred Goetz, pers. comm.). Finally, a single native char, which appeared to be an anadromous form, was captured and photographed in the lower Cedar River in 1992 (Eric Warner, pers. comm.). Presence / absence surveys for bull trout were conducted in the middle Cedar River upstream of the Landsburg Diversion during in 1996 by Seattle Public Utilities (SPU). No bull trout were observed during these surveys (SPU 1998). A single native char, however, was observed in the middle Cedar River immediately upstream of the Cedar Falls Powerhouse (RM 33.7) in 1998 (Al Solonsky, pers. comm.). This fish may have been a bull trout that passed over the Masonry Dam spillway from the upper watershed, but its origin could not be verified, and the species (bull trout or Dolly Varden) was not definitively determined. A study funded by the City of Seattle estimated that 200 bull trout may be lost per year from the upper drainage due to entrainment through Masonry Dam (Knutzen 1997; Seattle Public Utilities 1998).

A population of native char is present in the upper Cedar River drainage (i.e., upstream of Masonry Dam). Analysis of morphological characteristics using the Haas discriminant function (Haas and McPhail 1991) indicated that these fish were bull trout and not Dolly Varden (Connor et al. 1997). The bull trout population in the upper Cedar River drainage is mainly adfluvial. Mature adults are found in Chester Morse Lake and range in size from approximately 350 to 680 mm total length. Immature bull trout are also found in the lake, and range in size between 200 and 350 mm total length. Aging of these fish using otoliths indicates that bull trout in the upper Cedar River drainage mature between four and six years of age, which is consistent with the age of maturation of bull trout observed in other Washington drainages (WDW 1992). Bull trout in this system may have lifespans exceeding 10 years of age (Connor et al. 1997). These fish are widely distributed throughout the profundal and littoral zones of this lake (Connor et al. 1997). Bull trout in Chester Morse Lake forage on a wide variety of organisms, including invertebrates, fish, and salamanders. Pygmy whitefish, which are abundant in the lake, may be an important prey item for larger, piscivorous bull trout (Connor et al. 1997).

Adults migrate into the Cedar and Rex rivers to spawn during the period September and through late November. The period of peak spawning varies from year to year and is probably a function of discharge and water temperatures. Peak spawning occurs from early October through mid-November (Reiser et al. 1997). Most spawning occurs in the lower sections of the upper Cedar and Rex rivers (i.e., within five and three miles of the reservoir, respectively). Bull trout were found to use the same reaches of these rivers for spawning during three consecutive years of observation (Reiser et al. 1997), and continue to use these same reaches (Dwayne Paige, pers. comm.). Bull trout remain as juveniles in the Cedar and Rex River drainages including smaller tributaries for two to three years, and then migrate to Lake Chester Morse (Connor et al. 1997). Habitat conditions are considered to be generally favorable for bull trout in the upper Cedar River municipal watershed, although logging and forest road building have occurred throughout the drainage (WDFW 1998). Water temperatures may become too warm (> 15°C) for juvenile bull trout during the summer and fall, during some years in certain lower reaches of the Cedar and Rex rivers (R2 Resource Consultants 1999). Lake Chester Morse becomes stratified during the summer and fall, and possesses a cold hypolimnion that likely provides important cold water refuge habitat to bull trout during warm periods. The City's proposed 50-year Habitat

Conservation Plan (HCP) for the Cedar River Municipal Watershed, however, contains provisions to protect and restore aquatic and riparian ecosystem function. It includes a provision, for example, to not commercially harvest timber within the municipal watershed, thereby protecting virtually all forest, including non-forested habitats, in reserve status over the full term of the plan (Dwayne Paige, pers. comm.).

With the exception of the population located within the upper Cedar River Municipal Watershed, no self-sustaining native char populations have been identified to date in the Lake Washington Basin. Temperatures in most tributaries of the lower Lake Washington system are considered to be too warm to support native char juveniles and spawners (Bob Pfeifer, Washington Dept. of Fish and Wildlife, pers. com.). Adult native char likely migrate into the Lake Washington Basin to forage during the winter and early spring when water temperatures are cold. Adults may also migrate into tributaries within the basin during the fall to spawn if water temperatures have dropped to suitable temperatures (< 8°C) (WDFW 1998).

2.7.3 Green River Basin

Although the Green River Basin is known to support a native char subpopulation, and recent surveys document bull trout within the subpopulation (*Federal Register* 64[210]:58910-58933), information on the abundance and distribution of native char in the Green River Basin is very limited (WDFW 1998). Suckley first observed native char in the Duwamish and Nisqually rivers, as well as "other rivers emptying into the Puget Sound" during June 1856. These fish were found in relatively low numbers until October, when fish were observed to enter the mouths of rivers in "vast numbers" and continued to be captured until "near Christmas" (Suckley and Cooper 1860). Only a few native char have been observed in the lower sections of the Green River drainage, indicating that the number of native char that presently use this river is small. The Green River was described as possessing a "few" Dolly Varden during the 1930s (Pautzke and Meigs 1940). A single native char was reported in Soos Creek in 1956, and a single native char was also observed at the mouth of the Duwamish River in the spring of 1994 (Eric Warner, pers. comm.). Historically, native char have been captured in the Green River as far upstream as River Mile 40 (Watson and Toth 1994). Local fisherman have reported that native char have

been seen, on rare occasions, in the lower Green River over the past 50 years (Hal Boynton, pers. comm.). No native char have been found in the upper Green River watershed above Howard Hanson Reservoir during extensive presence / absence surveys conducted by Plum Creek Timber (Watson and Toth 1994), and during fish distribution and habitat surveys conducted by the USFS (1996). The City of Tacoma's Headworks diversion dam has been a barrier to the upstream migration of fish since 1912, and Howard Hanson Dam has been a barrier to upstream migration since 1961. Also, the migration of native char into the Green River from the White River was cut off when a permanent barrier was installed between these two systems in 1907. Prior to the construction of this barrier, bull trout were able to move into the Green River from the White River, which still possesses a population of native char. The native char that have been observed in the lower Green River in recent years may be anadromous forms, which occasionally migrate into this drainage from other rivers, via Puget Sound (WDFW 1998).

Habitat conditions in the lower Green River below Howard Hanson Dam have been degraded by flood control activities, urban and residential development, logging and agriculture, and water diversions (WDFW 1998). Water temperatures in the lower Green River likely become too warm during the late summer and fall to support juvenile bull trout. Temperature effects together with the degraded habitat conditions would prevent the development of a self-sustaining population. Habitat conditions in the upper Green River watershed have been impacted by the construction and operation of Howard Hanson Dam, and logging and road building activities of private landowners (e.g., Plum Creek, Weyerhaeuser), Tacoma Water, and the USFS. Habitat conditions, however, are favorable for native char in many streams within the upper Green River drainage (i.e., above Howard Hanson Dam). Moreover, fishing pressure has been largely eliminated because public access to the upper watershed is restricted (the upper watershed serves as Tacoma's main water supply).

Warm water temperatures during the summer may be a limiting factor to the distribution of native char in the lower Green River watershed, though it is likely that water temperatures in headwater streams in this drainage are sufficiently cold to support native char populations. Recolonization from the lower watershed is impossible due to the presence of the Tacoma's Headworks diversion dam and Howard Hanson Dam. As part of their Habitat Conservation

Plan, the City of Tacoma has proposed to construct a trap-and-haul facility at their Headworks facility to move fish, including native char, migrating into the upper Green River watershed (Tacoma Water 1999). Consequently, it is possible that native char may become re-established in the upper Green River watershed in the future, if they are indeed absent in this drainage.

2.7.4 White River Basin

A population of native char is present in the White River watershed, including sections located in King County. Nine native char were observed during electrofishing surveys conducted between River Miles 43 and 53.3 during the summer of 1993 (WDFW 1998). These fish ranged from 99 to 300 mm in length. Four native char were captured during electrofishing surveys conducted in the West Fork White River during this same period, and ranged from 127 to 203 mm in total length. Native char have also been observed at the Mud Mountain Dam trap and haul facility, which is operated by the Army Corp of Engineers. This facility is located adjacent to Puget Sound Energy's diversion dam at Buckley. Fish have been counted at the Mud Mountain Dam trap and haul facility since 1974 (Fred Goetz, pers. com.). The number of native char captured at this trap has ranged from 8 to 46 on an annual basis (WDFW 1998). These fish are thought to be anadromous forms (WDFW 1998), but could also be fluvial. Bull trout are present in low numbers in the upper White River within Mt. Rainier National Park (WDFW 1998).

Urban and residential development, agriculture, logging, severe winter floods, and water diversions by Puget Sound Energy have degraded habitat in the lower White River (WDFW 1998). The upper White River likely provides good to excellent habitat conditions, except in tributaries which have been heavily damaged by floods and logging activities.

Historical information suggests that the White River supported substantially greater numbers of native char than are observed today. A relatively large number of native char was observed at the White River fish screens between 1950 and 1953, with a total of 693 fish counted in 1953 (Rees and Dunston 1953).

3.0 Recommended Sampling Approach

Surveys to detect the presence of bull trout/native char have been conducted in various locations in King County, including the upper Skykomish River, the upper and middle Cedar River, and the upper Green River. However, a systematic and formal sampling program targeting bull trout has not been implemented within the county. Moreover, the USFWS and WDFW do not have complete data on the distribution and status of bull trout/native char populations within King County. For this reason, the King County Department of Natural Resources (KCDNR) is proposing a pilot sampling program to generate data describing the presence of bull trout in drainages within the county where the presence or absence of bull trout/native char populations has not been confirmed.

This stratified sampling program incorporates a strategy for improving knowledge of bull trout spawning and rearing activity within the geographic extents of King County, from the Puget Sound shores to the Cascade crest. Development of this program incorporated relevant information regarding surveying techniques and life history information for both native char, broadly, and bull trout, specifically, although the explicit aim of this program is to gather data specific to bull trout. Information obtained from this program will be valuable to those completing Biological Assessments that are part of the Section 7 project review process and to those developing and implementing multi-species recovery strategies in King County watershed areas in response to ESA listings. Ultimately the information gathered through this sampling program is intended to improve decision-making for actions that would protect and restore habitat important to the sustainability of bull trout populations in the sampling area. To increase the likelihood that this proposed sampling program is implemented and the information it generates is shared among those most interested in it, King County will seek the direct involvement of those stakeholders with direct (e.g. land ownership or land management responsibility) interests within the recommended sampling areas.

3.1 Summary of Sampling Techniques and Designs for Bull Trout/Native Char

Any sampling program targeting an individual species or life history stage must account for the behavioral traits and habitat preferences of that species or life history stage. Bull trout juveniles

and adults, as described previously, are closely associated with the bottom of the stream channel. Juveniles of this species have a strong benthic orientation (Goetz 1997b), and are typically found resting upon or hiding within coarse bed materials such as cobbles and boulders, or woody debris accumulations. This behavior makes finding and counting bull trout difficult relative to other salmonids. The propensity for bull trout to hide within substrates or woody debris makes them even more difficult to locate and observe. Fortunately, bull trout become more active at night (Goetz 1997b, Thurow 1997), moving from the substrates and into the water column to feed. Bull trout have also been found to be more active during the day when water temperatures exceed 9°C (Thurow 1997).

A number of sampling techniques can be used for detecting the presence and estimating the abundance of bull trout in streams, including streambank observations, snorkeling, and electrofishing (Goetz 1997b). Streambank observations can be effective in some streams where fish are active (especially for adult fish during the fall spawning period), but are ineffective within turbulent water conditions, in the presence of abundant substrate and woody debris cover within which fish can easily hide, or when fish become inactive and subsequently move within substrates and other types of cover when water temperatures are cold (< 9°C).

Electrofishing may be an effective method for detecting and enumerating bull trout under certain situations and habitat conditions. Electrofishing may be the most effective sampling technique for detecting and estimating the abundance of bull trout fry, since they typically are found along the margins of the stream channel in shallow, low-velocity areas including side channels, and tend to hide at night when larger bull trout are most active (Goetz 1994). This method, however, may not be appropriate for streams located in the headwaters of the Cascades as they have low conductivity, resulting in poor capture rates (Goetz 1997b). This problem can sometimes be remedied in smaller streams by putting salt blocks in the water immediately above the section being electrofished. Unfortunately, electrofishing can result in injury and mortality to fish. For this reason, the WDFW is presently restricting the use of electrofishing in waters containing bull trout. Because bull trout were listed as a threatened species on November 1, 1999, it is unlikely that the USFWS will allow electrofishing as a sampling method except under special circumstances. Due to the likelihood that this method may result in direct injury or mortality to

native char, it is not recommended as a method for surveying native char populations within King County.

Snorkeling can be an effective method for sampling bull trout, but is most effective at night (Goetz 1997b), especially when water temperatures are less than 9°C (Thurow 1997). Daytime snorkeling may be an effective method for detecting the presence of and for enumerating bull trout when temperatures exceed 9°C. Night snorkeling was found to provide the highest encounter rate for juvenile bull trout in surveys conducted in western Washington streams (Bonar et al. 1997).

Minnow traps placed in low-velocity areas of small streams and rivers can also be an effective method for detecting the presence of juvenile bull trout fry, especially in streams that are too small or shallow to snorkel effectively. Minnow traps, which were baited with canned salmon in a translucent 35 mm film canister with a 5 mm hole punched in the cap, were found to be efficient and effective for capturing juvenile bull trout in the upper Cedar River Municipal Watershed. Traps baited in this manner could be effectively fished for a period of up to seven days (bait effectiveness), but were typically deployed for a three-day period (Dwayne Paige, pers. com.). In addition, surveying to visually observe newly-emerged bull trout fry (25-45mm in length) in quiet water at stream edges and in backwater sections has also been effective in detecting the presence of bull trout in this watershed (Dwayne Paige, pers. com.)

Several statistically based sampling methods have been developed for determining the presence of bull trout in streams and rivers. All methods assume a standard 100-m long stream reach as the basic sampling unit. Hillman and Platts (1993) developed the first sampling methodology for bull trout based upon the random sampling of stream reaches. This method assumed that bull trout were distributed in streams according to a Poisson distribution, and provided a statistical basis for determining the minimum number of sampling reaches required to determine if bull trout were present in a stream above a specified population density value. The number of samples necessary to detect the presence of bull trout above a threshold density value (0.25 fish/100 m) was calculated based upon the statistical probability (or power) of encountering fish within a 10 km section of stream. This method was used to detect the presence of bull trout

within forested streams in Washington, Idaho, and Montana (Watson et al. 1997).

More recently, the WDFW has developed a sampling methodology for detecting the presence and enumerating the abundance of juvenile and spawning bull trout in streams and rivers (Bonar et al. 1997). The survey design, provided as part of this methodology, is based upon a similar statistical approach to that used by the Hillman and Platts (1993) methodology. The WDFW survey protocol is different from the earlier methodology in that it assumes that only a certain percentage of bull trout will be detected during sampling. Moreover, the WDFW methodology is based upon sampling a contiguous watershed area described as a "patch", instead of a 10 km reach. The patch-sampling concept was developed based upon the understanding that most bull trout subpopulations are located in isolated drainages or patches, as described by Rieman and McIntyre (1993). Bonar et al. (1997) defines a patch as a stream reach or group of reaches within a drainage (including mainstem and tributaries) where a bull trout population, if present, would be isolated from other populations by migrational barriers such as waterfalls, dams, or stream sections having unsuitable water temperatures.

Bonar et al. (1997) recommends night snorkeling as the method of choice for detecting the presence and enumerating the abundance of bull trout. Daytime snorkeling can be used if water temperatures are above 9°C. Nighttime snorkeling can be potentially hazardous, and should only be conducted in those areas where access and water conditions are safe. Prior to sampling, a watershed should first be stratified to identify those areas that are "preferred" habitat for bull trout (Bonar et al. 1997). These are stream sections which contain suitable spawning or rearing habitat, including cool water temperatures (< 15°C for juveniles, and < 10°C for spawning) and good habitat conditions (i.e., abundant substrate or woody debris cover for juvenile fish; abundant gravels in low gradient sections for spawning fish). Bull trout surveys should be conducted within those areas delineated as containing suitable habitat. Waters which may occasionally contain bull trout, but do not contain critical spawning and rearing habitat (i.e., those areas required to maintain a reproducing population), should not receive a high priority for presence/absence surveys (Bonar et al. 1997). Areas having a low sampling priority include those coastal rivers and streams where bull trout occasionally enter to feed, and the lower sections of rivers which are used mainly as migration corridors. Sampling priority should

instead be placed on identifying spawning and rearing areas, since these areas are critical to the health of native char populations.

Bonar et al. (1997) also recommends that reconnaissance surveys be conducted first prior to implementing a "full scale" presence / absence survey. Stream sections within a subject watershed that are most likely to contain bull trout should be snorkeled, preferably at night. If bull trout are not detected during these initial surveys, then a statistically based random sampling design should be employed to determine if bull trout are present. The WDFW methodology initially recommends that 20 randomly chosen reaches of preferred habitat be sampled within a patch to determine if fish are present, with a 95 percent confidence limit (this assumes a threshold density of 0.60 fish per 100 m and a sampling efficiency of 25 percent, which results in a detection density of 0.15 fish per 100 m). Smaller detection densities may need to be used in areas possessing uniformly low densities of native char. It should be emphasized that the lack of positive results using this method does not mean that native char are absent from the areas surveyed, but rather that native char (if present) are at densities below detection limits. Bonar et al. (1997) recommends that sampling efforts be equivalent between stream sections that are both impacted and unimpacted by human disturbance, provided that they possess suitable habitat conditions for bull trout.

3.2 Recommended Sampling Approach for King County

A two-phase approach is recommended for the purpose of delineating the distribution of bull trout populations within King County. The first phase would entail a reconnaissance sampling program which would occur during the summer and fall of 2000. This reconnaissance sampling program would have the objective of locating native char in those drainages where self-sustaining populations have not yet been found, but where individual fish have been occasionally observed and where habitat conditions are highly suitable for native char spawning and juvenile rearing. The second phase would entail the completion of more detailed presence/absence surveys in drainages where native char are most likely to occur based on suitable habitat conditions. The objectives of the second phase sampling program would be to more thoroughly delineate the distribution of bull trout spawning and rearing areas in King County, as well as

identify areas where spawning and rearing habitats are not present. The second phase of the sampling program would commence during the summer and fall of 2001, and would adopt the methods consistent with sampling protocols presently being developed independently by the American Fisheries Society (AFS) to determine the presence of native char in streams and rivers. It is likely that the presence / absence survey protocols developed by the AFS will be based upon the methodologies developed by Bonar et al. (1997) and Hillman and Platts (1993), both of which were reviewed as this proposed sampling program for King County was developed. Both sampling programs phases would be conducted in cooperation with USFWS staff in Olympia, Washington, and with local stakeholder groups interested in contributing necessary technical expertise to the sampling effort.

3.2.1 Phase 1/Year 1: Reconnaissance Sampling

The objective of the reconnaissance sampling program is to identify, through field surveys, the presence of native char in those King County drainages where habitat characteristics are suitable for bull trout spawning and rearing, but the presence of self-sustaining populations has not yet been conclusively proven. Based upon the findings of this literature review, the recommended candidate areas for reconnaissance sampling within King County are: 1) Snoqualmie River above Snoqualmie Falls; 2) upper Tolt River drainage; 3) upper Issaquah Creek including Holder Creek, Carey Creek, and smaller tributaries in higher elevation areas which are accessible to migrating fish; 4) Rock Creek in the lower Cedar River drainage above the Landsburg Diversion Dam (not to be confused with the Rock Creek that enters the Cedar River downstream of Landsburg), 5) headwater tributaries in the upper Green River drainage; and 6) tributaries of the White River within King County (Figure 3.1). This list includes the highest priority candidate areas for Phase 1 sampling and does not rule out additional or supplemental sampling in other appropriate areas.

This initial sampling program phase will also serve to: 1) train technical staff from participating organizations to identify native char in the field; 2) allow staff to gain experience in survey methods and protocols for bull trout; and 3) to enable staff to recognize the special habitat conditions required by these fish. As described earlier, bull trout is a species closely oriented to the bottom of streams and rivers. Because of this behavioral trait, special training is

Figure 3.1 Sampling areas within King County initially proposed for bull trout reconnaissance surveys (multiple sources cited in report).

recommended for staff members participating in the proposed native char surveys to gain a "search image" for this species. Training would be conducted in stream reaches where native char are known to be present. Selected tributaries to the North Fork Skykomish River would be particularly well suited for this purpose.

The reconnaissance surveys would be conducted during the late summer and early fall (July through September), when rearing juveniles and adults are easiest to observe because of seasonally low flows and warm water temperatures, and during the spawning period in the fall (late-September through mid-November). Surveys would be conducted within a 1.0-mile section within each of the candidate areas described earlier (Figure 2). These survey sections would be identified as those possessing the best habitat conditions for native char within each candidate drainage, including cold water temperatures during the summer and fall, and good habitat cover (i.e., clean cobbles and boulders; abundant woody debris). At this time, the candidate areas are mainly headwaters which possess the coldest water temperatures within King County. A comprehensive temperature monitoring program employing recording thermographs is recommended for describing the thermal regime of drainages within King County in more detail.

Following training, survey participants would snorkel each reach for the period of one day. Dry suits would be required because of cold water temperatures in the stream reaches to be surveyed. Survey participants would move in an upstream direction to maximize search efficiency, and would focus on deep pools, pocket water areas, and woody debris accumulations where holding adults and rearing juveniles are most likely to be found, as well as potential spawning areas.

Surveys would initially be conducted during the day for safety reasons. Night snorkeling surveys would be conducted in selected sites that provided safe access and flow conditions. Each survey team would include a minimum of three participants, though more surveyors may be required in larger streams and rivers.

3.2.2 Phase 2/Year 2 and Out: Presence/Absence Sampling

Phase 2 sampling will be conducted in those areas within King County where native char were not found during the Phase 1 sampling program, but that contain habitat features believed to be important for native char spawning and juvenile rearing. The following recommendations are made relative to a Phase 2 presence/absence sampling program for native char within King County:

- A temperature monitoring program should be implemented immediately to identify those river sections which are suitable for bull trout spawning or rearing, as well as those areas which exceed the thermal tolerances of this species.

- The highest priority for presence/absence sampling should assigned to those stream and rivers sections in King County which contain habitat conditions considered to be suitable for bull trout spawning or rearing. Suitable spawning areas are those which have water temperatures during the fall (September and October) which do not exceed 10°C, and abundant and clean gravels not heavily embedded by sediments. Suitable juvenile rearing areas are those having water temperatures that do not exceed 15°C for a period more than a week during the summer. Rearing areas should contain abundant habitat cover provided by clean cobbles and boulders, or woody debris accumulations.

- Snorkel surveys should be used as the primary method for sampling. Daytime snorkel surveys can also be employed provided that water temperatures exceed 9°C during the time of the survey, or if access and water conditions are not safe for nighttime snorkeling. Daytime snorkeling may not be an effective method for detecting bull trout if water temperatures drop below 9°C. Under these conditions, nighttime snorkeling will be the preferred sampling method provided that safety requirements are met.

- The number of reaches to be sampled should be determined using the sampling

protocols presently being developed by the AFS;

- Once native char have been found in a candidate area, several fish should be captured with a hand net (relatively easy to do at night), fin clips obtained for genetics testing, and the fish returned to the stream live and in a manner providing the highest likelihood of survival. Genetic testing of the fin clip would provide information useful for determining if the captured fish are bull trout or Dolly Varden.

- Radiotelemetry studies should be considered, since they would be useful for determining migration patterns and spawning areas locations of bull trout in King County. Adult fish captured at existing fish traps located on the South Fork Skykomish River and the White River might be used for this purpose.

3.3 ESA Section 10(a)(1)(A) Compliance in Implementation of Sampling Program

The nature of the proposed sampling program requires the risk of direct contact with bull trout at various stages in their life cycle. In some cases, this contact could be categorized as "take" of this listed species under the provision of Section 9 of the ESA. However, given proper training of participating staff it is unlikely that the proposed field activities will result in direct injury or mortality to native char. It is more likely that potential “take” would be in the form of "harassment" of the species, as technical staff members would at times be in the water in close proximity to these fish.

Under these circumstances, implementation of the sampling program will require observance of permitting requirements described in Section 10(a)(1)(A) of the ESA. When met, this permitting requirement provides coverage for take of listed species that results from the implementation of "research and enhancement" activities intended to contribute directly to the recovery of the species. Application for a Section 10(a)(1)(A) permit is made to the USFWS and will require a clear statement of the scope of work to be undertaken, specific methodologies to be employed, options for avoiding “take” in achieving desired outcomes, a quantification of expected lethal take of the species, qualifications of the technical staff undertaking the survey effort, and other

aspects of the program which describe the summary contribution to recovery from the activity. These permit requirements under Section 10(a)(1)(A) may be obviated provided that the sampling program involves direct oversight and field participation by USFWS staff.

4.0 References

Adams, S.B., and T.C. Bjornn. 1997. Bull trout distributions related to temperature regimes in four central Idaho streams. Pages 371-380 In: Mackay, W.C., M.K. Brewin, and M. Monita (eds.). Friends of the bull trout conference proceedings. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary.

Armstrong, R.H. 1984. Migration of anadromous Dolly Varden charr in southeastern Alaska - a manager's nightmare. Pages 559-570 In: Johnson, L., and B. Burns (eds.). Biology of Arctic charr: proceedings of the international symposium on Arctic charr. Univ. of Manitoba Press, Canada.

Baxter, J.S., and J.D. McPhail. 1997. Diel microhabitat preferences of juvenile bull trout in an artificial stream channel. N. Am. J. Fish. Manage. 17(4):975-980.

Baxter, J.S., E.B. Taylor, R.H. Devlin, J. Hagen, and J.D. McPhail. 1997. Evidence for natural hybridization between Dolly Varden (*Salvelinus malma*) and bull trout (*Salvelinus confluentus*) in a north central British Columbia watershed. Can. J. Fish. Aquat. Sci. 54(2):421-429.

Benke, R.J. 1984. Organizing the diversity of the Arctic charr complex. Pages 3-22 In: Johnson, L., and B. Burns (eds.). Biology of Arctic charr: proceedings of the international symposium on Arctic charr. Univ. of Manitoba Press, Canada.

Bonar, S.A., M. Divens, and B. Bolding. 1997. Methods for sampling the distribution and abundance of bull trout / Dolly Varden. Washington Dept. of Fish and Game, Resource Assessment Division, Olympia. Report RAD97-05.

Bonneau, J.L., and D. L. Scarnecchia. 1998. Seasonal and diel changes in habitat use by juvenile bull trout (*Salvelinus confluentus*) and cutthroat trout (*Oncorhynchus clarki*) in a mountain stream. Can. J. Zoology 76(5):783-790.

Cavender, T.M. 1978. Taxonomy and distribution of the bull trout, *Salvelinus confluentus* (Suckley), from the American Northwest. California Fish and Game 64:139-174.

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, U.S.A. Pages 403-412 In: Mackay, W.C., M.K. Brewin, and M. Monita (eds.). Friends of the bull trout conference proceedings. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary.

Crane, P.A., L.W. Seeb, and J.E. Seeb. 1994. Genetic relationships among *Salvelinus* species inferred from allozyme data. Can. J. Fish. Aquat. Sci. 51(suppl. 1):182-197.

Crawford, J. 1896. Seventh annual report of the State Fish Commissioner of the State of Washington. Olympia, Washington.

Darwin, L.H. 1921. Biological survey of Washington waters: Baker Lake. Report by State Fish Commissioner and State Game Warden, Seattle.

Donald, D.B., and J. Alger. 1993. Geographic distribution, species displacement, and niche overlap for lake trout and bull trout in mountain lakes. Can. J. Zool. 71:238-247.

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 Science 63:133-143.

Goetz, F. 1989. Biology of bull trout (*Salvelinus confluentus*): a literature review. Willamette National Forest, Eugene, Oregon. 53 p.

Goetz, F. 1994. Distribution and juvenile ecology of bull trout (*Salvelinus confluentus*) in the Cascade Mountains. Masters Thesis, Oregon State University, Corvallis. 173 p.

Goetz, F. 1997a. Distribution of bull trout in Cascade Mountain streams of Oregon and Washington. Pages 237-248 In: Mackay, W.C., M.K. Brewin, and M. Monita (eds.). Friends of the bull trout conference proceedings. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary.

Goetz, F. 1997b. Diel behavior of juvenile bull trout and its influence on selection of appropriate sampling techniques. Pages 387-402 In: Mackay, W.C., M.K. Brewin, and M. Monita (eds.). Friends of the bull trout conference proceedings. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary.

Haas, G.R., and J.D. McPhail. 1991. Systematics and distribution of Dolly *Varden (Salvelinus malma*) and bull trout (*Salvelinus confluentus*) in North America. Canadian Journal of Fisheries and Aquatic Sciences 48:2191-2211.

Haas, G.R., and J.D. McPhail. 2000. Errors in and problems with species identification: general comments and the specific test case of bull trout (*Salvelinus confluentus*) and Dolly Varden (*S. malma*). British Columbia Ministry of Fishes, Research Section, Univ. of British Columbia. Vancouver, British Columbia, Canada. 26 p.

Hillman, T.W., and W.S. Platts. 1993. Survey plan to detect the presence of bull trout. Don Chapman Consultants, Boise, Idaho.

Jones, S. 1979. Washington state fishing guide. Stan Jones Publications, Seattle, Washington. 334 p.

Kanda, N. 1998. Genetics and conservation of bull trout: comparison of population genetic structure among different genetic markers and hybridization with brook trout. Ph.D. Thesis, Univ. of Michigan, Ann Arbor. 134 p.

Knutzen, J.A. 1997. Evaluation of fish entrainment potential from Chester Morse Lake / Masonry Pool system. Report prepared by Foster Wheeler Environmental for Seattle City Light, Environmental and Safety Division, Seattle, Washington.

Kraemer, C. 1994. Some observations on the life history and behavior of the native char, Dolly Varden (*Salvelinus malma*) and bull trout (*Salvelinus confluentus*) of the north Puget Sound Region. WDF draft manuscript.

Leary, R.F., and F.W. Allendorf. 1997. Genetic confirmation of sympatric bull trout and Dolly Varden in western Washington. Trans. Am. Fish. Soc. 126(4):715-720.

Leary, R.F., F.W. Allendorf, and S.H. Forbes. 1993. Conservation genetics of bull trout in the Columbia and Klamath River drainages. Conserv. Biol. 7:856-865.

Martin, S.W., M.A. Schuck, K. Underwood, and A.T Scholz. 1992. Investigations of bull trout (*Salvelinus confluentus*), steelhead trout (*Oncorhynchus mykiss*), and spring chinook salmon *(O. tshawytscha*) interactions in southeast Washington streams. 1991 Annual Report. U.S. Dept. of Energy, Bonneville Power Administration. Portland, Oregon. 206 p.

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. British Columbia Ministry of Environment, Lands and Parks. Fisheries Management Report No. 104. 35 p.

Mongilla, P.E. 1993. The distribution and status of bull trout / Dolly Varden in Washington State. Washington Dept. of Wildlife, Fisheries Management Division, Olympia. Report 93-22.

Pautzke, C.F., and R.C. Meigs. 1940. Transactions of the American Fisheries Society 17:209-220.

Pratt, K.L. 1992. A review of bull trout life history. Pages 5-9 In: Howell, P.J., and D.V. Buchanan (eds.). Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter of the American Fisheries Society, Corvallis.

R2 Resource Consultants. 1999. Letter report on Skykomish River bull trout surveys. Report prepared for USDA Forest Service, North Bend Ranger District. North Bend, Washington.

Ratliff, 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; 1983-94. Oregon Dept. of Fish and Wildlife, Portland. Inland Fisheries Report 96-7. 44 p.

Rees, W., and W. Dunston. 1953. Puget Sound stream studies. Progress Report. Washington Dept. of Fisheries, Olympia.

Reiser, D.W., E. Connor, K. Binkley, D. Paige, and K. Lynch. 1997. Evaluation of spawning habitat used by bull trout in the Cedar River watershed, Washington. Pages 331-338 In: Mackay, W.C., M.K. Brewin, and M. Monita (eds.). Friends of the bull trout conference proceedings. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary.

Rieman, B.E., and J.D. McIntyre. 1993. Demographic and habitat requirements for conservation of bull trout. U.S. Dept. of Agriculture, Forest Service. Intermountain Research Station, Ogden, Utah. Gen. Tech. Rep. INT-302. 38 p.

Rieman, B.E., D.C. Lee, and R.F. Thurow. 1997. Distribution, status, and likely future trends of bull trout within the Columbia River and Klamath River basins. North American Journal of Fisheries Management 17(4):1111-1125.

Schultz, L.P., and A.C. DeLacy. 1935. Fishes of the American Northwest: A catalogue of the fishes of Washington and Oregon, with distributional records and a bibliography. Journal of the Pan-Pacific Research Institution 10(4).

Seattle Public Utilities. 1998. Draft Cedar River Habitat Conservation Plan. Seattle Public Utilities, Seattle, Washington.

Sexauer, H., and P. James. 1997. Microhabitat use of juvenile bull trout in four streams located in the eastern Cascades, Washington. Pages 361-370 In: Mackay, W.C., M.K. Brewin, and M. Monita (eds.). Friends of the bull trout conference proceedings. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary.

Shepard, B., K.L. Pratt, and P. Graham. 1984. Life history of westslope cutthroat trout and bull trout in the upper Flathead River basin, Montana. Montana Dept. of Fish, Wildlife, and Parks.

Suckley, G. 1858. Descriptions of several new species of Salmonidae, from the north-west coast of America. Ann. Lyc. Nat. Hist. 7:1-10.

Suckley, G. 1874. On the North American species of salmon and trout. United States Fish Commission of Fish and Fisheries, Washington, D.C. Part II: Report of the Commissioner for 1872 and 1982.

Suckley, G., and J.G. Cooper. 1860. The natural history of Washington Territory and Oregon. Bailliere Brothers, New York.

Sweeney, S.J., K.W. Kurko, and T.C. Juelson. 1981. North Fork Snoqualmie Basin wildlife study. Final Report of the State of Washington, Dept. of Game to the U.S. Army Corps of Engineers, Seattle District. 275 p.

Tacoma Water. 1999. Draft Habitat Conservation Plan for the Green River. City of Tacoma, Washington.

Tappel, P., and K. Tappel. 1995. South Fork Tolt Reservoir and Tributaries 1994 Fisheries Survey. Report prepared by Fisheries Consultants for Seattle Water Department, Seattle, Washington. 83 p.

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

Thurow, R.F., and D.J. Schill. 1996. Comparison of day snorkeling, night snorkeling, and electrofishing to estimate bull trout abundances and size structure in a second-order Idaho stream. N. Am. J. Fish. Manage. 16:314-323.

U.S. Fish and Wildlife Service. 1998. Bull trout interim conservation guidance. Dept. of Interior, U.S. Fish and Wildlife Service, Olympia, Washington. 47 p.

Watson, G., and S. Toth. 1994. Limiting factors analysis for salmonid fish stocks in the Plum Creek Habitat Conservation Plan (HCP) areas. Report prepared by Plum Creek, Seattle, Washington.

Watson, G., and T.W. Hillman. 1997. Factors affecting the distribution and abundance of bull trout: an investigation of hierarchical scales. N. Am. J. Fish. Manage. 17(2):237-252.

Watson, G., T. Hillman, S. Toth, and W. Platts. 1997. Implementation of a method to detect the presence of bull trout. Pages 421-426 In: Mackay, W.C., M.K. Brewin, and M. Monita (eds.). Friends of the bull trout conference proceedings. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary.

Washington Department of Fisheries. 1938. Statistics for Fiscal Year 1938. Washington Dept. of Fisheries, Olympia.

Washington Department of Fish and Wildlife. 1998. Washington salmonid stock inventory: bull trout and Dolly Varden. Wash. Dept of Fish and Wildlife, Olympia. 437 p.

Washington Department of Fish and Wildlife. 1999. Bull trout of the Snohomish River system. Washington Dept. of Fish and Wildlife, Mill Creek, Washington.

Washington Department of Wildlife. 1992. Bull trout / Dolly Varden management and recovery plan. Washington Dept. of Wildlife, Fisheries Management Division, Olympia. Report 92-22. 125 p.

Wissmar, R.C., and S. Craig. 1997. Bull trout spawning Activity, Gold Creek, Washington. Univ. of Washington, Fisheries Research Institute, Seattle. FRI-UW-9701. 15 p.

5.0 Personal Communications

Beardslee, Kurt. Director, Washington Trout. P.O. Box 402, Duvall, Washington. Phone conversation with Ed Connor (R2 Resource Consultants) dated January 4, 2000.

Beauchamp, David. Fisheries Biologist. University of Washington, Fisheries Sciences Department. Conversations and e-mail communications with Kate O'Laughlin and William Mavros (King County Department of Natural Resources) during the month of February, 2000.

Boynton, Hal. Director, South King County Chapter of Northwest Steelhead and Salmon Council of Trout Unlimited. Tacoma, Washington. Conversation with Ed Connor (R2 Resource Consultants) dated May 16, 1999.

Chan, Jeff. Fishery Biologist, U.S. Fish and Wildlife Service. Aquatic Resource Division, 510 Desmond Drive SE, Suite 102, Lacey, Washington. Comment letter submitted to David St. John (King County Department of Natural Resources) dated December 14, 1999.

Foley, Steve. Fish Biologist, Washington Department of Fish and Wildlife. Regional Office, 16018 Mill Creek Blvd., Mill Creek, Washington. Conversation with Bill Mavros (King County Department of Natural Resources), dated May 4, 2000.

Fuerstenberg, Robert. Senior Ecologist, King County Department of Natural Resources. 201 South Jackson St., Seattle, Washington. Conversation with Ed Connor (R2 Resource Consultants) dated August 10, 1999.

Goetz, Fred. Fish Biologist, U.S. Army Corp of Engineers. 4735 E Marginal Way, Seattle, Washington. Phone conversation with Ed Connor (R2 Resource Consultants) dated August 10, 1999.

Kraemer, Curt. Fish Biologist, Washington Department of Fish and Wildlife. Regional Office, 16018 Mill Creek Blvd., Mill Creek, Washington. Conversations with Ed Connor (R2 Resource Consultants) dated August 20, 1999, February 18, 2000 and May 2, 2000.

Mavros, Bill. Senior Ecologist, King County Department of Natural Resources, 201 South Jackson Street, Suite 600, Seattle, Washington. Conversation with David St. John (King County Department of Natural Resources) dated May 4, 2000.

Paige, Dwayne. Wildlife Biologist, Seattle Public Utilities. 19901 Cedar Falls Road, North Bend, Washington. Written comments to Ed Connor (R2 Resource Consultants) dated February 15, 2000.

Solonsky, Al. Fishery Biologist, Seattle City Light. Environment and Safety Division, 700 5th Ave., Seattle, Washington. Phone conversation with Ed Connor (R2 Resource Consultants) dated September 15, 1999.

Spruell, Paul. Geneticist, University of Montana. Missoula, Montana. Presentation and conversation at American Fisheries Society Bull Trout workshop in Nelson, British Columbia dated November 10, 1998.

Warner, Eric. Fisheries Mitigation Specialist, Muckleshoot Indian Tribe. 39015 SE 172nd Ave., Auburn, Washington. Conversation with Eric Jeanes (R2 Resource Consultants) dated March 26, 1998.