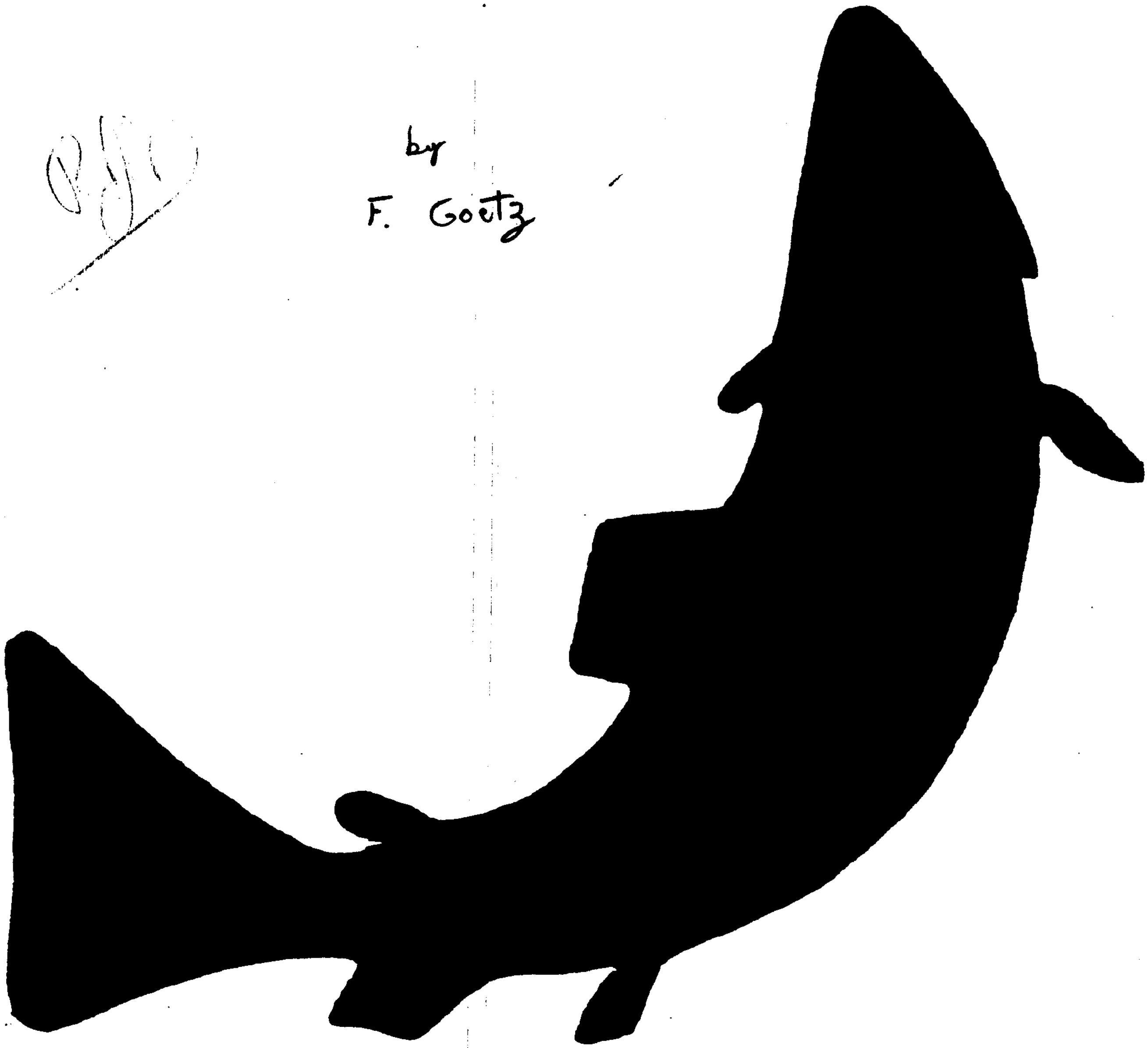
BIOLOGY OF THE BULL TROUT

Salvelinus confluentus

a

Literature Review



by

F. Goetz

Willamette National Forest
Eugene, Oregon
February 1989

PROLOGUE

The recent USDA Forest Service National Fisheries Initiative "Rise to the Future," has generated an increased awareness of, and concern for, the fish resources of National Forest lands. A major goal of the initiative is to . . . "maintain and enhance the fish habitat capability of National Forests." To attain this lofty goal, knowledge of the interrelationships between the fish species present and the critical habitat components is essential.

As part of an ongoing effort to understand fish species/habitat relations of lesser known species indigenous to the west slope of the Cascade mountains, the Willamette National Forest is cooperating in a study of the bull trout *Salvelinus confluentus* with Dr. Douglas Markle, Associate Professor of Fisheries at Oregon State University. Preliminary to the study, Fred Goetz, a graduate teaching assistant of Dr. Markle's, searched the available literature and produced this literature review for the Willamette National Forest.

This document is expected to be of use not only to those individuals and agencies currently involved in intensive bull trout management activities, but also those who need a better understanding of the role of bull trout in stream ecology.

The Forest believes this report does an excellent job of synthesizing the current knowledge of bull trout. However, the broad geographical interest in rehabilitating or enhancing habitat and populations indicates there will be rapid increases in the knowledge base. The reader is encouraged to network with those actively implementing research or habitat projects to gain latest information upon which to build his/her program.

DELBERT G. SKEESICK
Forest Fish/Wildlife Biologist
Willamette National Forest

ANADROMOUS GAME FISH
INVESTIGATIONS
8594 HIGHWAY 101
PORT TOWNSEND, WA 98368

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The geographical distribution and preferred habitat of the endemic western brook charr, *Salvelinus confluentus* or bull trout, has become increasingly restricted in recent years. The attempt of this paper is to summarize previous research that may be of benefit to fishery biologists with bull trout populations in their management areas.

Historically, the bull trout was found in most major river systems in the Pacific Northwest. However, within the past 30 years its western and southern boundaries have been greatly reduced in area. The bull trout is now considered extinct in the McCloud River of California (Rode 1988). In the Willamette Basin of Oregon, it is now found only in the McKenzie watershed. Before 1979 its range included the Clackamas, North Santiam and the Middle Fork Willamette drainages within the basin. It may also have been exterminated from the upper Deschutes River Basin within the past 25 years (Oregon State Game and Wildlife Commission 1947-74, Oregon Department of Fish and Wildlife 1975-79).

An explanation for this decline in distribution and numbers may be related to the special habitat requirements of spawning adults and rearing juveniles. In Montana for example, the bull trout is used as an environmental indicator because of the sensitivity of each life stage to disturbances (Fraley and Shepard 1988). The trout is also used as indicator for forest plans implementation in Oregon.

In the production of salmonids, two "bottlenecks" are assumed - reproduction and juvenile mortality (McPhail and Murray 1979). According to Allen (1969), each stream has its own carrying capacity that produces a finite number of young per species per year. The amount of living space, or cover, may be the main habitat feature determining capacity. For salmonid juveniles, if sufficient preferred cover is not available, surplus individuals are displaced through emigra tion or increased mortality (Bjornn 1971; Burns 1971). McPhail and Murray (1979) suggested the survival of bull trout fry is the "bottleneck" that limits production of the population. Finite amounts of quality, juvenile rearing habitat may also be a primary factor restricting abundance in the Flathead River Basin (Fraley and Shepard 1988).

Fishery biologists in the Pacific Northwest are focusing more attention on declining bull trout populations within their management areas. They are considering plans to protect or augment existing populations. To accomplish these plans, they have proposed improvements to juvenile rearing habitats and stock transfers. Before any alteration to habitats or introductions are undertaken, a thorough examination of bull trout behavior, habitat preferences and genetic variation is needed. Additionally, habitat alteration studies involving other salmonid young and their application to bull trout rearing areas need to be investigated.

TAXONOMY

Before 1978, the Dolly Varden (*Salvelinus malma*) was grouped into anadromous and interior forms. Cavender (1978) redescribed the interior form as a separate species *Salvelinus confluentus* (Suckley), commonly known as the bull trout. Morphometric, meristic and osteological characteristics were used to differentiate the bull trout from the Dolly Varden. Consistency between these features was found throughout each species' geographic range. The holotype for *S. confluentus* came from the Puyallup River (near Ft. Steilacoom), Washington (Cavender 1978). Brown (1984) also concluded from meristic and morphometric comparisons of eastern Washington specimens and those investigated by Cavender (1978 and 1980a), that the bull trout inhabits eastern slope streams and lakes of the Cascade Mountains. Cavender (1980a and 1984) believes the closest relative of *S. malma* is not the bull trout, but the arctic charr (*Salvelinus alpinus*). *S. confluentus* may be a sister to the arctic charr-Dolly Varden group. The stone charr of the Kamchatka Basin, USSR is considered by Behnke

(1980) to be a possible subspecies of the bull trout. Both the stone charr and the bull trout share a common karotype -- 2N = 78. (Behnke 1984; Cavender 1984).

Leary (1985), in examining electrophoretic data, concluded that the bull trout is more closely related to the arctic charr than the eastern brook or lake trout. Genetic divergence between the bull trout and the arctic charr is half the distance found between the bull trout and the brook and lake trout. Leary (1985) also found that the genetic variation in Columbia River system stocks is low within populations but is higher between populations -- 26.4 percent greater. This variation in populations illustrates the importance of preserving diverse stocks as a genetic resource (Rode 1988).

Identification

The bull trout has a wide long head, large, downward curving maxillaries that extend beyond the eye, a well-developed fleshy knob and an obvious "notch" on the nose, light-colored spots covering an olive green-brown back and flanks and a well-rounded and compressed body (Brown 1971; Cavender 1978; Brown 1984). The Dolly Varden, in contrast, has a shorter, narrower head, more slender maxillaries, not-so-dorsal eyes, a less-rounded body, no kype or notch on the nose and are smaller in size. Maximum length is 500mm versus 900mm for bull trout (Cavender 1978 and 1980b; Brown 1984). Branchiostegal ray counts are listed by Morton (1980) to be between 19 and 26 for the Dolly Varden and 25 to 31 for the bull trout. He suggests this character may be used at any age for identification with up to 90 percent accuracy without killing the fish. Morton (1970) also noted that resident bull trout from Oregon and Washington differ in meristic counts from fluvial and adfluvial types. The bull trout also has no vermiculations on its dorsal surface, unlike brook trout (Brown 1984).

McPhail and Murray (1979) described the breeding colors of the bull trout in Canada. Males in breeding condition become very dark green on their flanks and back, dorsal spots fade, their ventral surface turns coral and their sides become purple; and the gill cover, mandible and head turns black. Ventral and pectoral fins display tri-coloration with a white anterior margin. A gray-black band follows this and the posterior margin is orange. Females retain a lighter green body color with a gray-white underside. Fin coloration is similar to the male. Males spawning in Idaho and Montana have more reddish-orange flanks and hooked lower jaws. The leading edge of these males' paired fins is much whiter than females (Heimer 1965).

McPhail and Murray (1979) determined that the fastest and most accurate method of identifying the sex of nonbreeding adults was to examine the adipose fin. Males have a large and fleshy fin. In females it is smaller and more rounded.

Juveniles and resident populations may have eight to twelve irregular, dark parr marks with dark speckling on their ventral surface (Scott and Crossman 1973). Armstrong and Morrow (1980) observed that resident populations were very dark in color with bright, red spots and often had yellow undersides. Brown (1984) noted that juveniles lack an obvious kype and had a straighter maxillary than adults. Emergent fry have a dark brown back, no parr marks and a large, black triangle on the tail. Neutrally buoyant fry are a lighter tan and have well defined parr marks (McPhail and Murray 1979). In examining the differences among larval charr, Gould (1987) found that the gular ridge is unique to the bull trout. Use of this characteristic may allow identification of bull trout spawning areas.

Names

At different times and in different places, the bull trout and the Dolly Varden have been referred to by as many as 23 distinct names (Schultz and Delacey 1935; Wales 1939; Dimick and Merryfield 1945; Morton 1970; Scott and Crossman 1973; Morton 1980; Hesseldenz 1981). Both species were originally known as the Dolly Varden, an apparent reference to the fishes' bright coloration and similarity to a character in a Charles Dickens' novel or a popular dress style of the 19th century (Rode 1988).

Wales (1939) and Morton (1970) list names for the bull trout and the Dolly Varden in Oregon and Washington respectively as red spotted trout and Che-wah (wagh), a name used by the Skagit and Nisqually Indians. In Washington at the turn of the century, *S. confluentus* and *S. malma* were also known as the bull trout (Jordan 1907). Dimick and Merryfield (1945) recorded names for the bull trout in Oregon as Dolly Varden trout and Oregon charr. Budd (1968) attributes the origin of the name "bull trout" to the fish's "large, broad head, large mouth, prominent jaws and highly piscivorous diet." Before its elimination, the McCloud River *S. confluentus* was considered a genetically distinct population. The California Department of Fish and Game designated this stock with a unique name -- the California bull trout (Hesseldenz 1981).

Hybrids

The bull trout has been found to hybridize naturally with the eastern brook trout (*S. fontinalis*). Hybrids are reported in Oregon, Montana and Alberta (Paetz and Nelson 1970; Cavender 1978; Leary et al. 1983). Rode (1988) reported that the brook and the bull trout had been successfully crossed in 1892 at Sisson Hatchery, Mt. Shasta, California. At the Wallowa Hatchery in Oregon, female Dolly Varden were unsuccessfully crossed with brook trout (K. Witty, Oregon State Game Commission, Wallowa District Annual Report 1969). Brook trout and bull trout were bred and hybrids successfully raised at the Kootenay Hatchery in British Columbia (P. Brown, personal communication 1989).

Behnke (1984) observed no evidence of hybridization between the Dolly Varden and the arctic charr. In examining museum specimens, Cavender (1978) discovered possible bull trout/Dolly Varden hybrids from the Skeena River Basin, British Columbia.

Leary et al. (1983) found only male hybrids from Montana streams. This indicates sterility in the offspring of bull and brook trout crosses (in all areas of co-occurrence, bull trout populations are declining). The best characteristics for hybrid identification are vertebral and pyloric caeca counts. Hybrids have high counts for both of these features. The bull trout has low numbers for pyloric caeca and the brook trout has low vertebral counts (Leary et al. 1983). Hybrids that Cavender (1978) observed had darker pigmentation on all of their body parts, mottling on their dorsal fin and ventral fins that were tri-colored. Hybrids also had consistently smaller, light spots on their flanks than bull trout.

DISTRIBUTION

Zoogeography

The Columbia River Basin is considered the region of origin for the bull trout. From here, dispersal to other drainage systems was accomplished by marine migration and stream capture. Behnke (1980) postulated dispersion to drainages east of the continental divide may have occurred through the North and South Saskatchewan Rivers (Hudson Bay drainage) and the Yukon River system. Marine dispersal was from Puget Sound north to the Fraser, Skeena and Taku Rivers of British Columbia. Cavender (1978) examined a specimen of an anadromous bull trout that was collected from Puget Sound before 1900.

The southern distribution of the bull trout was established sometime in the Miocene and Pleistocene eras. During this time period, there was a connection between the Columbia and the Klamath Rivers.

The Pit and Sacramento Rivers in California were also linked to the Klamath at this time (Moyle 1976). Today, the bull trout is not found in most basins of southeastern Oregon because of the dessication of pluvial lakes and the rise in temperature of the remaining drainage systems (Balon 1981).

Dolly Varden are considered to be separate forms north and south of the Aleutian Mountain Range on the Alaskan perinsula. McPhail (1961) speculated that the southern form of Dolly Varden and the bull trout evolved south of the glacial ice sheet. The northern form may have evolved in unglaciated coastal areas of Alaska.

The historical distribution of the bull trout extended from 41 to 60 degrees north latititude. North of the 49th parallel, the bull trout is found in most drainages on both sides of the continental divide (Cavender 1978). The geographic range of bull trout and Dolly Varden overlap in the Puget Sound area and along the British Columbia coast.

Cavender (1978) examined two possible specimens of Dolly Varden from the McCloud River, California. If Dolly Varden were in the McCloud River they were probably eliminated by 1900. Bull trout are now considered extinct in the McCloud River, which had been their southern geographical boundary.

Dolly Varden have never been recorded in Oregon coastal streams (Oregon Department of Fish and Wildlife records). Morton (1970) considered the Quinault River in Washington as the southern limit of *S. malma's* distribution. Data from the Washington Department of Wildlife document Dolly Varden in tributaries of the Chehalis River (P. Monjello 1988). Tables 1 and 2 list the historical recorded distribution of bull trout and Dolly Varden in Oregon and Washington respectively. The last listed sighting of bull trout in these waters is provided. Areas of decline and extermination can be inferred from these observations. Abundance and longitudinal stream distribution of bull trout in remaining occupied waters is low and restricted for many populations. Figures 1 and 2 display the historical geographical distribution of these two species for Oregon and Washington.

(See Tables 1 and 2 and Figures 1 and 2 on the following pages)

Table 1

Historical Distribution of Bull Trout in the State of Oregon 1/

Drainage Basin	Stream/Lake	Last Year Observed
Willamette (2)		
Lower (2a)	Clackamas River	1960
Middle (2b)	North Santiam River	1945
	South Santiam River	1953
Upper (2c)	Carmen Reservoir	1965
	Cougar Reservoir	
	Hills Creek Reservoir	1979
	Leaburg Lake	
	Long Tom River	1962
	McKenzie River	
	M Fk Willamette River	1969
	N Fk Willamette River	1962
	Olallie Creek	1967
	Salt Creek	1960
	Smith Reservoir	1962
	Staley Creek	1960
	Swift Creek	1960
	Trail Bridge Reservoir	
Hood River (4)	Clear Branch Creek	
	Farm Ditch	1955
	Hood River	
	Mosier Creek	1958
	West Fk Hood River	1963
Deschutes (5)	Bakeoven Creek	1958
	Candle Creek	
	Canyon Creek	
	Clear Creek	1954
	Crane Prairie Reservoir	1955
	Crescent Lake	1959
	Crooked River (sec. 1)	
	Davis Lake	
	Deschutes River	
	(locations along river)	
	- Bend-Pringle Falls	
	- Pringle Falls-Wickiup	1960
	- Cove	1960
	- Grandview	1960
	- Maupin	1960
	- Mecca	1960
	- Oak Springs	1960
	- Sherars	1960
	- Trout Creek	1960
	- Warm Springs	1960
	(none below Maupin Dam presently)	

Table 1 (Continued)		
Deschutes (5) Continued	Fall River	1954
	Jack Creek	
	Jefferson Creek	
	Lake Billy Chinook	
	Lake Simtuscus	1971
	Metolius River	
	Odell Creek	
	Odell Lake	
	Sherars Creek	1955
	Shitike Creek	
	Suttle Lake	1961
	Upper Warm Springs River	
	Wickiup Reservoir	1957
John Day (6)	Canyon Creek	1956
	Clear Creek	1963
	Crane Creek	1959
	Davis Creek	1959
	Deardorf Creek	1962
	Desolation Creek	1930s
	Granite Creek	1963
	John Day River	
	North Fk John Day River	1963
	Rail Creek	1961
	Reynolds Creek	1955
	Roberts Creek	1967
	Upper M Fk John Day River	
Umatilla (7)	Buck Creek	
	Little Walla Walla River	1963
	Meacham Creek	
	Mill Creek	1964
	North Fk Umatilla River	
	North Fk Walla Walla River	1963
	South Fk Umatilla River	
	South Fk Walla Walla River	
	Thomas Creek	
	Umatilla River (upper mainstem)	
	Walla Walla River	
Grande Ronde (8)	Big Sheep Creek	1966
	Catherine Creek	
	Grande Ronde River	
	Imnaha River	
	Kinney Lake	1972
	Lick Creek	1960
	Little Minam River	1965
	Little Sheep Creek	1962
	Looking Glass Creek	
	Lostine River	
	Minam River	
	Snake River (Hells Canyon to Oxbow dam)	1966
	Wallowa Lake	

Table 1 (Continued)		
Powder River (9)	Brownlee Reservoir	1959
	Eagle Creek	1968
	Powder River	1960
	West Fk Eagle Creek	1965
Malheur (10)	Beulah Reservoir	
	Big Creek	1964
	Bosenberg Creek	1957
	Corral Creek	1954
	Crane Creek	1957
	Lake Creek	1953
	Little Crane Creek	1966
	Little Malheur River	1967
	Middle Fk Malheur River	
	North Fk Malheur River	
Klamath (14)	Branchroot Creek	1979
	Brownsworth Creek	
	Cherry Creek	1970s
	Coyote Creek	
	Deming Creek	
	Dixon Creek	
	Klamath Lake	
	Leonard Creek	
	Linn Creek	
	(Wood R drainage)	1978
	Long Creek	
	North Fk Sprague River	1962
	Seven-Mile Creek	1879
	South Fk Sprague River	1962
	Sun Creek	1948
	Sycan River	

1/ Oregon Department of Fish and Wildlife and Oregon State University records.

ANADROMOUS GAME FISH
INVESTIGATIONS
8594 HIGHWAY 101
PORT TOWNSEND, WA 98368

Table 2

Historical Distribution of Bull Trout and Dolly Varden in the State of Washington 1/

* = Dolly Varden
** = Unknown

County	Stream/Lake	Last Year Present	Last Year Checked
Asotin	Asotin Creek	1971	1973
	Charley Lake	1964	1964
	Wenatchee River	1971	1973
Benton	Yakima River	1972	1973
Chelan	Buck Creek	1956	1956
	Chelan Lake	1957	1973
	Chiquakum Lake	1947	1961
	Chiquakum River	1958	1972
	Chiwawa River	1972	1973
	Entiat River	1961	1973
	French Creek	1959	1959
	Icicle Creek	1971	1973
	Little Wenatchee River	1971	1971
	Mad River	1952	1973
	Nason Creek	1959	1973
	Steheken River	1955	1969
	Wenatchee Lake	1973	1973
	Wenatchee River	1973	1973
	White River	1939	1970
Clallam	Aldwell Lake	1968	1969*
	Bogachiel River	1941	1972*
	Dungeness River	1971	1973*
	East Fk Dungeness River	1967	1967*
	Elwah River	1971	1973*
	Graywolf River	1960	1960*
	Hoh River	1966	1968*
	Lyre River	1962	1972*
	Morse Creek	1954	1972*
	Pleasant Lake	N/A	N/A*
	Soleduck River	N/A	N/A*
	Sutherland Lake	1952	1971*
Clark	Beaver Lake	1962	1971
	Burnt Bridge Creek	1938	1950
Columbia	Armstrong Lake	1961	1961
	Big Four Lake	1971	1972
	Blue Lake	1963	1973
	Butte Lake	1972	1972
	Cummings Creek	1960	1960
	Curl Lake	1960	1973
	Deer Lake	1964	1972
	East Fk Butte Creek	1960	1972
	New Lake	1960	1960

Table 2 (Continued)			
Columbia Continued	North Fk Touchet River	1970	1973
	Panjab Creek	1971	1971
	Rainbow Creek	1970	1970
	Rainbow Lake	1970	1973
	Sheep Creek	1960	1960
	Snake River	1973	1973
	South Fk Touchet River	1970	1973
	Spring Lake	1973	1973
	Touchet River	1971	1973
	Trout Creek	1970	1972
	Tucannon Lake	1962	1973
	Tucannon River	1973	1973
	Twenty Mile Creek	1958	1970
	Upper Tucannon River	1955	1957
	Watson Lake	1962	1972
	West Fk Butte Creek	1972	1972
Cowlitz	North Fk Lewis River	1988	1988
	Yale Reservoir	1988	1988
Douglas	Columbia River	1956	1973
Franklin	Dalton Lake	1968	1968
	Emma Lake	1968	1968
	Scootney Lake	1961	1973
	Snake River	1968	1973
Garfield	Bear Creek	1945	1948
	Crooked Fork Creek	1963	1971
	Pataha Creek	1972	1973
	Tucannon River	1961	1961
	Watson Lake	1963	1963
Grant	Banks Lake	1972	1973
	Crab Creek	1988	1988
	Moses Lake	1969	1973
Grays Harbor	Damon Lake	1969	1971*
	Elk Creek	1967	1972*
	Humptulips River	1958	1973*
	Quinault Lake	1969	1972*
	Quinault River	1970	1970*
	Wynoochee River	1988	1988*
Island	Bush Point Lake	1956	1973*
Jefferson	Duckabush River	1946	1973*
	Hoh River	1972	1972*
	Queets River	1955	1972*
King	Elliott Bay	1889	N/A
	Green River	1964	1973**
	Greenwater River	1970	1973**
	Lake Chester Morris	1988	1988**
	Lake Washington	1955	1973**
	N Fk Skykomish River	1964	1968**
	Red Creek	1956	1958**
	Skykomish River	1950	1967**

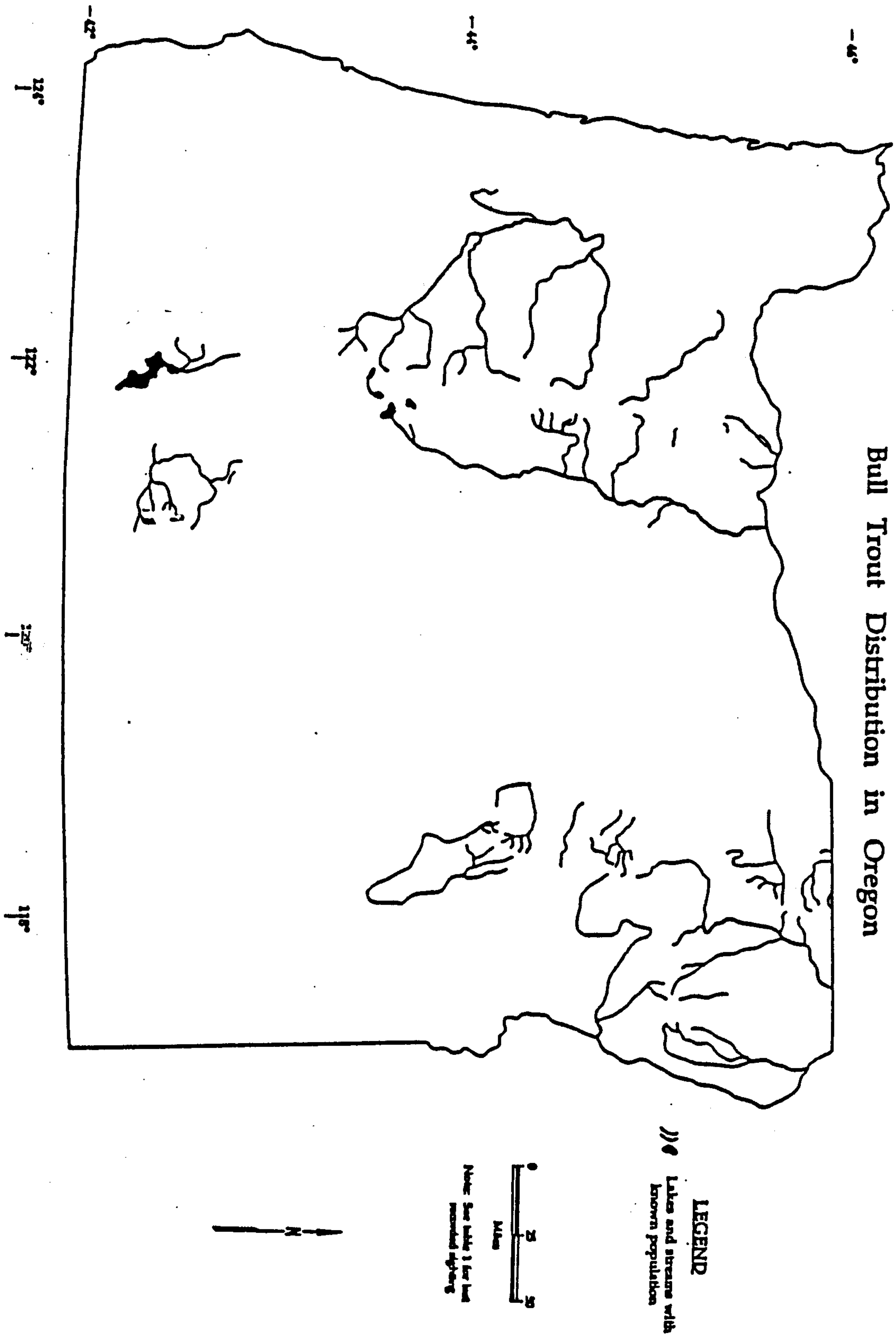
Table 2 (Continued)			
King Continued	Soos Creek	1956	1973**
	Upper Cedar River	1988	1988**
	Wilderness Lake	1971	1973
Kitsap	Puget Sound	N/A	N/A*
	Union River	1957	1966**
Kittitas	Cle Elum River	1940	1973
	Coleman Creek	1970	1973
	Kachess Lake	1972	1973
	Keechelus Lake	1971	1973
	Waptus Lake	1972	1972
	Yakima River	1967	1973
Klickitat	Drano Lake	1988	1988
	Rattlesnake Creek	1943	1972
	White Salmon River	1988	1988
Mason	Dewatto River	1966	1973**
	Hamma Hamma River	1948	1971**
	Lake Cushman	1968	1972**
	Skokomish River	1969	1973**
	S Fk Skokomish River	1970	1970**
Okanogan	Black Pine Lake	1960	1973
	Chewack River	1973	1973
	Columbia River	1964	1965
	Conconully Lake	1973	1973
	Davis Lake	1962	1973
	Early Winters Creek	1969	1971
	Eight Mile Creek	1973	1973
	Gold Creek	1970	1973
	Lost River	1973	1973
	Methow River	1973	1973
	Okanogan River	1953	1971
	Patterson Lake	1964	1973
	Salmon Creek	1949	1973
	Salmon Lake	1953	1971
	Twisp River	1973	1973
Pend Oreille	Pend Oreille River	1951	1962
Pierce	Carbon River	1961	1973**
	Puyallup River	1949	1973*
	White River	1956	1961**
Skagit	Bacon Creek	1957	1973**
	Baker Lake	1973	1973**
	Buck Creek	1956	1971**
	Cascade River	1971	1973**
	Downey Creek	1956	1956**
	Finney Creek	1963	1971**
	Gandy Lake	1961	1973**
	Gilliam Creek	1953	1961**
	Jordan Creek	1943	1948**
	Lake Shannon	1973	1973**
	Marble Creek	1948	1966**
	Pilchuck Creek	1972	1973**

Table 2 (Continued)			
Skagit Continued	Rocky Creek	1943	1963**
	Samish River	1964	1973**
	Sauk River	1973	1973**
	Skagit River	1973	1973* & **
	Tenas Creek	1956	1956**
Skamania	Lewis River	1959	1970
	Muddy River	N/A	N/A
	Rush Creek	1988	1988
	Swift Reservoir	1972	1973
Snohomish	Boulder River	1938	1969**
	Canyon Creek	1958	1970**
	Clear Creek	1961	1970**
	Fontal Lake	1973	1973**
	Jim Creek	1963	1970**
	North Fk Sauk River	1973	1973**
	N Fk Skykomish River	1968	1973**
	N Fk Stillaquamish River	1973	1973**
	Olney Creek	1954	1971**
	Pilchuck River	1951	1973**
	Sauk River	1973	1973**
	Skykomish River	1973	1973**
	Snohomish River	1973	1973**
	South Fk Sauk River	1973	1973**
	S Fk Stillaquamish River	1970	1973**
	Stillaquamish River	1973	1973* & **
	Suiattle River	1968	1973**
	Sultan River	1970	1973**
	Twin Lakes	1958	1973**
	Wallace River	1973	1973**
	Whitechuck River	1959	1970**
	Woods Creek	1961	1973**
Spokane	Little Spokane River	1972	1973
	Long Lake	1972	1973
Thurston	Nisqually River	1972	1973**
Walla Walla	Blue Creek	1937	1971
	Dry Creek	1959	1971
(Snake R)	Ice Harbor Pool	N/A	N/A
(Columbia R)	McNary Pool	N/A	N/A
	Mill Creek	1963	1971
	Mill Creek Reservoir	1962	1971
(Columbia R)	Quarry Pond	N/A	N/A
	Snake River	N/A	N/A
	Touchet River	N/A	N/A
	Walla Walla River	1940	1971
Whatcom	Baker Lake	1973	1973**
	Bertrand Creek	1956	1961**
	Canyon Creek	1973	1973**
	Canyon Lake	1968	1973**
	Diablo Lake	1973	1973**
	Gorge Lake	1970	1970**
	Little Canyon Creek	1954	1958**
	Mid Fk Nooksack River	1963	1971**

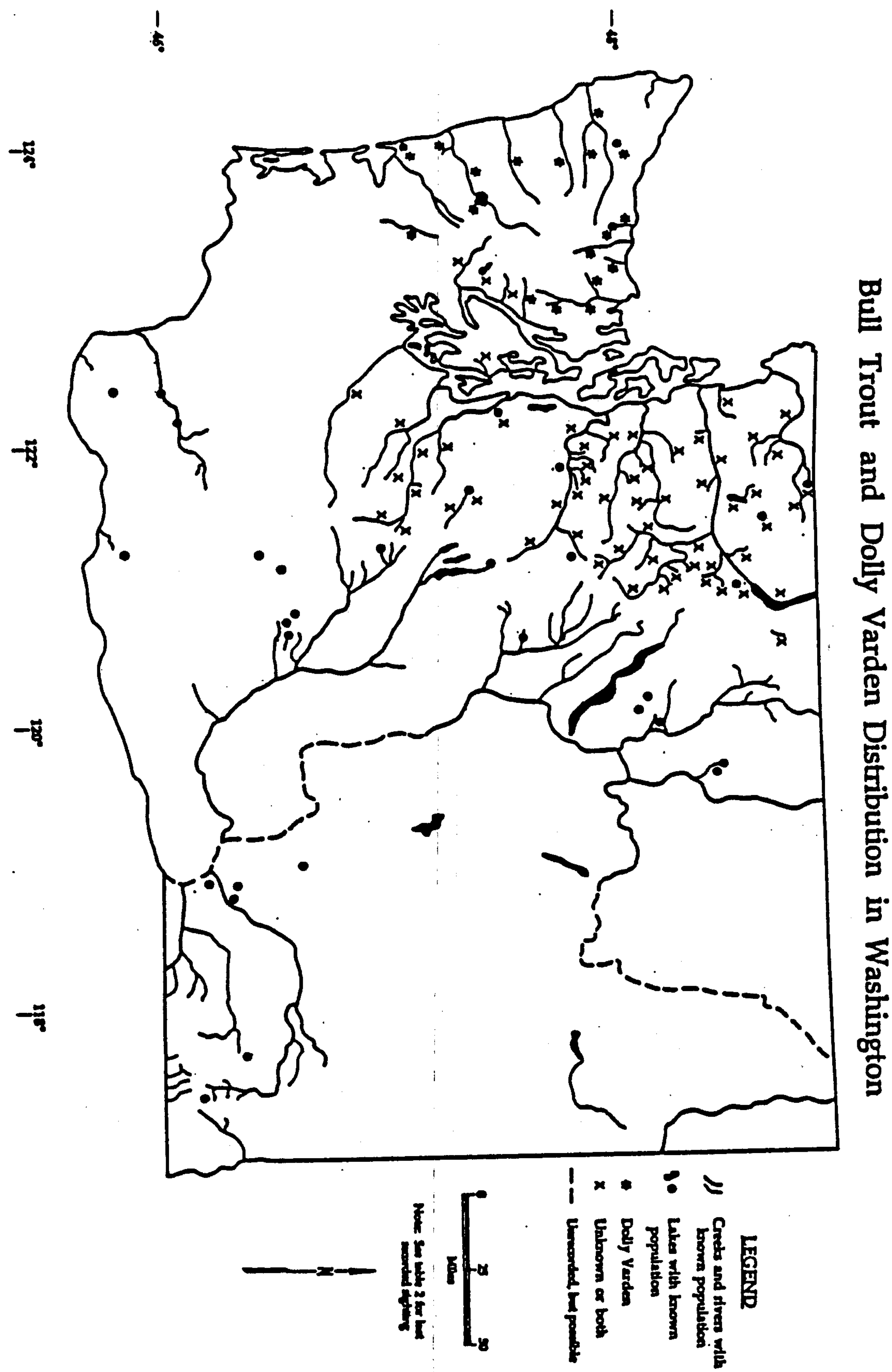
Table 2 (Continued)			
Whatcom Continued	Nooksack River	1973	1973* & **
	N Fk Nooksack River	1973	1973**
	Ross Lake	1973	1973* & **
	Skagit River	1964	1964**
	S Fk Nooksack River	1973	1973**
	Thunder Lake	1954	1966**
Yakima	Ahtanum Creek	1962	1971
	American River	1971	1973
	Big Rattlesnake Creek	1949	1967
	Bumping Lake	1972	1972
	Bumping River	1971	1973
	Clear Lake	1973	1973
	Cowiche Creek	1968	1973
	Dog Lake	1950	1973
	Fish Lake	1960	1960
	Mid Fk Ahtanum Creek	1963	1970
	Naches Lake	1973	1973
	Naches River	1971	1971
	North Fk Tieton River	1973	1973
	Oak Creek	1972	1973
	Rimrock Lake	1973	1973
	Satus Creek	1953	1973
	Tieton River	1972	1973

1/ Washington Department of Wildlife records.
2/ Includes bull trout.

Historical Distribution of Bull Trout in the State of Oregon



Historical Distribution of Bull Trout and Dolly Varden in the State of Washington



In what is now the southernmost portion of the bull trout's range, the Klamath River system, populations have been restricted to cold headwater streams. The abundance of these populations is low and one stream resident group in Cherry Creek may have been exterminated in the 1970s (J. Fortune, Oregon Department of Fish and Wildlife, personal communication 1988).

Prior to 1979, populations of bull trout below the 49th parallel had been found in most west slope drainages of the Cascade Mountains. In Oregon, the only remaining population in the Willamette Basin may be in the McKenzie River system. East of the Cascades, the bull trout has not been recorded in the upper Deschutes River for over 25 years.

In the Columbia River, the bull trout has not been documented in any tributaries west of the Lewis River in Washington. Whether *S. confluentus* was ever found in the Mount St. Helens watershed is unknown.

In Washington, populations of bull trout in many east slope Cascade streams and rivers have shown accelerated declines in abundance and distribution in recent years. Spawning runs in some streams are meager enough to suggest stock endangerment (Brown 1984). The bull trout is considered to be extinct in Lake Chelan and the Okanogan River.

Rostlund (1951) mentioned an 1834 report of a charr found in the Bear River, a tributary of the Great Salt Lake. Miller and Morton (1952) listed several tributaries of the Bruneau River system in Nevada that were inhabited by bull trout. These two sources document the southeastern limit of the bull trout.

BIOLOGY

Life History

The bull trout is identified as having three different life history patterns -- resident, fluvial and adfluvial. Dolly Varden are predominately anadromous. In stream and lake resident populations, adults and juveniles occupy the same area throughout their lives. Resident adults do not migrate. These populations are usually isolated from others by some physical barrier. These barriers may be geological, formed by faulting or glaciation, or from deterioration of downstream habitat. Marnell (1985) also reported the introduction of a bull trout population into an isolated lake in Glacier National Park.

Many of these resident populations occupy headwater streams. Examples of lake and stream resident stocks are found in Fish Lake, Klickitat Drainage, Washington, and Sun Creek and other headwater tributaries of the upper Klamath River Basin, Oregon (Wallis 1948; University of Washington fish collection 1960; Bond and Long 1979). A stream resident population of Dolly Varden was reported by Cavender (1978) above Soleduck Falls, Soleduck River, Washington.

These isolated stocks mature at an early age, are reduced in size and age and have low fecundity. They may also retain juvenile characteristics such as parr marks (Scott and Crossman 1973; Marnell 1985). Maximum size of the resident bull trout found in Oregon and Washington range from 200 to 300mm (University of Washington fish collection; J. Fortune, Oregon Department of Fish and Wildlife, personal communication 1988).

A unique population of resident fish is found in the headwaters of the Lost River, Washington. Both six and seven-year-old individuals were found to be sexually immature (K. Williams, Washington Department of Wildlife, personal communication 1988).

In fluvial and adfluvial bull trout populations, adults undergo spawning migrations of up to 225 kilometers (Shepard et al. 1984b). Adults from fluvial populations are found in rivers and larger streams. Smaller tributaries act as breeding grounds and rearing areas for juveniles. Adfluvial populations are found in regions with lakes or reservoirs. Juveniles may remain from one to six years in nursery streams before migrating downstream to rivers (fluvial) or lakes (adfluvial). As adults, they usually live in rivers or lakes for two to three years before spawning (Allen 1980; Fraley and Shepard 1988).

Historically, bull trout populations in most drainage systems in Oregon and Washington were fluvial (Dimick and Merryfield 1945; Washington Department of Wildlife unpublished data). Dam construction has since changed many populations to an adfluvial pattern. Rode (1988) suggests that the fluvial bull trout of the McCloud River was unable to adjust to an adfluvial strategy in Shasta Reservoir, and is now extinct.

After examining museum specimens, Cavender (1978) speculated that the bull trout was at one time anadromous in Puget Sound. Behnke (1980) also suggests the bull trout may have been anadromous in the Frazer, Skeena and Taku Rivers of British Columbia. The bull trout population, from which Cavender's (1978) sample was a part, might still be in existence in western Washington. If so, this stock no longer has access to Puget Sound (B. Pfieffer, Washington Department of Wildlife, personal communication 1988).

McCart (1985) asserts that there are many similarities in life history patterns between the fluvial and adfluvial bull trout population and other migrating northern species such as lake trout, arctic charr, grayling, whitefish and ciscoe. Comparable traits include advanced age of maturity, increased size, alternate year spawning, extensive migrations and separation of juvenile and adult populations. These life history features may be adaptations to the unstable northern environment (McCart 1985).

Reproduction

Bull trout spawning usually takes place in the fall during September and October (Table 3). Ratliff (1987) observed spawning occurring as early as the first week in August in tributaries of the Metolius River. Initiation of breeding appears to be related to declining water temperatures. A threshold temperature was found, 9 C, below which spawning began in Flathead Basin tributaries and in the upper Arrow Lakes, British Columbia (McPhail and Murray 1979; Weaver and White 1985). In Washington, Wydoski and Whiting (1979) reported spawning activity was most intense at 5 to 6 C. Spawning occurs primarily at night (Heimer 1965; Weaver and White 1985).

(See Table 3 on the following page)

Table 3

Bull Trout Spawning Periods

Stream/Lake	Period	Source
Flathead River, Montana	9/9-10/10	Shepard et al. 1984b
Wigwam River and Ram Creek, British Columbia	Mid-September to Mid-October	Oliver 1979
MacKenzie Creek, Upper Arrow Lakes British Columbia	9/14-10/29	McPhail and Murray 1979
Meadow Creek, Duncan River, Kootenay Lake, British Columbia	9/15-10/11	Leggett 1969
Clark Fork River, Idaho	9/18-10/20	Heimer 1965
John Day River, Oregon 1/	9/1-10/31	Clair 1988
Metolius River, Oregon	8/7-9/31	Ratliff 1987

1/ Oregon Department of Fish and Wildlife, personal communication 1988.

Annual and repeat spawning has been found in bull trout and Dolly Varden populations. Repeat spawning varies by age and sex in the Flathead drainage (Fraley and Shepard 1988). In Pend Oreille, Pratt (1985b) observed that most adults spawn in consecutive years. Resident Dolly Varden spawn annually while anadromous populations utilize annual and repeat strategies (Armstrong and Morrow 1980). Approximately 50 percent of the bull trout in Flathead Lake spawn each year (Fraley 1985).

Age of maturity in Flathead Lake bull trout is mostly 6 to 7 years but may be as early as 4 years (Fraley and Shepard 1988). Leathe and Enk (1985) found fish on the Swan River system to mature at 5 and 6 years. On the upper Clark Fork River, Heimer (1965) and Pratt (1985b) listed the age of breeding adults as 4 to 7 years. Stream resident fish from eastern Washington sometimes will not reach maturity until age 8 (K. Williams, personal communication 1988).

The largest size spawners are found in tributaries of the Upper Flathead River where the average length of breeding fish reaches a maximum of 690mm. The smallest average length of bull trout spawners (171mm) was recorded for a population of stream resident fish in Sun Creek, Oregon. Size of spawners and sex ratios for various waters are listed in Tables 4 and 5.

(See Tables 4 and 5 on the following pages)

Table 4

Length of Bull Trout Spawners

Length (Mean and Range in MM)

Stream/Lake	Average	Range	Source
Flathead River, Montana	611	406-876	Shepard et al. 1984b
Bull River, Project Creek, Montana	619	455-740	Brunson 1952
Clark Fork River, Pend Oreille Lake, Idaho	598	445-775	Heimer 1965
Wigwam River and Ram Creek, British Columbia	518	290-730	Oliver 1979
MacKenzie Creek, Upper Arrow Lakes, British Columbia	443	290-587	McPhail and Murray 1969
Meadow Creek, Duncan River, Kootenay Lake, British Columbia	515		Leggett 1969
Howell Creek	690	330-820	
Cabin Creek	593	295-765	
Couldrey Creek, Flathead River, British Columbia	686	445-855	Aquatico 1976
Central Oregon Lakes	647	338-805	Oregon State Game Commission 1952-64
Sun Creek, Klamath River, Oregon	171	160-184	Wallis 1948
Yakima River, Wenatchee River, Entiat and Chelan River Basins, Washington	510		Brown 1984

Table 5

Sex Ratios of Spawning Adult Bull Trout

Stream/Lake	Male/Female	Source
Flathead River, Montana	1.0:1.1	Shepard et al. 1984b
Howell, Cabin, and Couldrey Creeks, Flathead River, British Columbia	1.0:1.3	Aquatico 1976
Swan River, Montana	1.0:1.4	Fraley and Shepard 1988
MacKenzie Creek, Upper Arrow Lakes, British Columbia	1.0:0.8	McPhail and Murray 1979
Meadow Creek, Duncan River, Kootenay Lake, British Columbia	1.0:1.1	Leggett 1969
Sun Creek, Klamath River, Oregon	1.3:1.0	Wallis 1948

Choice of spawning sites is influenced by a number of physical habitat factors. Shepard (1985) lists these variables: higher order streams (third and fourth), stream bed composition with a low percentage of boulders and greater amounts of gravel and rubble, low channel gradients, areas of overhanging bank cover, maximum stream temperatures of less than 18 C, and areas of groundwater recharge.

Redd locations in low gradient, low velocity areas have been reported by several researchers (Blackett 1968; Oliver 1979; McPhail and Murray 1979; Wydoski and Whiting 1979; Allan 1980: Fraley and Shepard 1988). Groundwater seeps or springs are found in several spawning areas (Wallis 1948; Heimer 1965; Armstrong and Morrow 1980; Fraley and Shepard 1988). Loose, uncompacted gravel substrates are important. Redds are often located downstream from low gradient/high gradient interfaces, or aggrading areas (Graham et al. 1981). Mean velocities over redds range form 0.04 to 0.61 meters per second, water depth from 0.24 to 0.61 meters per second and egg deposition depths vary from 0.03 to 0.25 meters for streams and rivers in Montana, Idaho, British Columbia and Alberta. Characteristics of redd sites from different river systems are presented in Table 6.

(See Table 6 on following page)

Table 6

Characteristics of Bull Trout Redds (Adapted from Shepard et al. 1984b)

Drainage	Mean Depth Over Redd (m)	Mean Vel. Over Redd (m/sec)	Mean Disturb Area (m2)	Streambed Composition Percent: Cobble and Larger	Large Gravel	Small Gravel	Sand	Egg Deposition Depth (m)	Source
				(>50mm)	(16-50)	(2-16) 39	(<2mm) 13	0.10- 0.20	Shepard et al. 1984b
Flathead River, Montana	0.28	0.29	2.30	18	30				
Flathead River, Montana	0.30		3.72				3/	0.20	Block 1955
				(>60mm)	(33-59)	(2-32)	(<2mm)		
Clearwater River, Alberta -Sawmill Sprgs	0.24	0.52	0.69	5	12	72	10	0.03- 0.18	Allan 1980
-Timber Creek	0.58	0.44	0.62	4	14	70	9		
MacKenzie Crk Upper Arrow Lakes, British Columbia		0.60	0.50	(>75mm)	(26-75) 31	(1.5-25) 61	(<1.5mm) 8	0.10- 0.16	McPhail & Murray 1979
Wigwam River and Ram Creek, British Columb	0.34	0.43	1.47	(>50mm) 20	(10-50) 50		(<10mm) 30	0.17- 0.25	Oliver 1979
Kootenay Lake, Meadow Creek, & John Creek, British Columb	0.77	0.33	0.73	29	59		12	0.10 0.20	Leggett 1969 & 1980
Clark Fork River, Idaho				(>50mm)	(25-60) 5	(2-25) 85	(<2mm) 10	0.08- 0.15	Heimer 1965
Pend Oreille drainage, Id				(>50mm)	(16-50) 38	(2-16) 20	(<2mm) 42		Pratt 1985b
Washington streams & rivers 1/	1.05	1.71	3.59	(>100mm) 10	(25-100) 60	(<25mm) 30			Hunter 1973
Hood Bay Crk, Alaska 2/	0.4	0.75	0.60	(>50mm) 10	(25-50) 28	(6.35-25) 32	(<6.35mm) 30	0.15	Blackett 1968

1/ Bull trout and Dolly Varden.
2/ Dolly Varden.
3/ Predominately medium-coarse gravel.

Local habitat areas where redds were constructed in some British Columbia streams included the end of long pools, channel margins and meander bends. The distance to the streambank averaged 2.5 meters (Oliver 1979). In the Upper Flathead River of British Columbia, nests were found in the deepest part of the channel in fast runs (Aquatico 1976).

Fraley et al. (1981) suggest redd counts can help define population distribution, abundance and stability. Surveys should be completed soon after spawning, before siltation occurs. Graham et al. (1981) lists features to look for in identifying redds: the presence of a pit, association with a tailspill, large size (1 x 2 meters), and cover with "clean," recently disturbed gravel. Drainage counts can vary from year to year because of changes in flow levels. Water levels influence wetted perimeter, accessibility and water temperature.

Redd construction is usually completed by one male and one female, but sometimes by more than two fish (Fraley and Shepard 1988). Female Dolly Varden and bull trout dig redds with an up and down tail-action, moving in an upstream direction (Blackett 1968; Scott and Crossman 1973). Redd superimposition has been noted in British Columbia, Montana and Oregon (Heimer 1965; Oliver 1979; Ratliff 1987). This phenomenon might be the result of limited spawning habitat, or it could indicate the site specific characteristics required by the breeding bull trout.

Several researchers have given detailed accounts of the reproductive behavior of bull trout and Dolly Varden (Needham and Vaughn 1952; Blackett 1968; Leggett 1969 and 1980; McPhail and Murray 1979; Oliver 1979). Pre-spawning behavior includes body pressing and quivering. Females use anal fin feeling to choose nest sites. Eggs and milt are released after male and females have pressed together, arched their backs and vibrated with mouths agape. A female may be accompanied by as many as four to five males. Dominant males show aggression towards subordinates and defend localized areas (Scott and Crossman 1973).

Oliver (1979) observed nest digging at night. He also concluded males may spawn more than once (sex ratios were one male per two females in his study area). Aquatico (1976) reported pairs generally spent four to six days in a redd after spawning. In Wigwam River tributaries, females moved downstream soon after spawning. Males remained late into the fall (Oliver 1979).

Early-maturing males have been found in the Upper Arrow Lakes, upper Flathead River tributaries, the Clearwater Basin, Alberta and in Pend Oreille Basin (Aquatico 1976; McPhail and Murray 1979; Allan 1980; Shepard and Graham 1983b; Pratt 1985b). In the Upper Arrow Lakes, male bull trout entered tributaries while still green and left without spawning (McPhail and Murray 1979). Jacks ranging from 290mm to 350mm in length were found in North Fork Flathead River streams. Aquatico (1976) assumed these fish were 4 years of age. Shepard and Graham (1983b) noted precocious males (average length 215mm and 3 years of age) were seen actively spawning with larger females (500 to 600mm in length). In the Pend Oreille Basin, "small" bull trout have been recorded in spawning beds (Pratt 1985b).

Bull trout eggs are orange-yellow in color, demersal and nonadhesive. The egg chorion is thick and translucent (McPhail and Murray (1979). In other salmonids, egg size varies with the size of females. The bull trout and the Dolly Varden, however, show only a slight variation in egg size, with a range from 5.0 to 6.2mm (Heimer 1965; Blackett 1968; Aquatico 1976; McPhail and Murray 1979). Egg number changes with female size in bull trout (Table 7). Martin (1985) reported an average egg retention of five percent for bull trout.

Table 7

Fecundity of Bull Trout Spawners

Drainage	Length Mean (Range in MM)	Eggs/ Female	Source
Falls Creek, Alaska 1/	114 (91-207)	66 (38-212)	Blackett 1968
Sun Creek, Oregon 2/	181 (152-201)	249 (74-337)	Wallis 1948
MacKenzie Creek, British Columbia	470 (409-550)	1442 (1340-1607)	McPhail and Murray 1979
Clark Fork River, Idaho	544 (470-660)	3821 (2136-6753)	Heimer 1965
Bull River, Project Creek, Montana	619 (455-740)	4926 (1337-8845)	Brunson 1952
Flathead River, Montana	611 (406-876)	5482	Shepard et al. 1984b

1/ Stream resident Dolly Varden.
2/ Stream resident bull trout.

Egg Deposition to Emergence

Water temperature affects embryonic development and streambed composition. Optimal incubation temperatures for embryo survival have been shown to lie between 2 and 4 C (McPhail and Murray 1979; Brown 1985; Carl 1985). Fraley and Shepard (1988) found intergravel temperatures in an upper Flathead tributary to range from 1.2 to 5.4 C. McPhail and Murray (1979) reported the smallest size at hatching and lowest survival rates were for temperatures of 8 to 10 C (survival rates of 0 to 20 percent). A number of researchers report the selection of areas of groundwater seepage by spawners (Heimer 1965; Armstrong and Morrow 1980; Shepard et al. 1984b; Pratt 1985b). Groundwater may mitigate harsh winter temperatures and the formation of anchor ice.

The period of development required for eye-up averages 200 CTU or 33 to 35 days from the time of egg deposition (Shepard et al. 1984b; Gould 1987). Incubation time to hatching ranges from 350 CTU for bull trout (113 days from deposition) to 380 CTU for Dolly Varden (Armstrong and Blackett 1980; Shepard et al. 1984b). Field observations show emergence to occur after 634 CTU, 223 days from deposition (Shepard et al. 1984b). McPhail and Murray (1979) found that fry remained in gravel for three weeks after emergence before filling their swim bladders.

Dolly Varden alevins average 18.0 to 19.5mm in length at hatching and are 20 to 25mm long when they emerge in late April or May (Blackett 1968; Scott and Crossman 1973). In Montana, when the bull trout emerges, it ranges in size from 25 to 28mm (Shepard et al. 1984). Balon (1980) reported that among the charr, hatch time is shortest for the Dolly Varden. Exogenous feeding also begins earliest for the Dolly Varden and the arctic charr. Feeding of bull trout fry has been shown to occur while still in the gravel (McPhail and Murray 1979). Shepard et al. (1982a) discovered that 83 percent of bull trout fry in some Flathead River tributaries emerged within a four day period, during and following a preliminary spring peak flow. Weaver and White (1985) believed that this small peak flow may physically stimulate the fry.

Weaver and White (1985) found emergence success to be dependent on the amount of fine materials (less than 9.5mm) in the substrate. Survival in their study was 53 percent. Of mortality factors, entombment may have caused up to 15 percent of the deaths. Shepard et al. (1984a) examined survival rates with different substrate mixtures. Mortality increased sharply with mixtures of 30 percent or more fines (less than 6.35mm). Zero survival was reported for mixtures of 50 percent or more fines. Extreme streamflows may contribute greatly to embryo and fry mortality. High flows scour out gravel, and low flows expose redds. This freezes the incubating eggs (Weaver 1985).

Juvenile Behavior

Both the bull trout and the Dolly Varden young display aggressive and territorial behavior within its species and between other species.

Armstrong and Elliott (1972) noted aggression in the Dolly Varden juvenile. Newman (1960) found that the Dolly Varden young is extremely aggressive compared with the juvenile lake trout. In mixed communities of coho and Dolly Varden fry, the Dolly Varden did not have obvious territories. In mixed communities of coho and Dolly Varden juveniles age 1 or older, a single Dolly Varden acted as tyrant in observed interactions (Armstrong and Elliott 1972). These researchers also found that Dolly Varden fry do not have obvious territories.

Once neutral buoyancy is attained, the bull trout fry displays overt aggression (McPhail and Murray 1979). Under lab conditions, this aggressive behavior is only displayed under high fry density. Fry are not territorial in rearing tanks, but defend an individual space. The largest fry collect near the surface at the point of food introduction. McPhail and Murray (1979) found that under natural conditions of low density and high current in stream tanks, fry defended established territories. Dominant fry were upstream at the food source and displayed well-defined parr marks. Subordinate fry had indistinct parr marks.

The bull trout juvenile tends to focus its territory on a fixed site, usually a small pocket of low velocity water just above the stream bed (Shepard et al. 1984b). It also tends to maintain its feeding site throughout the summer (McPhail and Murray 1979).

With plentiful cover, this territoriality and aggression might be reduced. Individuals may occupy smaller areas if this cover affords them "visual isolation" from their neighbors (Elliott 1986). If isolation is not possible, and stream carrying capacity is reached, fry are forced to migrate downstream (Pratt 1985a). Armstrong and Elliott (1972) found that the Dolly Varden is more willing to leave than other juvenile salmonids as a result of inter or intraspecific competition.

Juvenile Habitat

Juvenile bull trout and Dolly Varden, particularly young of the year (YOY), have very specific habitat requirements. Small bull trout (less than 100mm), are primarily bottom-dwellers, occupying positions above, on or below the stream bottom. Bull trout and Dolly Varden fry are found in shallow, slow backwater side channels or eddies, often in association with logging residue (Shepard et al. 1984b; Elliott 1986; D. Ratliffe, Portland General Electric, personal communication 1988). The preferred habitat of YOY bull trout in Montana streams is "clean" gravel-cobble-rubble substrates (T. Weaver, Montana Department of Fish, Wildlife and Parks, personal communication 1988).

Small individuals of both *Salvelinus spp*. occupy a variety of stream flow patterns. Dolly Varden fry on Prince of Wales Island, Alaska were observed in shallow riffles. Pools were utilized by 2- and 3-year-olds (Cardinal 1980). Side pools and eddies were listed by Blackett (1968) as preferred areas for Dolly Varden young. Riffles and riffle-glides were used by juvenile Dolly Varden and bull trout in Alaska and British Columbia (Armstrong and Elliott 1972; Ptolemy 1979; Stuart and Chrislott 1979). Bull trout in the Wigwam and MacKenzie River Systems of British Columbia were found in pools and rolling or broken flows (McPhail and Murray 1979; Oliver 1979).

For both species, age 1+ and older individuals are found in deeper and faster water than YOY. Often they are in pools with shelter-providing large organic debris or "clean" cobble substrate (McPhail and Murray 1979; Heifetz et al. 1986), In larger rivers, the highest abundance of juveniles was found in rocks along the stream margin or in side channels (Fraley and Graham 1981).

Griffith (1979) and Tredger (1979) documented the use of substrate and debris as cover by Dolly Varden in British Columbia. In Alaska, Cardinal (1980) also listed debris as important cover for Dolly Varden young. Coarse and fine obstructive debris was utilized, as were undercut banks. Ptolemy (1979) also observed bull trout using undercut banks.

Substrate types associated with juvenile bull trout are primarily gravel and cobble. These materials may compose 50 to 70 percent of the streambed (Griffith 1979; Ptolemy 1979; Stuart and Chislett 1979; Tredger 1979; Shepard et al. 1984b). In the Wigwam River and Ram Creek of British Columbia, Oliver (1979) observed fry in sand and gravel and juveniles in areas of rubble and boulder. Shepard et al. (1984b) listed similar substrate types for fry and 2 and 3 year olds.

Bull trout are strongly influenced by temperature. They are seldom found in tributaries with summer temperatures exceeding 18 C and are often found near cold perennial springs (Allan 1980; Shepard et al. 1984b). Fry and age 1+ individuals in the Metolius Drainage only occupy groundwater fed tributaries . These streams seldom exceed 50 F (10 C) (Ratliff 1988).

Little information is available on the winter habitat of bull trout young. Armstrong and Elliott (1972) found that during winter months, Dolly Varden juveniles hide in dense mats of debris, or they may swim upstream to areas of ground water seepage. An adaptation to freezing conditions in streams for brook trout and other salmonid juveniles is the habit of burrowing under rock rubble. As water temperatures decline, feeding rates decrease, as do metabolic needs(Bjornn 1971; Bustard and Narver 1975). From this, Chapman (1966) concluded that salmonid populations during winter require living space as their major need for survival. Territories of juveniles tend to break down with declining temperatures. With a paucity of cover, salmonid groupings tend to grow larger and emigration increases.

Juvenile Migration

Juveniles in most river systems have been found to migrate at 2 to 3 years of age (McPhail and Murray 1979; Oliver 1979; Fraley and Shepard 1988). In Alberta, juveniles may remain in nursery areas for up to six years (Allan 1980). Newly emergent fry tend to migrate in the spring, moving downstream to areas of lower water velocity (Aquatico 1976; McPhail and Murray 1979; Oliver 1979; Allan 1980). In the Wigwam River system, Oliver (1979) found that 1 and 2-year-olds had migrated from Ram Creek, a small tributary. Young moving out of the mainstem Wigwam were 2 to 3 years of age.

The timing of runs varies by age, size and habitat availability. Pratt (1985a) reported peak migration of fry at the beginning of May. When rearing area carrying capacities are exceeded, fry are pushed downstream into mainstem reaches. High water flows in spring may also expel fry from tributaries.

In British Columbia streams, juveniles have been found to move downstream continuously through summer and fall. Oliver (1979) speculated there might be a large migration just prior to the spring runoff. Researchers working for Aquatico (1976) discovered a peak run during the first week of October in the upper Flathead tributaries of British Columbia. Shepard et al. (1984b) listed movement from North and Middle Fork Flathead streams occuring in June and July. Migration from the mainstem to Flathead Lake took place from August to September. These periods are similar to those of the cutthroat trout. The bull trout young tends to move quickly. They have been observed only along the margins of larger rivers. Armstrong and Morrow (1980) concluded that the Dolly Varden smolt migrates at night. Its peak movement periods are determined by size rather than by age.

Upstream migrations have been recorded for the bull trout and the Dolly Varden. Armstrong and Morrow (1980) discovered upstream movement by Dolly Varden young during the late fall. Juveniles concentrated in spring areas that had warmer water temperatures. Fraley and Shepard (1988) reported fry migrating from lower stream reaches (spawning areas) to upper sections to rear. These areas were not used by adults and temperatures did not exceed 15 C.

Adult Habitat

The adult bull trout, like its young, is a bottom dweller, showing preference for deep pools of cold water rivers, lakes and reservoirs (Moyle 1976). In Oregon's upper Klamath River, summer habitat for stream resident adults included water temperatures from 9 to 15 C, gradients of 10 to 20 percent, moderate to fast currents and stream widths of two to five meters (Bond and Long 1979). Another resident population, found in Crater Lake National Park, occupied a stream with summer temperatures of 5 C, velocities of 0.6 to 1.8 meters per second, a stream width of three meters and a gravel rubble substrate. It was fed by groundwater seeps (Wallis 1948). Resident Dolly Varden were noted by Armstrong and Morrow (1980) to overwinter in deep pools, or they migrated downstream to deeper water near tributary mouths.

Fluvial populations also winter in deep pools or move further downstream to lower reaches of mainstream rivers (Dimick and Merryfield 1945; Allan 1980). In Alberta, adults inhabiting deep pools are found to associate with large concentrations of mountain whitefish, an abundant food source (Carl 1985). On the John Day River of Oregon, summer temperature preferences are 48 to 55 C (E. Clair, Oregon Department of Fish and Wildlife, personal communication 1988). In the lower river reaches, the bull trout is found in deep pools with boulder-rubble substrate. Upper river sections with adults never exceed a water temperature of 10 C. Individual fish make use of abundant woody debris and overhanging banks.

During upstream migrations adults hold under cover - debris jams, deep pools and undercut banks (Shepard et al. 1984b). In the Upper Arrow Lakes, McPhail and Murray (1979) observed pairs holding in small plunge pools or undercut banks. Oliver (1979) found adults under debris accumulations and along channel margins during the day. Characteristic areas had low velocity water and shallow depths (less than 50cm). Fraley and Shepard (1988) reported that large numbers of adults hold below the mouths of spawning tributaries often under debris cover. They may remain in these areas for up to one to two months before spawning. Once in the tributary, during spawning periods, adults have been observed in shallow runs, under log jams or in deep pools (Aquatico 1976; Shepard et al. 1984b).

Adult Migration

Adfluvial adults mature for two to three years in lakes and reservoirs before undergoing spawning migrations (Oliver 1979; Fraley and Shepard 1988). Most adults start their upstream movement from Flathead Lake during April and May and arrive at tributary streams in July and August (Martin 1985).

In the Wigwam River, the migration period is from July to September (Oliver 1979). Hunter (1973) listed total migration periods from July to December for the bull trout and the Dolly Varden in Washington. Most movement occurs at night. Adults feed little or not at all on upstream drives (Oliver 1979; McPhail and Murray 1979; Shepard et al. 1984b). Tagging returns record maximum distance covered in one day as two kilometers. The greatest total distance (one direction) was 225 kilometers (Hanzel 1985).

McPhail and Murray (1979) found peak upstream movement to coincide with maximum water temperature (10-12 C) and minimum flows(0.76 to 0.8 meter depth). Two peaks in spawning runs have been recorded by Oliver (1979) and McPhail and Murray (1979). The fish making up the earier run were the smallest and youngest. These individuals tended to remain in tributaries for longer periods than the older, larger second run adults. Martin (1985) recorded adults entering spawning streams from mid-September through the end of October. These breeding adults returned to Flathead Lake in October and November. Oliver (1979) observed a similar period of movement in British Columbia. Downstream movement is very fast. Females may head back to wintering areas immediately after egg deposition (Oliver 1979; Shepard et al.1984b). Adults migrating back to Flathead Lake often feed on spawning concentrations of mountain whitefish.

McPhail and Murray (1979) suggest that the bull trout may form pairs during upstream migration or on its spawning grounds. These researchers also concluded that aggression was infrequent in breeding areas. Usually a dominant male attacked a subordinate male. For the arctic charr, social dominance is associated with the intensity of male coloration. McPhail and Murray (1979) thought this was true for the bull trout in their study area, as these fish were quite pale in color.

Homing

The bull trout has been observed to have a strong homing instinct (Scott and Crossman 1973). In Flathead River tributaries, some adults return to the same specific spawning area each year (Fraley et al. 1981). On the Metolius River, a female spawner has returned for three consecutive years to the same nest site (D. Ratliff, personal communication 1988). Anadromous Dolly Varden display a high degree of homing to natal streams. Armstrong and Morrow (1980) discovered no indication of straying between adjacent streams. These researchers concluded that imprinting occurred during the last day of smolt migration.

Other authors suggest that the bull trout does not precisely home. In the Upper Arrow Lakes, McPhail and Murray (1979) found that as individuals grew they had a tendency to shift to new, larger spawning streams. Tagging returns on the Wigwam River show the bull trout were taken by angling in streams other than its location of tagging (Oliver 1979). The relative importance of each spawning tributary in the Pend Oreille drainage varies each year, hence, homing may not be as important in this system (Pratt 1985b).

Lake Life

Hanzel (1985) reports that the bull trout has the most diverse habitat useage of any fish inhabiting Flathead Lake. It is thought to go as deep as 360 feet. It consistently travels along the entire shoreline of the lake (Hanzel 1965). Adults are found throughout the water column in most lakes during the fall, winter and spring, often near the mouths of migration routes. In summer they move to deeper water. In Priest Lake, the bull trout was reported by Bjornn (1961) to occupy the lower thermocline in summer, using depths from 12 to 18 meters and temperatures from 7.2 to 12.8 C. In spring and fall, these fish moved to near surface waters when temperatures were below 12.8 C. Shepard (1985) listed the thermal preference of the bull trout in Libby Reservoir to be between 8 and 14 C, a major influence on its vertical distribution. Kokanee were found in areas up to 15 C and *Salmo* species at 18 C.

Diel migrations have been noted for the adfluvial bull trout and the Dolly Varden. Through gill net sampling, Thompson and Tufts (1967) concluded that the bull trout moves from deep to shallow water in areas with sloping bottoms. Andrusak and Northcote (1971) observed a similar pattern for lake resident Dolly Varden during the summer. In Flathead Lake during the fall, adults move into the lower reaches of the river to eat concentrations of pygmy whitefish. They also move along the lakeshore into spawning areas of salmon (Hanzel 1977; Shepard et al. 1984b).

The adult bull trout in Flathead Lake is not found in schools. It acts as a solitary fish (D. Hanzel, personal communication 1988). Schutz and Northcote (1972) reported that the lake resident Dolly Varden, when resting, lie directly on the bottom. The Dolly Varden appears more gregarious than the bull trout, forming groups of two to three, or loose aggregations of five or more.

Interactions With Trout

Leathe and Graham (1982) concluded that the adult bull trout shares little with the food habits of other salmonids because of its piscivorous nature. Armstrong and Morrow (1980) suggest that for the Dolly Varden juvenile, there may be direct competition in small streams for food and space with grayling, coregonids, sculpins and osmerids. These groups all prey on benthic insects. A number of other studies have also been completed examining interactions between the Dolly Varden and the coho juvenile and the Dolly Varden and the adult cutthroat (Andrusak and Northcote 1971; Armstrong and Elliott 1972; Schutz and Northcote 1972).

The most detailed information on interspecific competition of the juvenile Dolly Varden was compiled by Armstrong and Elliott (1972). They found that in mixed fry communities of coho and Dolly Varden, the coho dominated. Mixed communities of juveniles were usually dominated by a Dolly Varden "despot." This dominant juvenile occupied the most favorable feeding area. In lab studies, Armstrong and Elliott (1972) were able to show that interactive segregation might be at work. Juvenile coho ate surface insects and occupied the upper-half of the water column. Dolly Varden young preyed on benthic insects and remained near the bottom in the presence of coho. Solitary Dolly Varden spent less time on the bottom. Coho not in the presence of Dolly Varden made greater use of benthic areas. Andrusak and Northcote (1971) and Schutz and Northcote (1972) present evidence of selective segregation between adult cutthroat and lake resident Dolly Varden. Allopatric cutthroat preyed more frequently at the surface, while the Dolly Varden used the benthos.

Research has been completed examining competition between the bull trout and the cutthroat trout juvenile and the feeding habits of the adult bull trout, the northern squawfish and the rainbow trout (Jeppson and Platts 1959; Thompson and Tufts 1967; Pratt 1984; Boag 1987). In some northern Idaho lakes, Jeppson and Platts (1959) found that the northern squawfish competes with the bull trout for food at sizes between eight and 12 inches (200-300mm). Both species shifted to a predominately fish diet at this size. Thompson and Tufts (1967) documented a similar diet overlap of the northern squawfish and the bull trout in a Washington lake. Boag (1987) examined rainbow trout and bull trout populations in an Alberta stream. When both species were present in the same locale, the bull trout tended to be more piscivorous. No competition for food was suggested. Allan (1980) also hypothesized that rainbow trout are not competitors with the bull trout for living space and food. In the Upper Arrow Lakes of British Columbia, McPhail and Murray (1979) indicated habitat partitioning could be occurring between juvenile rainbow trout and bull trout. Rainbow trout regularly chose areas of higher water velocity. Growth of these individuals was very slow. Depressed development rates of these rainbow trout may be due to the presence of bull trout. In the Upper Clark Fork River of Idaho, bull trout are still found in tributaries despite intensive plantings of hatchery rainbow trout (Knudson 1984).

Pratt (1984) conducted an intensive study of juvenile cutthroat and bull trout interactions. In the presence of one another, cutthroat and bull trout chose different habitat areas within nursery streams.

Cutthroat had a focal point one meter above the streambed. Bull trout stayed in one place (behind velocity obstructions) or moved along the bottom. Cutthroat fed on surface drift. Pratt (1984) discovered a possible association between first year cutthroat and larger bull trout. This relationship suggests that bull trout chose cutthroat fry areas because of their potential as a food source.

Shepard et al. (1984b) reported interspecific aggression between larger bull trout juveniles and adult cutthroat trout. If bull trout were conspicuous in a pool, the adult cutthroat chased them toward areas of cover. Juvenile bull trout were observed occupying habitat similar to that used by slimy sculpins, *Cottus cognatus*, in North Fork Flathead tributaries (Aquatico 1976). Young of both species hold and rear in the stream substrate.

Wallis (1948) found the feeding habits of stream resident brook and bull trout to be similar. Both species primarily consumed aquatic insects, although the brook trout took a slightly higher percentage of terrestrial insects. Fluvial populations of bull trout and brook trout share the same available habitat during at least one stage of their life histories (Peters 1985; Rode 1988). Hybridization between these two species appears to be quite extensive (Cavender 1978; Leary et al. 1983). Resident and fluvial bull trout populations in all areas of sympatry with brook trout in Montana appear to be on the decline (Leary, personal communication 1988).

Rode (1988) believes large scale stocking of brook trout in the McCloud Reservoir could have contributed to the demise of the California Bull Trout. Rode (1988) also speculates that competition between the brown trout and the bull trout occurred on lower reaches of the McCloud. The potential for this interaction resulted from adverse changes to river habitat following dam construction. Bond and Long (1979) found stream resident bull trout in association with red band trout (*Salmo sp.*) and brown trout. Stream temperatures where brown and bull trout association occurred was 15 C.

Sympatric populations of Dolly Varden and bull trout exist in several Puget Sound tributaries and in the Skeena and Taku River Basins of British Columbia (Cavender 1978; J. Johnson, Washington Department of Wildlife, personal communication 1988). In his study of museum specimens, Cavender (1978) hypothesized there is an ecological segregation between these two species. In sympatric areas, Dolly Varden occupied lower river sections. The bull trout was found in smaller tributaries. Bull trout and Dolly Varden in Washington's Skagit River reach sexual maturity at the same time in the same general area. What their habitat use in these areas is remains to be discovered (Johnson 1988).

A unique instance of well-defined habitat partitioning was reported by Marnell (1985). In the Isabel Lakes of Glacier National Park, cutthroat and bull trout coexist as the only resident fish species. The bull trout is typically larger than the cutthroat trout and preys upon it in other areas of sympatry. In this situation, the cutthroat trout is larger, and the bull trout is not piscivorous. The normal predator-prey relationship of these two species is absent here. Marnell (1985) also attributed the decline of the bull trout in some park areas to the introduction of the lake trout, *Salvelinus namaycush*

In western drainages of the Oregon Cascades, bull trout at one time were sympatric with sea-run and freshwater cutthroat trout, rainbow trout, chinook and chum salmon (Dimick and Merryfield 1945). Historical association of the bull trout with these other fish species in the Willamette Basin of Oregon is listed in Table 8.

(See Table 8 on following page)

Table 8

Community Associations of Bull Trout With Other Fish Species in Western Oregon Prior to 1945 1/

Drainage Basin	River	Species
Lower Willamette	Clackamas	Oncorhynchus keta O. tshawytsch Salmo clarki clarki Prosopium willamsoni
Middle Willamette	North Santiam	O.tshawytscha S. clarki Salmo gairdneri P. williamsoni RicharDsonius balteatus Rhinichthys oeculus
Upper Willamette	McKenzie	O. tshawytscha S. clarki S. gairdneri C. macrocheilus Acrocheilus alutaceus Ptychocheilus oregonensis R. balteatus
Upper Willamette	Middle Fork Willamette	O. tshawytscha S. clarki S. gairdneri P. williamsoni C. macrocheilus P. oregonensis R. balteatus Rhinichthys cataractae R. osculus

1/ From Dimick and Merryfield (1945).

Age and Growth

Hanzel (1985) found aging of the bull trout to be problematic. The average agreement between otolith and scales for ages 3 to 9 was 50 percent. Fraley et al. (1981) listed 100 percent agreement between otolith and scale readings for ages 0 to 3. Aging of scales is considered the best method, while otoliths should be used to verify scale readings. Brown (1984) found a probable bias in eastern Washington samples. A lower than actual age may have been given to older trout examined. Scales could not be read in fish 4 to 5 years of age or older. Otolith analysis was also considered difficult. McPhail and Murray (1979) noted an increase in ring width, showing a shift of individuals from streams to lakes.

Cavender (1980b) lists size ranges for the bull trout as 350 to 900mm. The Dolly Varden is 250 to 500mm. Scott and Crossman (1973) describe size and age as a function of life history pattern and location. Adfluvial populations reach the largest size. Headwater residents are the smallest, seldom exceeding 305mm in length. Northern populations may live to a greater age (Marnell 1985).

Size ranges reported for resident populations in Oregon and Washington are from 115 to 300mm (Wallis 1948; J. Fortune, Oregon Department of Fish and Wildlife, personal communication 1988; University of Washington fish collection records). Dolly Varden lake and spring resident adults range from 100 to 250mm and live to 10 years of age (Andrusak and Northcote 1971; Armstrong and Morrow 1980).

Maximum size published for an adfluvial bull trout is 40.5 inches (1025mm) and 32 pounds (14.5kg) for a fish from Pend Oreille Lake. A bull trout caught on the Lardeau River was reported to weigh 18.3kg (40 pounds) (Scott and Crossman 1973; Armstrong and Morrow 1980). In central Washington river systems, Brown (1984) listed maximum size as 37 inches and 25.5 pounds. The Metolius River in Oregon has been the site of three consecutive state records. Fish weighing 19, 20 and 20 pounds 7 ounces were caught in recent years (D. Ratliff, personal commumication, 1988). An individual bull trout of the fluvial McCloud River population weighed in at 16 pounds. Another bull trout from this system was purported to reach an age of 19 years (Shebley 1931; Wales 1939).

The maximum period of growth appears to occur between the third and fourth years of age. Most individuals by this time have reached sufficient size to switch to a piscivorous diet. From age 4 and on, year-to-year size increases are largely constant. Adfluvial populations average a 90mm increase per year. Northern fluvial populations in Alberta grow at a slower rate, averaging a 50mm yearly increase. Size ranges from various river systems are listed in Table 9 (growth calculations for Alberta may be underestimating the age of fish or overestimating early growth).

(See Table 9 on the following page)

Table 9

Bull Trout Growth (mm) in Various Drainages (Adapted From Leathe and Graham 1982)

Total Length (mm) at Annulus

Drainage	I	II	III	IV	V	VI	VII	VIII	IX	Source
MONTANA										
-Middle Fork Flathead River	52	100	165	297	399	488	567	655		
-North Fork Flathead River	73	117	165	301	440	538	574			
-Flathead Lake	68	129	204	291	384	472	566	658	731	Fraley & Shepard 1988
-Hungry Horse Reservoir	72	144	225	324	429	513	594	671		Huston 1974
-Lake Koocanusa	67	123	212	309	390	482	518			May et al 1979
IDAHO										
-Pend Oreille Lake	91	164	272	403	497	578				Pratt 1985b
-Priest Lake	71	114	183	310	424	516	605			
-Upper Priest Lake	66	102	155	239	358	462	546	612		Bjornn 1961
OREGON										
-Upper Willamette River	93	142	165			264	284	347	452	
-Roberts Creek, John Day River	67	111	132							Oregon Game Comm. 1/
-Metolius River Tributaries	51	92	141							Ratliff 1987 2/
BRITISH COLUMBIA										
-Ram Creek, Wigwam River	78	137	218	303						
-Wigwam River	64	114	176	385	476	557	668			
ALBERTA										
-Jasper National Park	68		215	275	365	445	520	590		Bajkov 1927
-Bow River		165	211	246	269	320	335			Miller 1949
-Clearwater River	174	215	249	298	344	395	451			Allan 1980
-Muskeg River	193	234	276	341	402	430	462			Boag 1987

1/ Unpublished data.
2/ Length frequency data.

Habitat degradation may impact bull trout development. Weaver and White (1985) found fry size at emergence to average 25.5 to 26.6mm in length. The size of these fry declined as the percentage of fine material in the substrate increased. Removal of logging debris from streams and its effect on rearing the Dolly Varden was examined by Elliott (1986). Observed fish length and weight decreased after debris was removed. Length declined from 106 to 79mm and weight was reduced from 12.2 to 5.9g.

Carl (1985) concluded juveniles grow slowly in cold temperatures and low productivity streams. Hatchery growth of bull trout young is slow compared to other hatchery raised species (Brown 1985). In the Wigwam River, Oliver (1979) observed a high variation in development rate of juveniles. He hypothesized this may be due to the timing of emergence, or from differential productivity in rearing areas. Juveniles in river habitat were smaller than those in tributaries. Oliver (1979) suggests smolting is a function of size rather than age. Faster growing age groups smolt first. Once a juvenile reaches a lake, its growth rate is fairly constant (Fraley and Shepard 1988).

Fluvial and stream resident populations in Washington may remain immature for up to 7 years (K. Williams, personal communication 1988). Females up to 500mm in length may not be sexually mature (Brown 1984).

In Flathead Lake, Fraley and Shepard (1988) report most fish mature at age 6 or 450mm in length. Females may spawn 1 year later than males. Dolly Varden young may remain in nursery streams from three to five years (Elliott 1986). Fish in the Kananaskis River of Alberta mature at 5 years of age at lengths of 500mm (Nelson 1965).

Brown (1984) found age ranges from 5 to 12 years in eastern Washington samples. The bull trout lives to 10 years of age in Priest Lake and from 10 to 20 years in Alberta (Bjornn 1961; Carl 1985).

Mortality

A variety of factors contribute to mortality of different age classes of bull trout. Problems encountered during egg incubation were outlined in a previous section. Predation occurs at all stages of bull trout life history. Heimer (1965) reported whitefish and suckers feeding on eggs during nest construction in an artificial channel. Extreme flows of water may push fry into mainstem rivers. Predation rates are much higher in these areas (Pratt 1985a). The greatest predation of the bull trout and Dolly Varden juvenile is by larger members of their own species (Armstrong and Morrow 1980; Leathe and Graham 1982). In the Flathead River and its tributaries, adults are eaten by bear, mink, otter and osprey (Martin 1985).

Fraley (1985) assumes pre and post-spawning mortality in Flathead tributaries is between 30 and 40 percent. Angling and natural mortality rates are unknown. In the Pend Oreille Basin, total annual mortality for ages 4 to 6 is 47 to 82 percent (Pratt 1985b). Illegal harvest of adults holding in spawning tributaries is a large percentage of this mortality. Poaching is also a problem on the Flathead River, but estimates of mortality are impossible to accumulate (Fraley 1985). Legal annual harvest in Flathead Lake is 40 percent (Hanzel 1985).

Parasites

In Oregon, Shaw (1947) reported bull trout infected with the cestode *Abothrium crassum*, the nematode *Dachnitis truttae* and the trematodes *Crepidostum cooperi* and *Aponunus sp*. Wallis (1948) found roundworms, nematodes, and tapeworms in fish from a stream resident population. Patches of *Saprolegnia* covered some individuals. Hanzel (1985) listed the tapeworm *Dibothriocephalus latum* and the external copepod *Salmicola edwardsonii* from Flathead Lake. Dolly Varden and bull trout specimens from nine locations in British Columbia all contained parasites (Bangham and Adams 1954). The cestode *Eubothrium salvelini* was found in 20 percent of the sampled fish, while 69 percent were infected with the acanthocephalan *Neoechinorhynchus rutili* and the trematode *Crepidostomum farionis*.

At the Kootenay Hatchery in British Columbia, Brown (1985) noted eggs and fry were infected with mxyobacteria, flexibacteria (similar to cold water disease) and gill disease. The bacterial gill disease Costia was reported at the Wallowa Hatchery in Oregon (Oregon State Game Commission 1968).

Food Habits

A number of researchers have documented the opportunistic and adaptive feeding habits of the bull trout and the Dolly Varden. Boag (1987) studied a population of bull trout in an Alberta stream separated by a beaver dam. Two distinct feeding groups were observed. Downstream of the dam, the bull trout was more piscivorous. Stocked rainbow trout and their eggs made up 24 percent of this group's diet. Upstream of the barrier, in an unstocked area, bull trout ate insects exclusively.

Thompson and Tufts (1967) found the bull trout in Lake Wenatchee, Washington switching from a diet of wild sockeye fingerlings to almost exclusive predation of hatchery raised fish after their release into the lake. In the Flathead Lake and River system, adult bull trout eat whatever fish species are most available (Shepard et al. 1984b).

The Dolly Varden also displays flexible feeding habits. Elliott (1986) examined the effects of debris removal in an Alaskan stream. Before removal, the Dolly Varden ate more benthos. Following steam treatment, it increased its use of surface prey. In some coastal British Columbia lakes, Schutz and Northcote (1972) reported a change in the feeding habits of resident Dolly Varden with and without the presence of coastal cutthrout trout. If it was the only lake resident, the Dolly Varden used the entire water column in feeding. Association with cutthroat trout restricted the Dolly Varden to use of the bottom.

Feeding behavior of the bull trout and the Dolly Varden is quite similar. The Dolly Varden in coastal lakes is primarily a bottom feeder. Resident adults cruise constantly while searching for food (Schutz and Northcote 1972). The juvenile bull trout in Idaho and Montana streams hold in one place or cruise the bottom (Pratt 1984). McPhail and Murray (1979) established that the juvenile bull trout rarely uses the surface, instead it concentrates on benthos. Cannabalism of fry and juveniles by larger individuals has been noted for both species (Armstrong and Elliott 1972; Aquatico 1976; Cavender 1978; and Leathe and Graham 1981). It was suggested by Pratt (1984) that fry have a strong need for cover (fine debris or substrate) to separate them from older age classes.

In Flathead Lake, the bull trout moves independently of its prey. No correlation has been found between the bull trout and the distribution and movement of its prey (Hanzel 1985). The bull trout shows seasonal changes in its choice of prey. Shepard et al. (1984b) listed the food preferences of bull trout primarily as: yellow perch in winter, lake and mountain whitefish in fall, kokanee in the spring and nine different forage species in the summer. Armstrong and Morrow (1980) stated that salmon eggs are an important part of the Dolly Varden diet during the fall. Eggs that are eaten are from drift produced by redd construction.

The onset of exogenous feeding by Dolly Varden fry begins earier than that of most other charr species (Balon 1984). Bull trout fry begin feeding at emergence. They select items from all levels of the water column (McPhail and Murray 1979). Armstrong and Morrow (1980) found that Dolly Varden fry frequently eat benthic insects.

The juvenile bull trout of less than 110mm feeds almost exclusively on aquatic insects (Aquatico 1976; Shepard et al. 1984b). Dolly Varden young appear to eat more surface insects in sloughs, shaded pools and along stream margins than in other habitats (Armstrong and Elliott 1972). Juveniles of both species, as reported by Scott and Crossman (1973), consume adult and immature insects, snails and leeches. Salmon eggs are important during the fall. At sizes from 110 to 140mm, the bull trout becomes increasingly piscivorous (Aquatico 1976; Shepard et al. 1984b). However, Jeppson and Platts (1959) noted that in northern Idaho lakes bull trout from 100 to 300mm ate only insects. Upon reaching 400mm in size, they consumed fish exclusively.

Subadults in the Flathead River and the McKenzie River of Oregon have been observed in "clouds" of whitefish (Shepard et al. 1984b; S. Gregory, Oregon State University, personal communication 1988). Sculpins and Mysis shrimp are eaten by small bull trout in Flathead and Pend Oreille Lakes (Fraley and Shepard 1988; N. Horner, Idaho Fish and Game, personal communication 1989).

The food habits of the adult bull trout and Dolly Varden is a function of their life history patterns. Stream resident fish of both species feed almost exclusively on insects (Scott and Crossman 1973; Armstrong and Morrow 1980). In Sun Creek (Klamath River Drainage), Wallis (1948) studied a resident population of bull trout. Adult food preferences were for aquatic insects: in decreasing order of abundance were flies of the order Diptera, caddisflies, mayflies, and stoneflies. Dolly Varden in landlocked lakes of Alaska, were found by Blackett (1968) to be more piscivorous than fish in lakes with sea access.

Fluvial populations show an increased used of fish as prey items. Dimick and Merryfield (1945) reported.that the bull trout in the McKenzie River of Oregon ate forage fish, insects and crayfish. Of 25 fish examined, none were found to have eaten salmonids. On Oregon's Imnaha River, eight of nine bull trout (average length 350mm) that were studied had consumed only salmon fingerlings (Oregon Game Commission 1959).

Adfluvial populations of the bull trout reach the largest size of all life history types. This is due to their highly piscivorous nature. In Flathead Lake, fish larger than 550mm ate kokanee and whitefish almost exclusively (Shepard et al. 1984b). Selection for kokanee and whitefish was noted by Bjornn (1961) for Priest Lake. Prior to the introduction of kokanee to Priest Lake, the maximum size of the bull trout ranged from five to six pounds. After its introduction, individuals up to 25 pounds were harvested. A population of fish in Washington's Lake Cushman, which fed on kokanee, reached a similar size before its numbers were decimated by overharvest (J. Johnson, personal communication 1988). The largest fish caught in Oregon (20 lbs. 7oz.) was part of an adfluvial population on the Metolius River (D. Ratliff, personal communication 1988).

The bull trout is a voracious predator capable of consuming fish of over its length (Shepard et al. 1984b). Elrod (1930) first described the feeding habits of the bull trout in Flathead Lake. He examined a 19-inch (475mm) fish which had eaten a 13-inch (325mm) whitefish.

The bull trout consumes a number of exotic items, including squirrels, duckling, snakes, mice, frogs,the viscera of kokanee and even dipnets (Dimick and Merryfield 1945; Brown 1971; Moyle 1976; Elliott 1978; Leathe and Graham 1982).

Armstrong and Blackett (1966) reported the average time for digestion of fish by Dolly Varden was 12 hours. Boag (1987) determined that the bull trout requires a variable amount of time to assimilate its food.

Adults on upstream migrations probably feed very little if at all (Aquatico 1976; Fraley and Shepard 1988). Evidence presented by Armstrong and Morrow (1980) suggests juveniles feed very little over the winter season.

Population Density and Estimation

Very few published reports exist for bull trout population densities in Oregon and Washington. Bond and Long (1979) listed densities for stream resident bull trout in two tributaries of the upper Klamath River. Demming Creek had 15 to 20 fish per 100 yards. Long Creek had densities of three to five individuals per 100 yards for fish four to six inches in length, and 10 to 15 individuals per 100 yards for fish greater than eight inches. Unpublished data has been collected for wilderness areas in southeast Washington, but it was unavailable for inclusion in this report.

In an Alberta stream, Carl (1985) reported a decline in bull trout abundance from 83 fish per kilometer in 1970 to 13 fish per kilometer in 1980. Juvenile population densities in the upper Flathead range from 0.7 to 37.5 fish per 100 m2 (Pratt 1984). Researchers working in that river system have noted the difficulty in compiling accurate estimates of density due to fish movements and the multiple life history patterns of the bull trout (Fraley et al. 1981).

Carrying capacities of juvenile nursery areas could be determined from trapping results and density estimates. Summer densities of juvenile bull trout in the Flathead River System were 3.8 fish per 100m2 for age 0+, 2.9 fish per 100m2 for 1+, 1.9 fish per 100m2 for 2+ and 0.7 fish per 100m2 for age 3+ individuals. Results from trapping of juveniles show age 1+ fish representing 20% of the catch, 2+ fish were 50% and age 3+ were 30% of the catch (Montana Department of Fish, Wildlife and Parks records).

Determination and assessment of bull trout populations can be accomplished by monitoring spawning and rearing areas in tributary streams. Graham et al. (1980) listed redd counts as an excellent indicator of the number of spawning adults in tributaries. Conducted annually, these surveys can show the distribution of spawners throughout a drainage as well as the relative importance of each spawning tributary. Redd counts can also be used to measure the overall population status (Pratt 1985).

From studies in the Flathead River Basin, Fraley and Shepard (1988) found an average of 3.2 spawners per redd. Pratt (1985b) suggested an estimate of two fish per redd may be more appropriate for Swan Lake, Idaho.

Fraley and Shepard (1988) stated that juvenile population densities may be as indicative of population conditions as is the monitoring of spawning escapement. In the Flathead system, areas with densities greater than 1.5 fish per 100 m2 were cited as critical rearing areas by Shepard et al. (1982a).

SAMPLING

An outline of materials and methods used in previous research is a necessary consideration for future studies. Bloom (1976) tested a minnow trap on Dolly Varden young. His results show these traps do not capture juveniles smaller than 51mm or larger than 130mm. Biologists from the Montana Department of Fish, Wildlife and Parks have used emergence traps (similar in design to Phillips and Koski 1969) to sample fry in the Flathead drainage (Weaver and White 1985). Fingerling trapping has been successful in Oregon and Washington for fish as small as 75mm (Graham et al. 1980; Lestelle 1978). The use of stratified habitat sampling for juveniles is suggested by McPhail and Murray (1979). This sampling method is necessary because of differences in juvenile habitat use.

Snorkeling counts of juveniles tend to underestimate its numbers. Smaller fish hide behind obstructions or under the substrate (Pratt 1984). Population estimation with snorkeling averaged 1.5 fish per 100 m2. Electrofishing results were 15.5 fish per 100 m2 (Fraley and Shepard 1988). Branding of juveniles with liquid nitrogen has not been successful (Graham et al. 1980).

Aquatico (1976) and Oliver (1979) documented the sensitivity of migrating adults to handling. In both studies, adults migrating upstream turned downstream when handled. Furthermore, Oliver (1979) noted an extreme sensitivity to daylight handling. Cessation of spawning and several mortalities resulted.

Underwater observation of migrating adults is most accurate during upstream movements (Aquatico 1976). Adult bull trout do not have a downstream avoidance reaction. Instead, they attempt to swim upstream past observers. McPhail and Murray (1979) noted holding behavior of adults at upstream barriers. They may remain there several weeks allowing ease of capture, marking and observation. Weaver and White (1985) easily captured migrating adults at night using lanterns and dipnets.

Sampling of lake individuals is best accomplished with sinking gill nets during the isothermal conditions of spring. Hanzel (1985) reported consistently higher counts were achieved using sinking nets versus floating nets in Flathead Lake. On sloping bottoms, nets should be set parallel to the shore. Steep slopes require perpendicular placement to the shore (Thompson and Tufts 1967; Leathe and Graham 1982).

ANGLING

Some authors have reported that the bull trout does not give the quality angling experience that other trout species do. However in the Flathead River System, creel surveys reveal fishermen may travel hundreds of miles to "trophy" bull trout (Aquatico 1976). A first-class fishery for these fish is also developing on the Metolius River in Oregon. Size records for bull trout in the state of Oregon have been set and reset for the past three consecutive years in this river sytem.

A variety of lures have been successful in landing the highly piscivorous bull trout. On tributaries of the Flathead River in British Columbia, large red or yellow plugs have been used (Aquatico 1976). McAfee (1966) listed deeply fished salmon eggs as the preferred choice on the McCloud River. Fish also took flies on this river. On a disjunct stream population found in Alberta, Boag (1987) discovered that an upstream population of insect-eating fish primarily took imitation insect lures. A downstream population which was more piscivorous more readily took fish lures. Lure preferences of these separated populations reflect their food habits.

On Lake Wenatchee, Thompson and Tufts (1967) used silver and brass spoons and "flatfish" plugs with a high degree of success. Graham and Fredenberg (1983) noted that large lures or plugs on monofilament line are used in the the shallow waters of Flathead Lake. During the summer months, the majority of anglers seeking trophy fish in this lake were "deep trollers" fishing in depths of 70 to 180 feet using steel lines on under downriggers (Hanzel 1986). In western Washington streams, Budd (1968) suggests that unweighted spoons drifted with the current may produce good results in landing Dolly Varden.

McAfee (1966) lists rivers and lake inlets as the best locations to catch the bull trout. In Flathead Lake, the majority of fish are caught near the mouths of rivers, which are used as migration routes during spring and late fall (Hanzel 1986). Ice fishing in winter was near these tributary mouths. On the North Fork Flathead River, the best fishing was found in July and early August in spawning tributaries when adults were still moving upstream. The fish are not feeding at this time. Aquatico (1976) assumed when the bull trout strikes a lure, it was more of an aggressive reaction than for feeding. In the Pend Oreille system the greatest fishing pressure occurs in tributaries during migration (Jeppson 1960).

Wallis (1948) reported that the fish in a stream resident population repeatedly hit offered bait until it was hooked. Because of its highly piscivorous nature and voracious food habits, the bull trout may be easily overfished. Allan (1980) concludes overharvest is possible in mixed populations of salmonids because of the selectivity of angling for bull trout. Thompson and Tufts (1967) found that trolling was highly selective for bull trout. Carl (1985) believes populations may be easily overfished in low productive waters. Boag (1987) also concludes that the differential vulnerability of the bull trout to angling may explain its decline in Alberta. Immature fish less than 5-years-old were primarily harvested in Boag's (1987) study area.

Restriction of angling on spawning tributaries was initiated in the 1950s on the Flathead River system (Fraley et al. 1981). All major tributaries are now closed to angling. An 18-inch minimum size limit has been instituted for Flathead Lake and the main river. Metolius River spawning tributaries have also been recently closed to angling (Oregon Department of Fish and Wildlife). Protective regulations are now being enforced on some eastern Cascade streams in Washington (because of low numbers and continuing numerical decline of populations (Brown 1984)). In Alberta, all spawning and rearing tributaries have been permanently closed to angling (Carl 1985).

HABITAT ALTERATION

Research has not yet been conducted on the effects of habitat improvement on juvenile bull trout rearing areas. Studies have been completed regarding use of instream structures in brook trout nursery streams (Saunders and Smith 1962; Hunt 1976). In Alaska, research has been done on modifications to Dolly Varden rearing areas showing the importance of woody debris (Cardinal 1980; Bryant 1983; Elliott 1986; Heifetz et al. 1986).

Brook trout populations have been greatly increased through the addition of overhanging bank cover and formation of pools. The increased cover resulted in overwinter survival rates two times greater than before modification (Saunders and Smith 1962; Hunt 1976). Boussu (1954) found that trout populations declined when overhanging cover was removed. Cover seeking behavior of brook trout may be a response to light (Gibson and Power 1979). However, House and Boehne (1986) concluded structure is more important than shade in setting salmonid stream carrying capacitities.

Studies of salmonid nursery areas in Alaska show detrimental impacts on Dolly Varden young when woody debris is removed (Cardinal 1980; Bryant 1983; Elliott 1986; Heifetz et al. 1986). Clearcutting to the streambank in these areas significantly decreased pool area. Cover and pool habitat reductions resulted from removal of large organic debris and the collapse of undercut banks.

In a recent study of Dolly Varden young, Elliott (1986) found an 80 percent decline in population one year after removal of logging debris. Later year-to-year population numbers ranged from zero to 100 percent of the original abundance. Aggressive encounters multiplied with the loss of cover. Larger fish showed increased emigration rates, and smaller individuals were more susceptible to high stream flows in the fall. Feeding habits also changed as the Dolly Varden juveniles switched from benthic to surface feeding.

Large woody debris and rubble substrate have been previously noted to be important requirements of bull trout rearing areas. Pratt (1984) states that capacity of these nursery streams can be improved by creating submerged cover within 0.2m of the stream bed. These instream structures create pockets of slow water, the preferred habitat of juveniles. These structures should form depressions on the bottom, not pools. If boulders or rubble are used, they need to be stacked on top of each other to create interstitial spaces. Any increase in siltation will tend to fill in these spaces and decrease potential rearing habitat.

Single pieces of woody debris may also be used. Jams or tangles must be unconsolidated, allowing through flows of water. Application of single pieces is best done along the margins of tributaries (Pratt 1985a). Rootwads or boulders form backwater areas along channel margins satisfying the specific requirements of fry (Bisson et al. 1982).

Because of the close association of bull trout and the substrate, increasing habitat size alone may not increase juvenile abundance. What is required is greater surface area of the bottom, or more protection enhancing "visual isolation," between adjacent territory holders (Pratt 1985a). Augmenting natural production with additions of hatchery stock will only be effective if sufficient rearing habitat is available (Hanzel 1985).

Logging itself is not detrimental to bull trout rearing areas. Specific management practices may enhance aspects of the physical environment. For instance, waterflow can be changed by altering canopy cover. More snow is trapped when north-facing slopes are opened. Snow melt is then prolonged. This could augment late summer flows, increasing space available in low flow areas for YOY and maintaining access for spawning adults in otherwise inaccessible channels. Peak flows would decline, as would flushing of fry during the fall (Gibbons and Salo 1973; Shepard et al. 1984b).

Bisson et al. (1982) stated that preferred habitat of juvenile salmonids may be unique for each tributary. Hence, before any habitat modification project is undertaken, microhabitats of individual fish and behavior of different species must be determined. Hartzler (1983) suggested that this information could be used to set up criteria to assess each stream's habitat. Preliminary investigations should also include the inspection of streams at high and low flows. This is done to identify juvenile rearing areas under all conditions and to note the presence of stable debris locations (House and Boehne 1985). Additionally, tagging of fish during initial sampling may be necessary for monitoring of survival and dispersal patterns (Hartzler 1983).

ARTIFICIAL PROPAGATION

The bull trout and the Dolly Varden have been successfully raised at the Sisson Hatchery Mt. Shasta, California; at the Kootenay Hatchery, British Columbia; at the Wallowa Hatchery in Oregon; at the Clark Fork Hatchery in Idaho; at Sarotoga National Fish Hatchery, Wyoming; and at the Kitoi Hatchery, Alaska (Oregon State Game and Wildlife Commission 1968-74; Oregon Department of Fish and Wildlife 1974-77; Brown 1985; Rode 1988). Attempts to rear bull trout in Montana have been unsuccessful (Montana Department of Fish, Wildlife and Parks). The Cabinet Gorge Hatchery in Idaho is currently preparing to raise 100,000 fry in 1990 (N. Horner, personal communication 1988).

Brown (1985) noted some of the main problems in propogation of bull trout are in capturing and holding adults and collecting and transferring eggs. Before ripening, adults must be handled gently to avoid stress and should be held in locations with conditions as natural as possible. At the Kootenay and Wallowa Hatcheries, males have been found to ripen three to four weeks earlier than females.

Egg sources have been difficult to obtain in Alberta, British Columbia and Oregon (Oregon State Game and Wildlife Commission 1968-74; Oregon Department of Fish and Wildlife 1974-77; McPhail and Murray 1979; Brown 1985; Carl 1985). Eggs must be handled with care during transport as they are very sensitive (McPhail and Murray 1979).

Temperature is extremely important during incubation, affecting development and size of alevins at hatch. Optimum temperatures appear to be from 2 to 5 C. Higher temperatures decrease the size and survival of alevins (McPhail and Murray 1979; Brown 1985; Weaver and White 1985). Carl (1985) suggests the low temperature requirements of the bull trout makes common incubation with other species difficult. Weaver and White (1985) reported that excessive egg contact results in the growth and spread of fungus. The use of substrates prior to hatching can increase the size of alevins.

During rearing, temperatures may be increased to 7 or 8 C (Brown 1985). In lab tests, McPhail and Murray (1979) found a lack of interaction or aggression in fry by using water without current. At three months, fish at Kootenay Hatchery were transferred to ponds with temperatures of 7 to 11 C. Above 12 C fry become susceptible to disease (Brown 1985).

Food for fry at Kootenay Hatchery was silvercup salmon starter with 10 percent beef liver for six weeks. After this, Oregon moist pellet (OMP) was used. Juveniles were also fed OMP and silvercup salmon starter. Brown (1985) concluded that bull trout YOY show preferences for certain flavors and textures.

In British Columbia, YOY were released after three to four months (Brown 1985). Transport of the bull trout must be at lower densities than other cultured fish because it uses such a small portion of the water column. Planted fish should be scattered over as wide an area as possible because these fish move very little from release points until downstream migration.

McPhail and Murray (1979) recommended utilizing electrophoresis to determine genetic differences among populations. Stream surveys of spawning and rearing areas should also be conducted. Hanzel (1985) states that increased production will result only if preferred stream habitat is available. Additional stocking in lakes may result in increased harvest of endemic fish. The use of artificial channels, or instream structures may be needed to supplement available rearing habitat if stocking is employed.

As mentioned previously, bull trout and brook trout were successfully crossed at the Sisson Hatchery in California (Rode 1988). Similar crosses were attempted between female bull trout and male brook trout at Wallowa Hatchery in Oregon, but were not successful (K. Witty, Oregon State Game and Wildlife Commission, Wallowa District Annual Report 1969).

Prior to Cavender's (1978) redescription of the bull trout, Dolly Varden eggs from Alaska were imported to the Wallowa Hatchery from the Sarotoga Hatchery in Wyoming and the Kitoi Hatchery in Alaska. Dolly Varden raised to fingerling size were released into Wallowa Lake (Oregon State Game and Wildlife Commission 1968-74; Oregon Department of Fish and Wildlife 1974-77). Dolly Varden were also stocked in Lake Pend Oreille during the 1970s (Idaho Fish and Game records). Future research should investigate the impacts of these introductions on the native bull trout populations in both drainage systems.

Transplants have been reported in some northern sections of Nevada and in the Merced River and a chain lake within Yosemite Park. (La Rivers and Trelase 1952; Wallis 1952). Whether these transplanted stocks still exist is unknown.

FUTURE RESEARCH NEEDS

A wide data gap exists regarding information on the bull trout and Dolly Varden populations in Oregon and Washington. With recent declines in distribution and abundance of the bull trout and possible future losses, this missing data is sorely needed to provide guidance to area fish biologists. The following is a composite of possible research areas.

The extent floods damage spawning and rearing habitats is unknown. The relationship of streambed composition to embryo survival needs further study to predict recruitment losses.

The amount of substrate cleansed during spawning needs verification. Without this, it is not possible to estimate survival of eggs by comparison to nearby gravel compositions. The change in fines and gravel from redd to adjacent gravels is unknown.

The optimum size for release of hatchery fry needs determination. Data on river and lake survival of different sized young is a requisite for this. Techniques need to be developed for rearing eggs and fry in different hatchery facilities.

Data on genetic variation within and between populations in Oregon and Washington is required. Reintroduction of the bull trout to the McCloud River is being proposed, as are possible transfers within Oregon. During the late 1960s and 70s, Dolly Varden (*Salvelinus malma*) eggs were imported from Alaska to the Wallowa Hatchery in Oregon and the Clark Fork Hatchery in Idaho. Eggs were raised to fingerling and legal sizes and released into Wallowa Lake and River and Lake Pend Oreille. How the native bull trout populations have been impacted by this introduction (of what is now considered a distinct species) needs to be quantified.

The survival rate of bull trout young in tributaries versus rivers needs study. The length of time spent in rivers before lake entry is also unknown. No empirical data is available on large river rearing or movement. What role the larger streams and rivers play in total recruitment productivity has not been examined. Pratt (1984) suggests the need for a long-term monitoring index for juveniles in major tributaries. Additional information needs would be to determine the reasons juveniles enter rivers in the first place. Determination of the carrying capacity of smaller tributaries is one data source called for.

An assessment of habitat components is required for maintenance of existing populations , ie. what impact do temperature, groundwater, debris cover and stream productivity play in rearing areas. Pratt (1984) recommends an instream cover classification to account for substrate size and embeddedness.

The parameters that trigger spawning have not been determined. The differences between the bull trout and the Dolly Varden spawning preferences in areas of sympatry is an area of interest (Johnson 1988). It is not known whether adult size is a function of stream size. Do larger individuals come from larger tributaries and smaller fish from smaller streams, or vice versa? Also, a question remains whether adults change spawning tributaries as they increase in size. This would be important for transfer of eggs to new runs. The question whether longevity is greater and growth is depressed in northern and southern latitudes has been proposed.

Researchers need to answer why bull trout are found in some streams and cutthroat in others. What factors are responsible for differences in their distribution? The question of whether longevity is greater and growth is depressed in northern latitudes has been proposed.

A lack of life history information and the distribution of different types (fluvial, anadromous and resident) is lacking for Oregon and Washington for both the bull trout and the Dolly Varden. Determination of what limits populations within these states is required. A lack of juvenile rearing space, overfishing during spawning and the degradation of spawning habitat have been postulated as possible factors. Quantification of these and other possible impacts is called for.

Information on the habitat preferences of juveniles is needed for these areas. Information is also needed on the affect of addition or removal of debris on rearing populations in tributaries.

It is unknown which species interact with the bull trout in Oregon and Washington. No information is available on predation of bull trout young by other salmonids. There may also be possible competition between juvenile salmonids (native to Oregon and Washington but not found in other areas where juvenile studies have been completed) and bull trout.

The impacts on bull trout populations of stocking rainbow, brook, brown and lake trout is unknown. The extent of hybridization between bull and book trout needs to be investigated. Predation studies of lake trout upon bull trout needs to be undertaken (for instance in Odell Lake in Oregon). Situations where brown trout outcompete bull trout needs to be determined, and if this competition contributes to population declines.

Interaction studies of bull trout and Dolly Varden and determination of their distribution in areas of sympatry are called for. Lastly, information is needed on what restricts the Dolly Varden to areas north of the Chehalis River, Washington.

LITERATURE CITED

Allan, J. H., 1980.
- Life history notes on the Dolly Varden charr (*Salvelinus malma*) in the upper Clearwater River, Alberta. Alberta Energy and Natural Resources, Fish and Wildlife Division, Red Deer, Alberta, Canada.

Allen, K. R., 1969.
- Limitations on the protection of salmonid populations in streams. Pages 3-20 in T.G. Northcote, editor, Salmon and trout in streams. H.R. MacMillan lectures in fisheries, University of British Columbia, Vancouver, British Columbia.

Andrusak, H. and T. G. Northcote, 1971.
- Segregation between adult cutthroat trout (*Salmo clarki*) and Dolly Varden (*Salvelinus malma*) in small coastal British Columbia lakes. J. Fish. Res. Bd. Can. 28:1259-1268.

Aquatico Environmental Consultants, 1976.
- Sage Creek coal study, draft report on fisheries of the mine site vicinity. British Columbia Fish and Wildlife Branch, Vancouver.

Armstrong, R. H. and R. F. Blackett, 1966.
- Digestion rate of Dolly Varden. J. of Fish. Biol. 27:429-430.

Armstrong, R. H. and S. T. Elliott, 1972.
- Dissemination of information collected on Dolly Varden. Alaska Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1971-1972. Project F-9-4, 13:1-34.

Armstrong, R. H. and F. Blackett, 1980.
- A brief review of the early ontogeny of the Dolly Varden charr, *Salvelinus malma*. Pages 667-675 in E. K. Balon, editor, Charrs, salmonid fishes of the genus *Salvelinus*. W. Junk Publishers, the Hague, the Netherlands.

Armstrong, R. H. and J. E. Morrow, 1980.
- The Dolly Varden charr, *Salvelinus malma*. Pages 99-140 in E.K. Balon, editor, Charrs, salmonid fishes of the genus *Salvelinus*. W. Junk Publishers, the Hague, the Netherlands.

Armstrong, R. H. and W. M. Morton, 1969.
- Revised annotated bibliography on the Dolly Varden char. Alaska Department of Fish and Game Resources, Report 7.

Bajkov, A., 1927.
- Reports of the Jasper Park Lakes investigation, 1925-26. I. The fishes. Contrib. Can. Biol. Fish. n.s. 3(16):379-404.

Balon, E. K., 1980.
- Comparative ontogeny of charrs. Pages 703-720 in E.K. Balon, editor, Charrs, salmonid fishes of the genus *Salvelinus*. W. Junk Publishers, the Hague, the Netherlands.

Bangham, R. V. and J. R. Adams, 1954.
- A survey ofthe parasites of freshwater fishes from the mainland of British Columbia. J. Fish. Res. Bd. Can. 11(6):673-708.

Behnke, R. J., 1980.
- A systematic review of the genus *Salvelinus*. Pages 441-480 in E. K. Balon, editor, Charrs, salmonid fishes of the genus *Salvelinus*. W. Junk Publishers. the Hague, the Netherlands.

Behnke, R. J., 1984.
- Organizing the diversity of the Arctic charr complex. Pages 3-21 in L. Johnson and B. L. Burns, editors, Biology of the Arctic charr, Proceedings of the International Symposium on Arctic charr, May 1981. University of Manitoba Press, Winnipeg, Manitoba.

Bisson, P. A., J. L. Nielson, R. A. Palmason, and L. E. Grove, 1982.
- A system of naming habitat types in small streams, with examples of habitat utilization by salmonids during low stream flow. Pages 62-73 in N. D. Armentrout, editor, Acquisition and utilization of aquatic habitat inventory information. Western Division, American Fisheries Society, Bethesda, Maryland.

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

Bjornn, T. C., 1971.
- Trout and salmon movements in two Idaho streams as related to temperature, food, stream flow, cover and population density. Trans. Am. Fish. Soc. 100:423-438.

Blackett, R. F., 1968.
- Spawning behavior, fecundity and early life history of anadromous Dolly Varden in southeastern Alaska. Alaska Department of Fash and Game Research Report 6.

Blackett, R. F., 1973.
- Fecundity of resident and anadromous Dolly Varden (*Salvelinus malma*) in southeastern Alaska. J. Fish. Res. Bd. Can. 30:543-548.

Block, D. G., 1955.
- Trout migration and spawning studies on the North Fork drainage of the Flathead River. M. S. Thesis, University of Montana.

Bloom, A. M., 1976.
- Evaluation of minnow traps for estimating populations of juvenile coho salmon and Dolly Varden. Prog. Fish-Cult. 38:99-101.

Boag, T. D., 1987.
- Food habits of bull charr, *Salvelinus confluentus*, and rainbow trout, *Salmo gairdneri*, coexisting in a foothills stream in northern Alberta. Can. Field-Nat. 101(1):56-62.

Bond, C. E. and J. J. Long, 1979.
- Unique fish survey, Fremont National Forest. Final report. Cooperative agreement No. 237. U.S. Forest Service Pacific Northwest Forest Range Experimental Station and Oregon State University, Corvallis, Oregon.

Boussu, M. F., 1954.
- Relationship between trout populations and cover on a small stream. J. Wild. Man. 44:871-880.

Brown, C. J., 1971.
- Fishes of Montana. Montana State University, Bozeman, Montana.

Brown, L., 1984.
- Morphological and meristic characteristics of bull trout (*Salvelinus confluentus*), commonly called Dolly Varden, inhabiting the east slopes of the Cascade Mountains in central Washington state. Draft report. Wenatchee, Washington.

Brown, P., 1985.
- Dolly Varden culture in British Columbia. Pages 62-67 in D. D. MacDonald, editor, Proceedings of the Flathead River Basin bull trout biology and population dynamics modeling information exchange. Fisheries Branch, British Columbia Ministry of Environment, Cranbrook, British Columbia.

Brunson, R. B., 1952.
- Egg counts of *Salvelinus malma* from the Clark's Fork River, Montana. Copeia 3:196-197.

Bryant, M. D., 1983.
- The role and management of woody debris in west coast salmonid nursery streams. North Amer. J. Fish. Man. 3:322-330.

Budd, W. M., 1968.
- In love with "Dolly." Northwest Salmon Trout Steelheader 1(4):32-34.

Burns, J. W., 1971.
The carrying capacity for juvenile salmonids in some Northern California streams. Calif. Fish and Game. 57:44-57.

Bustard, D. R. and D. W. Narver, 1975.
- Aspects of the winter ecology of juvenile coho salmo (*Oncorhychus kisutch*) and steelhead trout (*Salmo gairdneri*). J. Fish. Res. Bd. Can. 32:667-680.

Cardinal, P. J., 1980.
- Habitat and juvenile salmonid populations in streams in logged and unlogged areas of south-eastern Alaska. M.S. Thesis, Montana State University, Boze-man, Montana.

Carl, L., 1985.
- Management plan for bull trout in Alberta. Pages 71-80 in D.D. MacDonald, editor, Proceedings of the Flathead River Basin bull trout biology and population dynamics modeling information exchange. Fisheries Branch, British Columbia Ministry of Envi-ronment, Cranbrook, British Columbia.

Cavender, T. M., 1978.
- Taxonomy and distribution of the bull trout, *Salvelinus confluentus* (Suckley) from theAmerican Northwest. Calif. Fish and Game 3:139-174.

Cavender, T. M., 1980a.
- A systematics of *Salvelinus* from the North Pacific Basin. Pages 295-322 in E.K. Balon,editor, Charrs, salmonid fishes of the genus *Salvelinus*. W. Junk Publishers. the Hague, the Netherlands.

Cavender, T., 1980b.
- Bull trout and Dolly Varden. Pages 113-114 in D. Lee, C. Gilbert, C. Hocutt, R. Jenkins, D. McAllister and J. Stauffer, editors, Atlas of North American Freshwater Fishes. Publication No. 1980-12, North Carolina biological survey, North Carolina State University of Natural History.

Cavender, T. M., 1984.
- Cytotaxonomy of North American *Salvelinus*. Pages 431-444 in L. Johnson and B.L. Burns, editors, Biology of the Arctic charr, Proceedings of the International Symposium on Arctic charr, May 1981. University of Manitoba Press, Winnepeg, Manitoba.

Chapman, D. W., 1966.
- Food and space as regulators of salmonid populations in streams. Am. Nat. 100:345-357. Dimick, R.E. and F. Merryfield. 1945. The fishes of the Willamette River system in relation to pollution. Oregon State College Engineering Experimental Station,Bulletin Series No. 20.

Elliott, C. L., 1980.
- Dipper swallowed by trout. Wilson Bull. 92:524.

Elliott, S. T., 1986.
- Reduction of a Dolly Varden population and macrobenthos after removal of logging debris. Trans. Am. Fish. Soc. 115:392-400.

Elrod, M. J., 1930.
- The fishes of Flathead Lake. University of Montana, Missoula, Montana. Evermann, B.W. and H.W. Clark. 1931. A distributional list of the species of freshwater fishes known to occur in California. California Department of Fish and Game, Fisheries Bulletin 35.

Fraley, J., D. Read, and P. Graham, 1981.
- Flathead River fishery study. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana.

Fraley, J. J. and P. J. Graham, 1981.
- Physical habitat geologic bedrock types and trout densities in tributaries of the Flathead River Drainage, Montana. Pages 178-185 in N.B. Armantrout, editor, Acquisition and utilization of aquatic habitat inventory information. 1982. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana.

Fraley, J., 1985.
- Status of the Flathead River bull trout spawning run. Pages 25-27 in D.D. MacDonald, editor, Proceedings of the Flathead River Basin bull trout biology and population dynamics modeling information exchange. Fisheries Branch, British Columbia Ministry of Environment, Cranbrook, British Columbia.

Fraley, J. and B. Shepard, 1988.
- Life history, ecology and population status of migratory bull trout, (*Salvelinus confluentus*) in the Flathead Lake and River system, Montana. (Draft). Montana Department of Fish, Wildlife and Parks, Kalispell, Montana.

Gibbons and Salo, 1973.
- An annotated bibliography of the effects of logging on fish of the western United States and Canada. USDA Forest Service. General technical report PNW-10. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Gibson, R. J. and G. Power, 1979.
- Selection by brook trout (*Salvelinus fontinalis*) and juvenile Atlantic salmon (*Salmo salar*) of shade related to water depth. J. Fish. Res. Bd. Can. 32:1652-56.

Gould, W. R., 1987.
- Features in the early development of bull trout (*Salvelinus confluentus*). N.W. Sci. 6(4):264-268.

Graham, P., D. Read, S. Leathe, J. Miller, and K. Pratt, 1980.
- Flathead River Basin fishery study. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana.

Graham, P. J., B. B. Shepard, and J. J. Fraley, 1981.
- Use of stream habitat classifications to identify bull trout spawning areas in streams. Pages 186-192 in N. B. Armantrout, editor, Acquisition and utilization of aquatic habitat inventory information. 1982. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana.

Graham, P. and W. Fredenburg, 1983.
- Flathead Lake fisherman census. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana.

Griffith, R. P., 1979.
- The spawning and rearing habitat of Dolly Varden char and Yellowstone cutthroat trout in allopatry and sympatry with selected salmonids. British Columbia Ministry of Environment, Fish and Wildlife Branch, Victoria, British Columbia.

Hanzel, D. A., 1965.
- Survey of the cutthroat trout and Dolly Varden in the Flathead River and tributaries above Flathead Lake. Job Completion Report, Federal Aid in Fish Restoration, Project F-7-R-13. Montana Department of Fish, Game and Wildlife, Kalispell, Montana.

Hanzel, D. A., 1977.
- Seasonal area and depth distribution of cutthroat trout and Dolly Varden in Flathead Lake. Job Performance Report, Project F-33-R-11, Job I-a. Montana Department of Fish, Game and Wildlife, Kalispell, Montana.

Hanzel, D. A., 1985.
- Past and present status of bull trout in Flathead Lake. Pages 19-24, 97-98 in D.D. MacDonald, editor, Proceedings of the Flathead River Basin bull trout biology and population dynamics modeling information exchange. Fisheries Branch, British Columbia Ministry of Environment, Cranbrook, British Columbia.

Hanzel, D. A., 1986.
- Seasonal area and depth distribution of cutthroat, bull trout (Dolly Varden) and lake trout in Flathead Lake. Job Progress Report, Project No. F-33-R-20, Job I-a. 1987. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana.

Hartzler, J. R., 1983.
- The effects of half-log covers on angler harvest and standing crop of brown trout in McMichael's Creek, Pennsylvania. North Amer, J. Fish. Man. 6:52-58.

Heifetz, J., M. L. Murphy, and K. V. Koski, 1986.
- Effects of logging on winter habitat of juvenile salmonids in Alaska streams. North Amer. J. Fish. Man. 6:52-58.

Heimer, J. T., 1965.
- A supplemental Dolly Varden spawning area. Master's Thesis. University of Idaho, Moscow, Idaho.

Hesseldenz, T. F., 1981.
- Developing a long term protection plan for the McCloud River, California. Pages 784-794 in R.E. Warner and K.M. Hendrix, editors, California Riparian Systems, Ecology, Conservation and Productive Management. University of California Press.

House, R. A. and P. L. Boehne., 1985.
- Evaluation of instream enhancement structures for salmonid spawning and rearing in a coastal Oregon stream. North Amer. J. Fish. Man. 5:283-295.

House, R. A. and P. L. Boehne., 1985.
- Effects of instream structures on salmonid habitat and populations in Tobe Creek, Oregon. North Amer. J. Fish. Man. 6:38-46.

Hunt, R. L., 1976.
- A long term evaluation of trout habitat development and its relation to improving management-related research. Trans. Amer. Fish. Soc. 105:361-364.

Hunter, J. W., 1973.
- A discussion of game fish in the state of Washington as related to water requirements. Fisheries Management Divison, Washington State Department of Game.

Huston, J. E., 1974.
- Hungry Horse Reservoir study. Job Progress Report, Project F-34-R-7, Job IIa. Montana Department of Fish and Game, Kalispell, Montana.

Jeppson, P. W. and W. S. Platts., 1959.
- Ecology and control of the Columbia squawfish in northern Idaho lakes. Trans. Am. Fish. Soc. 88:197-202.

Jeppson, P. W., 1960.
- Evaluation of kokanee and trout spawning areas in Pend Oreille Lake and tributary streams. Pages 43-66 in Biological and Economic Survey of Fishery Resources in Lake Pend Oreille. Final Report, Federal Aid to Fish Restoration, Project F-3-R-20, Idaho Department of Fish and Game.

Jordan, D. S., 1907.
- The trout and salmon of the Pacific Coast. Nineteenth Biennial Report of the State Board of Fish Commissioners of the State of California for the years 1905-1906. Sacramento 1907.

Knudson, K., 1984.
- A preliminary assessment of impacts to the trout fishery -- upper Clark Fork River, Montana. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana.

La Rivers, I. and T. J. Trelease, 1952.
- An annotated checklist of the fishes of Nevada. Calif. Fish and Game. 38(1):115.

Leary, R. F., 1985.
- Electrophoretic variation within and between populations of bull trout in the upper Columbia River Drainage. Page 68 in D.D. MacDonald, editor, Proceedings of the Flathead River Basin bull trout biology and population dynamics modeling information exchange. Fisheries Branch, British Columbia Ministry of Environment, Cranbrook, British Columbia.

Leary, R. F., F. W. Allendorf, and K. L. Knudsen, 1983.
- Consistently high meristic counts in natural hybrids between brook trout and bull trout. Syst. Zool. 32(4):369-376.

Leary, R. F., F. W. Allendorf, and K. L. Knudsen, 1985.
- Developmental instability and high meristic counts in interspectific hybrids of salmonid fishes. Evolution 39(6):1318-1326.

Leathe, S. A. and P. J. Graham, 1981.
Flathead Lake fish food habits study. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana.

Leathe, S. A. and P. J. Graham, 1982.
- Flathead Lake fish food habits study, final report. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana.

Leathe, S. A. and M. D. Enk, 1985.
- Cumulative impacts of micro-hydro development on the fisheries in the Swan drainage, Montana. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana.

Leggett, J. W., 1969.
- The reproductive biology of the Dolly Varden charr *Salvelinus malma*. M.S. Thesis, University of Victoria, Victoria, British Columbia.

Leggett, J. W., 1980.
- Reproductive ecology and behavior of Dolly Varden charr in British Columbia. Pages 721-737 in E. K. Balon, editor, Charrs, salmonid fishes of the genus *Salvelinus*. W. Junk Publishers, the Hauge, the Netherlands.

Lestelle, L. C., 1978.
- The effects of forest debris removal on a population of resident cutthroat trout in a small headwater stream. M. S. Thesis, Washington State University, Pullman, Washington.

Lindsey, C. C., 1957.
- Possible effects of water diversions of fish distribution in British Columbia. J. Fish. Res. Bd. Can. 14(4):651-668.

Mallet, J., 1964.
- Biological and economic survey of fishery resources in Lake Pend Oreille. Pages 19-42 in The Lake Pend Oreille creel census and life history studies. State of Idaho Fish and Game Department.

Marnell, L. F., 1985.
- Bull trout investigations in Glacier National Park, Montana. Pages 33-35 in D.D. MacDonald, editor, Proceedings of the Flathead River Basin bull trout biology and population dynamics modeling information exchange. Fisheries Branch, British Columbia Ministry of Environment, Cranbrook, British Columbia.

Martin, A., 1985.
- Reproduction of bull trout. Pages 99-101 in D.D. MacDonald, editor, Proceedings of the Flathead River Basin bull trout biology and population dynamics modeling information exchange. Fisheries Branch, British Columbia Ministry of Environment, Cranbrook, British Columbia.

May, B., J. Huston, and S. McMullin, 1979.
- Lake Koocanusa post-impoundment fisheries study. Completion Report. Montana Department of Fish and Game, Kalispell, Montana.

May, B. and C. Huston, 1983.
- Fisheries investigation, Kootenai River investigations. Final report. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana.

McAfee, W. R., 1966.
- Dolly Varden trout. Pages 271-274 in A. Calhoun, editor, Inland Fisheries Management. California Department of Fish and Game, Sacramento, California.

McCart, P., 1985.
- Parallels between life histories of bull trout and far northern fish species. Page 65 in D. D. MacDonald, editor, Proceedings of the Flathead River Basin bull trout biology and population dynamics modeling infromation exchange. Fisheries Branch, British Columbia Ministry of Environment, Cranbrook, British Columbia.

McPhail, J. D., 1961.
- A systematic study of the *Salvelinus alpinus* complex in North America. J. Fish. Res. Bd. Can. 18(5):793-816.

McPhail, J. D. and C. Murray, 1979.
- The early life historyand ecology of Dolly Varden (*Salvelinus malma*) in the upper Arrow Lakes. Report to the British Columbia Hydro and Power Authority and Kootenay Department of Fish and Wildlife.

Miller, R. B., 1949.
- Preliminary biological surveys of Alberta watersheds, 1947-1949. Alberta Department of Lands and Forests.

Miller, R. R. and W. M. Morton, 1952.
- First record of the Dolly Varden *Salvelinus malma* from Nevada. Copeia, 3:207-208.

Morton, W. M., 1970.
- On the validity of all subspecific descriptions of North American *Salvelinus malma* (Walbaum). Copeia, 1970 (3):581-587.

Morton, W. M., 1980.
- Goodbye Dolly. Fisheries 5(3):17-21.

Moyle, P. B., 1976.
- Inland Fishes of California. University of California Press.

Needham, P. R. and T. M. Vaughan, 1952.
Spawning of the Dolly Varden, *Salvelinus malma*, in Twin Creek, Idaho. Copeia, 3:197-199.

Nelson, J. S., 1965.
- Effects of fish introductions and hydroelectric development on fisheries in the Kananaskis River system, Alberta. J. Fish. Res. Bd. Can. 22(3):721-753.

Newman, M. A., 1960.
- A comparative study of the residential behavior of juvenile salmonids. University of British Columbia, Vancouver, British Columbia.

Oliver, G., 1979.
- A final report on the present fisheries use of the Wigwam River with an emphasis on the migratory life history and spawning behavior of Dolly Varden char, *Salvelinus malma* (Walbaum). Fisheries investigations in tributaries of the Canadian portion of Libby Reservoirs. British Columbia Fish and Wildlife Branch, Victoria, British Columbia.

Oregon State Game Commission, 1949-1970.
- Annual report. Fishery division.

Oregon State Wildlife Commission, 1971-1974.
- Annual report. Fishery division.

Oregon State Dept. of Fish and Wildlife, 1975-1979.
- Annual report. Fishery division.

Paetz, M. J. and J. S. Nelson, 1970.
- The fishes of Alberta. The Queens's Printer, Edmonton, Alberta.

Peters, D., 1985.
- Current status of bull trout in the headwaters of the Clark Fork River, Montana. Page 37 in D. D. MacDonald, editor, Proceedings of the Flathead River Basin bull trout biology and population dynamics modeling information exchange. Fisheries Branch, British Columbia Ministry of Environment, Cranbrook, British Columbia.

Phillips, R. W. and K. V. Koski, 1969.
- A fry trap method for estimating salmonid survival from egg deposition to fry emergence. J. Fish. Res. Bd. Can. 26:133-141.

Pratt, K. P., 1984.
- Habitat use and species interactions of juvenile cutthroat (*Salmo clarki lewisi*) and bull trout (*Salvelinus confluentus*) in the upper Flathead River Basin. M.S. Thesis. University of Idaho, Moscow, Idaho.

Pratt, K., 1985a.
- Habitat preferences of juvenile bull trout in the Flathead River Basin. Pages 16-17, 93-94 in D. D. McDonald, editor, Proceedings of the Flathead River Basin bull trout biology and population dynamics modeling information exchange. Fisheries Branch, British Columbia Ministry of Environment, Cranbrook, British Columbia.

Pratt, K., 1985b.
- Pend Orielle trout and char life history study. Idaho Department of Fish and Game.

Ptolemy, 1979.
- Production and carrying capacity relative to the design of a rearing channel for rainbow trout on Hill Creek near Galena Bay, West Kootenay. British Columbia Ministry of Environment, Fish and Wildlife Branch, Victoria, British Columbia.

Ratliff, D., 1987.
- Bull trout spawning report, Metolius River tributaries 1987. Portland General Electric, Portland, Oregon.

Reiman, B. D. and J. R. Lukens, 1979.
- Lake and reservoir investigations: Priest Lake creel census. Job Completion Report, Project No. F-73-R-1, Subproject III, Study I, Job I. Idaho Department of Fish and Game. Boise, Idaho.

Rode, M., 1988.
- Bull trout, *Salvelinus confluentus* (Suckley), in the McCloud River, status and recovery recommendations (draft). Inland Fishing Administration Report, California Department of Fish and Game.

Rostlund, E., 1951.
- Three early historical reports of North American freshwater fish. Copeia, 4:295-296.

Saunders, J. W. and M. W. Smith, 1962.
- Physical alteration of stream habitat to improve brook trout production. Trans. Am. Fish. Soc. 91:185-188.

Schutz, D. C. and T. G. Northcote, 1972.
- An experimental study of feeding behavior and interaction of coastal cutthroat trout (*Salmo clarki clarki*) and Dolly Varden *Salvelinus malma*). J. Fish. Res. Bd. Can. 29:555-565.

Schultz, L. P. and A. P. Delacey, 1935.
- Fishes of the American Northwest. Part 1. Catalog of the fishes of Washington and Oregon with distributional records. Pan-Pacific Research Institute. Mid-Pacific Magazine, 10(4):365-380.

Scott, W. B. and E. J. Crossman, 1973.
- Freshwater fishes of Canada. J. Fish. Res. Bd. Can., Bulletin 184. Shaw, J.N. 1947. Some parasites of Oregon wildlife. Agricultural Experiment Station Technical Bulletin no. 11, Oregon State University, Corvallis, Oregon.

Shebley, W. H., 1931.
- Trout lives nineteen years. Calif.Fish and Game 17(4):441.

Shepard, B., F. Fraley, T. Weaver, and P. Graham, 1982a.
- Flathead River fisheries study. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana.

Shepard, B. and P. Graham, 1982b.
- Monitoring spawning bed material used by bull trout on the Glacier View district, Flathead National Forest. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana.

Shepard, B. and P. Graham, 1983a.
- Coal Beetle salvage fisheries monitoring study. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana.

Shepard, B. and P. Graham, 1983b.
- Flathead River fisheries study. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana.

Shepard, B. S. Leathe, T. Weaver, and M. Enk, 1984a.
- Monitoring levels of fine sediment within tributaries to Flathead Lake and impacts of fine sediment on bul trout recruitment. Proceedings of the Wild Trout III Symposium. Mammoth Hot Springs, Yellowstone National Park, Wyoming. Sept. 24-25, 1984.

Shepard, B., K. Pratt, and J. Graham, 1984b.
- Life histories of westslope cutthroat and bull trout in the upper Flathead River Basin, Montana. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana.

Shepard, B., 1985.
- Habitat variables related to bull trout spawning site selection and thermal preferenceexhibited in a thermal gradient. Page 18 in D. D. McDonald, editor, Proceedings of the Flathead River Basin bull trout biology and population dynamics modeling information exchange. Fisheries Branch, British Columbia Ministry of Environment, Cranbrook, British Columbia.

Stuart, K. M. and G. R. Chrislett, 1979.
- Aspects of the life history of Arctic grayling in the Sukunka drainage. Unpublished manuscript. British Columbia Fish and Wildlife Branch, Nelson, British Columbia.

Thompson, R. B. and D. F. Tufts, 1967.
- Predation by the Dolly Varden and northern squawfish on hatchery-reared sockeye salmon in Lake Wenatchee, Washington. Trans. Am. Fish. Soc., 96(4):424-427.

Tredger, D., 1979.
- An evaluation of fish habitat and fish populations in Toboggan Creek near Smithers, relevant to steelhead enhancement opportunities. British Columbia Ministry of Environment, Fish and Wildlife Branch, Victoria, British Columbia.

Wales, J. H., 1939.
- General report of investigations on the McCloud River Drainage in 1938. Calif. Dept. Fish and Game 25(4):272-309.

Wallis, O. L., 1948.
- Trout studies and a stream survey of Crater Lake National Park. M.S. Thesis. Oregon State University, Corvallis, Oregon.

Wallis, O. L., 1952.
- Yosemite trout investigations, 1951-52. Comprehensive review of trout fishery problems of Yosemite National Park. U.S. National Park Service.

Weaver, T. M., 1985.
- Bull trout incubation. Pages 93-94 in D. D. MacDonald, editor, Proceedings of the Flathead River Basin bull trout biology and population dynamics modeling information exchange. Fisheries Branch, British Columbia Ministry of Environment, Cranbrook, British Columbia.

Weaver, T. M. and R. G. White, 1985.
- Coal Creek fisheries monitoring study no. III. Final Report. Montana Cooperative Fisheries Research Unit, Bozeman, Montana.

Wydoski, R. S. and R. R. Whiting, 1979.
- Inland fishes of Washington. University of Washington Press, Seattle, Washington.