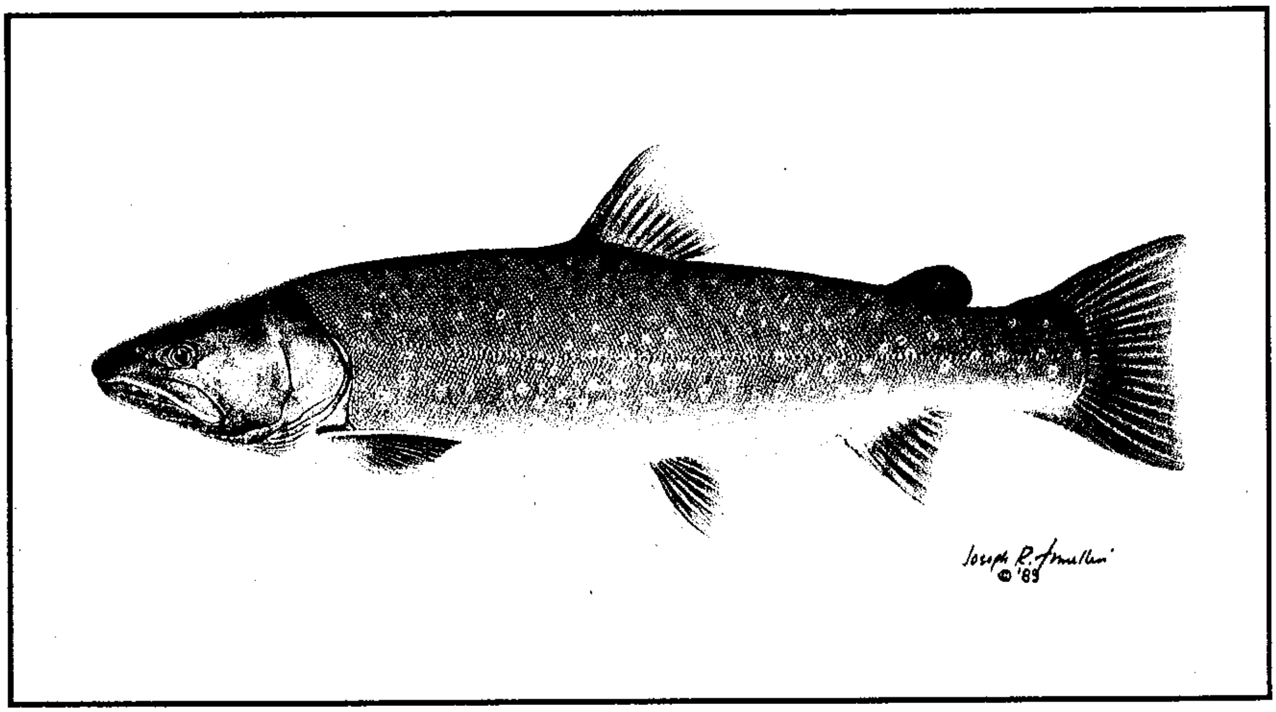
Proceedings

of the

Gearhart Mountain

Bull Trout Workshop



Oregon Chapter
American Fisheries Society

Proceedings of the Gearhart Mountain Bull Trout Workshop

Edited by

Philip J. Howell

David V. Buchanan

Judith M. Maule

Associate Editor

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Oregon Chapter
American Fisheries Society
P.O. Box 722
Corvallis, OR 97339

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Proceedings of the Gearhart Mountain Bull Trout Workshop

INTRODUCTION

Forty-five fisheries professionals gathered on a cold and rainy August afternoon (where else but Oregon) near the Gearhart Mountain Wilderness in 1989 (Figure 1). They were there to discuss bull trout *Salvelinus confluentus* and to survey bull trout streams at a workshop sponsored by the Natural Production Committee of the Oregon Chapter of the American Fisheries Society (AFS), Oregon Department of Fish and Wildlife (ODFW), and the *Salvelinus confluentus* Curiosity Society instigated by Del Skeesick, U.S. Forest Service (USFS). Those attending included biologists from 4 states and the following 11 agencies and companies: Oregon State University, ODFW, USFS, Washington Department of Wildlife, U.S. Fish and Wildlife Service, California Department of Fish and Game, Crater Lake National Park, Klamath Tribe, Eugene Water and Electric Board, Pacific Power and Light, Portland General Electric (PGE). An independent consultant, a fish artist, and a photographer and writer also participated.

Seven papers from the workshop are included in this proceedings. They have been revised and updated to include more recent information. The papers by Bond and by Pratt provide some general background on the species. Studies of specific populations are included for the Metolius River; Malheur River; and Sprague River and Sun Creek, both of which are in the Klamath Basin. Doug Markle discusses hybridization of bull trout and brook trout *S. fontinalis*, a serious threat to maintaining bull trout populations. A paper by Ratliff and Howell not originally presented at the workshop was added to provide on overview of the status of bull trout populations throughout Oregon.

Attitudes toward bull trout have changed dramatically since the late 1970s when the species was formally recognized as distinct from Dolly Varden *S. malma*, which it has been commonly called. Formerly, fishery managers and the public considered bull trout primarily as a predator of salmon and trout. Anglers would frequently toss them on the bank, and fishery managers generally had little concern for them and in some cases tried to exterminate them. A growing number of biologists and a much smaller percentage of the public are beginning to recognize that bull trout is a species in trouble.

AFS has classified bull trout as a species of special concern due to present or threatened destruction, modification, or curtailment of its habitat and other natural or anthropogenic factors affecting its continued existence, such as hybridizations, introduction of exotic or transplanted species, predation, and competition (Williams et al. 1989). The Oregon Department of Fish and Wildlife has listed bull trout as a sensitive/critical species. They are a Category 2 species or candidate species under the federal Endangered Species Act (ESA). This designation means that further information is needed to determine the appropriateness of listing them as threatened or endangered. The Oregon Chapter of AFS and fishery biologists from agencies and private companies have responded to this alert in part with these proceedings.

AFS is a scientific and professional organization that consists of biologists, resource managers, and private citizens. Two of its major functions are gathering and disseminating fisheries information and developing public policies to conserve aquatic resources. As Paul Brouha (1991), AFS Executive Director, recently stated, "If AFS members don't advocate the restoration of fish habitats and depleted species, we are, by our silence, advocating their loss." Through AFS-sponsored events such as the Gearhart Mountain Bull Trout Workshop, fishery biologists are able to transcend private, agency, and company boundaries, openly exchange information, and unite for the common cause of resource protection and restoration.

Extinction and Reintroduction--The California Experience

The geological record reminds us that species extinction is not a recent phenomenon. It is the rapidly accelerating rate of occurrence during this century, primarily as a result of human activities, that is a cause for deep concern. The natural background rate of extinction during the past 600 million years is near the order of one species per year (Raup and Sepkoski 1984). Today the world extinction rate may be over 1,000 species per year (Myers 1988). Ehrlich (1988) reminds us that "the loss of genetically distinct populations within species is, at the moment, at least as important a problem as the loss of entire species. Once a species is reduced to a remnant, ...its total extinction in the relatively near future becomes much more likely." In a report from a genetics study of bull trout in the Columbia and Klamath river basins, Leary et al. (1991) state that maintaining the genetic diversity of bull trout will require the continued existence of many populations throughout the region because of the substantial genetic differences among populations and the low genetic diversity within individual populations.

The recent extinction of bull trout in California and that state's reintroduction efforts point out the difficulties of losing populations. The recovery plan was outlined by Mike Rode of the California Department of Fish and Game at the Gearhart Workshop.

Bull trout were historically found in the McCloud River, a 60-mile long tributary of the Sacramento River. The last reported capture of an adult bull trout there was in 1975. Several factors contributed to the extinction of bull trout in the McCloud River: the construction of McCloud and Shasta dams, introduction of brook trout *S. fontinalis* and brown trout *Salmo trutta*, and overharvest by anglers (Rode 1990).

In 1980 California designated bull trout of the McCloud River as an endangered species and developed a recovery plan. The plan included reintroduction of bull trout into Huckleberry and Mud creeks, tributaries of the McCloud River. The streams were poisoned with rotenone to remove the exotic fish species present. Fish barriers were then installed in both tributaries to prevent their reinvasion.

The objective of the reintroduction program was to produce a self-sustaining resident population similar to populations found in Oregon's Klamath Basin. In the summer of 1989 approximately 60 small adults from Deming, Brownsworth, and Leonard creeks were captured for broodstock. Unfortunately, heavy mortality occurred at the hatchery. Only 270 fingerling bull trout were ultimately produced and transferred to California in 1990 for release The cooperative program between California and Oregon was terminated late that year because of the small size of the bull trout populations in the Klamath Basin. Whether such a limited release of juveniles can reestablish bull trout in California remains to be seen, but it seems doubtful.

Coyote Creek--A Troubled Stream

Coyote Creek, one of the streams surveyed during the bull trout workshop, exemplifies the situation faced by a number of bull trout populations in Oregon. In 1987 a single adult bull trout was observed in lower Coyote Creek, a tributary of the Sycan Marsh. Subsequently, biologists thoroughly sampled the 7 miles of Coyote Creek in 1989 and 1990. The samples included more than 120 brook trout, 1 rainbow trout, 1 brook trout x bull trout hybrid, and no bull trout. Ratliff and Howell (1992) categorized the bull trout population in Coyote Creek as having a high risk of extinction.

Both the riparian areas along Coyote Creek and its uplands have been heavily grazed by livestock. Excessive fine sediment and an absence of spawning gravel was documented in the lower and middle sections of Coyote Creek. A plugged culvert that created a barrier to spawning habitat upstream was first documented by fishery biologists from the Gearhart Workshop in 1989. Introduced brook trout appear to have almost totally displaced both native bull trout and rainbow trout.

Recovery and Rehabilitation--Some Cautious Optimism

Chief Seattle in 1854 predicted, "If all the beasts were gone men would die from great loneliness of spirit, for whatever happens to the beast also happens to man." While many of Oregon's bull trout populations are at risk, we are optimistic, albeit somewhat naive, that we can maintain the healthy populations, recover some of the depressed populations, and perhaps even reintroduce bull trout in a few of the suitable areas where they are now extinct. The current status of populations in Oregon indicates that this will not occur, however, unless the management of bull trout and their habitats are substantially changed. Protection of existing populations from further declines should be the first priority. Once a population becomes severely depressed, recovery becomes much more difficult, expensive, and uncertain, as evidenced by the McCloud River reintroduction program. Some populations will never recover where the capacities of those ecosystems have been drastically altered.

There are some promising bright spots on the horizon. A cooperative project to restore bull trout in the Metolius River involving PGE, ODFW, USFS, and the Confederated Tribes of the Warm Springs Reservation was begun in 1985. Bull trout redd counts in that system have steadily increased from 27 in 1986 to 149 in 1989 (Ratliff 1992).

Recovery efforts for the northern spotted owl *Strix occidentalis* are shifting from a single species focus to an ecosystem conservation approach. Recent recovery proposals include consideration of bull trout and other species associated with similar habitat. While there is currently only minor overlap in bull trout and spotted owl distribution, this type of approach has the most potential for remedying the complexity of problems facing bull trout and a large mix of other species.

David V. Buchanan and Philip J. Howell
Oregon Department of Fish and Wildlife
850 SW 15th Street
Corvallis, OR 97333

FIGURE 1. Participants in the Gearhart Mountain bull trout workshop.

Kneeling: Warren Griffen, Crater Lake National Park (CLNP); Jeff Ziller, Oregon Department of Fish and Wildlife (ODFW); Joe Tomelleri, Artist; Mike Faler, U.S. Forest Service (USFS); Dave Buchanan, ODFW; Ken Wieman, USFS; Bob Phillips, USFS/ODFW Retired; Don Ratliff, Portland General Electric, Mary Hanson, ODFW; Del Skeesick, USFS; Karen Pratt, Independent Consultant; Rich Nawa, Oregon State University (OSU); Jeff Dambacher, CLNP/ODFW.

Standing: Thom Johnson, Washington Department of Wildlife; Marv Yoshinaka, U.S. Fish and Wildlife Service; Fred Goetz, USFS/OSU; Linda Prendergast, Pacific Power and Light (PP&L); Tom Walker, USFS; Al Hemmingsen, ODFW; Dan Bottom, ODFW; unknown; Tom Cain, USFS; Mike Rode, California Department of Fish and Game (CDFG); Bob Buckman, ODFW; Joel Waldo, CDFG; Frank Shrier, PP&L; Debbie Urich, USFS; unknown; Bob Hooton, ODFW; Carl Bond, OSU Retired; Lenora Bond, OSU Retired; Doug Markle, OSU; Amy Stewart, ODFW; Phil Howell, ODFW; Rod French, ODFW; Todd Pearsons, OSU.

Attended but not in picture: John Fortune, ODFW; Lee Hillwig, USFS; Jake Conn, Klamath Tribe; Lisa Borgerson, ODFW; Dale Hagey, Eugene Water and Electric Board; Leslie Smith, ODFW; John Bragg, Photographer and writer; Chris Riley, USFS; Brian Platz, USFS.

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Notes on the Nomenclature and Distribution of the Bull Trout and the Effects of Human Activity on the Species

CARL E. BOND
Department of Fisheries and Wildlife
Oregon State University
Corvallis, OR 97331

Abstract. -- After having been described under several different names, the bull trout was in the synonymy of the Dolly Varden until its identity and the name *Salvelinus confluentus* were resurrected by Cavender in 1978. It can be distinguished from the Dolly Varden *S. malma* by several characters, including head size and shape, number of mandibular pores, and others. The bull trout probably reached its maximum distribution during and after the most recent glacial advance but later became confined to the colder streams within its range. Warming of waters, introductions of competing cold-water species, and many human activities are reducing the range and population sizes within the remaining range.

Taxonomy

In the genus *Salvelinus* there are complexes of species that resemble each other morphologically to the extent that ichthyologists have had extreme difficulty in establishing reliable distinguishing characteristics for them. At least 45 different scientific names have been applied to North American chars (Jordan et al. 1930), but now most systematists seem to recognize only five species (Phillips et al. 1989; Robins et al. 1991). There is still difficulty in recognizing northern and southern Dolly Varden *S. malma* and various strains of the Arctic char *S. alpinus* (Morrow 1980), and some still think that various populations of the latter in eastern North America deserve specific status. However, current knowledge sets the bull trout *S. confluentus* well apart, even though there are similarities between it and the Dolly Varden.

Spotting and number of scales, gill rakers and fin-rays are all similar, and small specimens of the two species tend to look alike. This may have led the ichthyologists of the 1880s, who did not have the habit of looking at large numbers of specimens, to consider bull trout and Dolly Varden as the same species. In the 1930s, check lists added the subspecific name *spectabilis* for the bull trout (Jordan et al. 1930). The bull trout had been given at least seven scientific names during the 1800s (Cavender 1978). A partial synonymy of the species follows:

Salmo spectabilis -- Girard 1856. Proc. Acad. Nat. Sci. Philad. 8:217-222.

Salmo confluentus -- Suckley 1858. Ann. Lyc. Nat. Hist. 7:1-10.

Salmo bairdii -- Suckley 1861. Ann. Lyc. Nat. Hist. 7:306-313.

Salmo parkei -- Suckley 1861. Ann. Lyc. Nat. Hist. 7:306-313.

Salmo campbelli -- Suckley 1861. Ann. Lyc. Nat. Hist. 7:306-313.

Salvelinus malma -- (in part) Jordan and Gilbert 1882. U.S. Nat. Mus. Bull. 16:1018 p.

Salvelinus malma spectabilis -- Jordan, Evermann and Clark 1930. U.S. Comm. Fish., Rept.,(1928):1-670

Salvelinus confluentus -- Cavender 1978. Calif. Fish and Game 64(3):139-174.

The species was formerly known by the common name western charr (*sic*) over part of its range (Evermann 1898), but bull trout appears to have had wider use. Other common names included Oregon charr (*sic*), redspotted trout, and golet (Jordan et al. 1930). In the 1970s Cavender examined specimens of Dolly Varden and bull trout from their entire ranges and defined the two species, resurrecting the name *Salvelinus confluentus* and using the common name bull trout, an action adopted by the American Fisheries Society (Cavender 1978; Robins et al. 1980).

In addition to having differing ranges, adult sizes, and degree of devotion to anadromy (depending on the prevailing climatic conditions), there are numerous morphological differences between the two species (Table 1). Haas (1988) developed a linear discriminant function to distinguish bull trout and Dolly Varden

TABLE 1. -- Morphometric and meristic characteristics of bull trout and Dolly Varden (based largely on Cavender 1978).

Characteristic	Bull trout	Dolly Varden
Head	More than 25% of standard length Wide Flat between the eyes	Less than 25% of standard length Narrow
Eye placement	Near upper profile of head	About 1/4 to 1/3 of head depth down from upper profile
Mouth	Large Maxillary curved along its length and extending well beyond eye Strong protuberance at tip of lower jaw, fitting into deep notch between premaxillaries	Shorter Maxillary straight
Mandibular pores (total)	Usually 14-17	Usually 11-13
Branchiostegals	12-16	9-12
Gill Rakers	Oval in cross-section and robust Set with many teeth Strongly ridged on edges, with teeth on edges strong Mean = 18	Flat Tips long and tapering Weakly ridged with no teeth on edges Mean = 16.6
Vertebrae	Mean = 66.6	Mean = 64.8
Supraethmoid	More than twice as long as broad No anterior constriction	Twice as long as broad Constriction of about 1/3 of the distance from the front of the bone
Adipose fin	Origin over posterior 1/3 of anal fin; does not extend beyond vertical line from end of depressed anal fin	Origin over insertion of anal fin; usually extends beyond vertical line from end of depressed anal fin

based on number of branchiostegals and anal fin rays, maxillary length, and standard length. He has refined that function with a larger sample size (Haas and McPhail 1991).

Distribution

Much insight into the character and requirements of the bull trout can be gained by considering the present geographical distribution as compared to the historical and probable prehistorical distributions. The western distribution of the species extends in a discontinuous pattern from about 41^0 N lat. to 60^0 N lat. -- from the McCloud River, where it may be recently extinct, to the headwaters of the Yukon. The range includes Puget Sound and various coastal rivers of British Columbia and southeastern Alaska. It holds out in parts of the Klamath drainage, is scattered through the Columbia system from the Willamette River to the headwaters in Montana and Canada, is isolated in Wood River of Idaho, and reaches Nevada in the Jarbridge River. Cavender (1978) believes it could have reached the Bonneville basin in pluvial times. It has managed to move from the Columbia to the Arctic and Hudson Bay drainages (McPhail and Lindsey 1970).

The inference is that the bull trout is a fish of cold waters, is maintaining itself in suitable habitat in the south, and is extending its range to the north. Cavender and others suggest that the species originated in the Columbia system and has extended and constricted its range according to climatic changes, extending mainly through headwater transfers, crossovers, and captures (Behnke 1972; McPhail and Lindsey 1970; chapters 3, 15, 16, 17 in Hocutt and Wiley 1986). In order for species to cross divides in the headwaters, it follows that they must use the main streams as access to the upper reaches. In colder times, which really weren't so long ago, the bull trout must have occupied even the lowland streams in this area and has been forced to headwaters and spring-fed sections by the warming climate.

Although anadromy does not seem to be an important part of the life of the bull trout at the present time, I believe it cannot be ruled out as a mechanism for coastal distribution. Given enough time and enough frigid weather on the coast, movement from stream to stream during feeding forays to the ocean could certainly occur. Entry to salt water is common in chars in cold climates. The brook trout *S. fontinalis* is anadromous in the northern part of its range, and the lake trout *S. namaycush* enters coastal waters in the Arctic (Hubbs and Lagler 1958).

Effects of Human Activities

Many people have speculated on the impacts that civilization has had on the distribution and abundance of the bull trout. Wales (1939) recognized climate as an important factor in the apparent reduction of the range of this "colorful remnant of a vanishing species" but referred also to angling and introductions of other species as possible factors. Nelson (1965) referred to introductions of brown trout *Salmo trutta* and possibly non-native suckers *Catostomus* spp. as factors in the decline of bull trout in the Bow River but thought that construction of reservoirs that blocked migrations and inundated spawning areas could have had effects. Moyle (1976) also suggests that dam construction and introduction of brown trout were factors contributing to the decline of bull trout in the McCloud River.

In the Pacific Northwest introduction of eastern brook trout with subsequent hybridization (Cavender 1978; Markle 1992) and possible competition certainly has had some effect, judging from some of the distribution patterns seen in studies in the Klamath Basin (Wallis 1948; Long and Bond 1979). There is at least one record of deliberate hybridization in the 1890s at a California hatchery (Evermann and Clark 1931).

More direct action may have had effects on the bull trout. A number of general works, including McAfee (1966), Dymond (1932), and Needham (1938) mention the low regard in which the bull trout (obviously included in remarks on the Dolly Varden) was held by anglers and fishery managers because of its reputed poor fighting qualities and piscivorous habits. Needham remarks that stocking of Dolly Varden (*sensu lato*) did "more harm than good." Brown (1971) tells of efforts to eradicate the species by means that included a commercial fishery with nets. In some areas angling regulations did little to protect the species and bounties were used as a management device (Simpson and Wallace 1978). Disturbance of watersheds and actual damage to streams may have direct or indirect effects on the species. For instance, a U. S. Forest Service employee, who worked during the 1920s and 1930s in the Middle Fork Willamette area and fished for "dollies" there, inferred that the species declined after logging and log drives down the stream (Bert Clark, personal communication, 1940)

There is always the possibility that anything that causes any deterioration, however slight, of the habitat of a species at the edge of its ecological or geographic range could contribute to the decline of that species. Probably the bull trout is affected by the insidious effects of uncounted natural and unnatural factors that each change the habitat so slightly that we do not notice the alteration, but the biota does. We may have to await another ice age for rehabilitation of some of the areas.

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A Review of Bull Trout Life History

KAREN L. PRATT
Independent Consultant
3653 Rickenbacker Road, Suite 214
Boise, Idaho 83705

Abstract. -- Literature related to the life history of primarily adfluvial bull trout *Salvelinus confluentus* was reviewed. Bull trout spawn in late summer through fall (August to November), often in areas with ground water infiltration. Cryptic fry emerge early in spring (April). For the first two years of life, most juveniles remain near the stream bottom in pockets of slow water created by objects in swift stream reaches. Unembedded substrate and dispersed woody debris are commonly used forms of cover. Small bull trout feed primarily on aquatic insects until they are about 110 mm, typically at the end of their second growing season. Most juveniles migrate at the beginning of the third growing season. They may or may not move directly into a lake. Growth in a lake is rapid. Bull trout usually mature at age 5 or 6. Adult migration begins early in the spring (March or April) may extend through the entire spring and summer. Most fish are in the spawning streams by August. Some adults will spawn more than once during their lifetime, but they may not spawn each year.

Introduction

Cavender (1978) described the taxonomic characteristics of bull trout *Salvelinus confluentus*. The American Fisheries Society accepted the species distinction of bull trout and Dolly Varden *S. malma* in 1980. Bull trout are primarily an inland char distributed in the Pacific Northwest and Intermountain West of the United States and in Canada. Information concerning the biology of bull trout is principally found in agency documents from northwestern Montana and southern British Columbia. This paper reviews life history information for bull trout populations and closely allied species, Arctic char *S. alpinus* and Dolly Varden.

Most of the literature available is based on adfluvial populations (i.e., fish that migrate between streams where they spawn and lakes or reservoirs) in the Intermountain West. Information on fluvial populations (i.e., fish that migrate between smaller streams used for spawning and larger rivers) is identified and added where available. Adfluvial individuals may attain large sizes (8-38 pounds) as adults. Applying habitat use, growth rates, and habits of these large fish to fluvial and particularly to resident populations in other areas may not be valid.

Much of the data presented here was previously summarized by Shepard et al. (1984) and Goetz (1989). This document does not present the tabular comparisons of data found in those documents.

Embryonic Development

Egg survival varies with water temperature. McPhail and Murray (1979) compared egg survival and water temperature and reported 0-20, 60-90, and 80-95 percent of the eggs survived to hatching in water temperatures of 8-10, 6, and 2-4°C, respectively.

Bull trout required approximately 350-440 temperature units (°C) after fertilization to hatch (Weaver and White 1984; Gould 1987). This was similar to the incubation period for Dolly Varden (380 temperature units) (Armstrong and Blackett 1980). Embryos require fewer temperature units to develop as incubation temperatures decline (Weaver and White 1985). Hatching is completed after 100-145 days, usually at the end of January (Heimer 1965; Blackett 1968; McPhail and Murray 1979; Allan 1980; Weaver and White 1984). Anadromous Dolly Varden and bull trout alevins required at least 65-90 days after hatching to absorb their yolk sacs. Gould (1987) reports a total of 820 temperature units between egg fertilization and yolk sac absorption.

Bull trout remain within the interstices of the stream bed as fry for up to three weeks before filling their air bladders (McPhail and Murray 1979). Parr marks develop and feeding begins while fry are still in the gravel. Bull trout reached lengths of 25-28 mm before emerging from the stream bed approximately in April and filling their air bladders.

Weaver and White (1985) demonstrated a negative relationship between the proportion of fine substrate and emergence success. Approximately 40, 20, and 1 percent of the fertilized bull trout eggs survived to hatch in laboratory channels with a spawning substrate containing 20, 30, and 40 percent material less than or equal to 9.5 mm in diameter, respectively. Weaver and White (1985) also developed an equation from field data relating embryo survival and emergence to substrate composition. Laboratory tests indicated survival rates in gravels with more than 30% fines were lower than those documented in the field. Weaver (Montana Department of Fish, Wildlife and Parks, personal communication, 1989) suspects that ground water or stream bed recharge present in the field sites was responsible for higher survival to emergence in the field.

Juvenile Life History

Distribution and Habitat

Water temperature may be an important feature of juvenile bull trout habitat. Cool water temperatures during the early life history of bull trout result in higher egg survival, faster fry growth rates, and possibly faster juvenile growth rates (McPhail & Murray 1979; Shepard et al. 1984). The distribution of bull trout in a basin has also been associated with water temperatures (Pratt 1984). Jensen (1981) discusses temperatures over 14°C as thermal barriers to distribution of the closely related arctic char.

Juvenile bull trout are closely associated with the stream bed and may exhibit fixed-site territoriality. Small bull trout are found immediately above, on, or within the stream bed (Pratt 1984; Oliver 1979; Griffith 1979). Turning over stream bed material was often the only way to locate small bull trout (Pratt 1984; Shepard et al. 1984). The mean distance above the stream bed increased slightly with fish size (30 mm above the streambed for fish less than 100 mm; 80 mm above the streambed for fish 100-200 mm) but still implies association with the stream bottom (Pratt 1984). The bottom-dwelling habit of bull trout has also been described in hatchery situations (Brown 1985).

Along the stream bottom, juvenile bull trout use small pockets of slow water (0-0.1 m/s) near high velocity, food-bearing water (Pratt 1984; Shepard et al. 1984). These small pockets of water are usually created by objects that provide cover, visual isolation, and a velocity break. The highest observed densities of juvenile bull trout in the Flathead River basin were in stream reachs dominated by gravel or cobble substrate (Shepard et al. 1984). Juvenile bull trout densities decline as the spaces between the substrate fill with fine materials (Enk 1985). Where unembedded substrate is not available, woody debris, turbulence and undercut banks seem to be critical cover components (Cardinal 1980; Pratt 1984; Don Ratliff, Portland General Electric, personal communication, 1989). This is consistent with the use of woody debris reported for juvenile Dolly Varden, a closely related char. Cardinal (1980) reported increasing numbers of juvenile Dolly Varden in Alaskan streams with the addition of logging debris. Similarly, Elliott (1986) observed a reduction in Dolly Varden populations after removal of woody debris.

Food Habits

Bull trout less than 110 mm feed on aquatic insects (Shepard et al. 1984). *Ephemeroptera* and *Diptera* were the most abundant aquatic insects in benthic samples and the most common food item in bull trout stomachs. Juvenile bull trout greater than 110 mm feed on fish and aquatic insects (Horner 1978; Shepard et al. 1984). Fish identified in juvenile bull trout stomachs include sculpins, salmon fry, and other bull trout.

Boag (1987) infers food habits of fluvial bull trout varied with location within a river basin. Aquatic insects dominate bull trout diets in the upper reaches of an Alberta stream, while bull trout downstream were more piscivorous. His observations are consistent with the increased piscivory in adfluvial populations; larger, older fish prey more on fish as they move downstream into larger waters.

Sub-adult bull trout captured in the Flathead River were frequently found in areas of high densities of yearling whitefish. Shepard et el. (1984) suggest whitefish may be an important food item of bull trout in the Flathead River. Similar relationships between chars and their prey influence the feeding migrations of Dolly Varden and arctic char (McBride 1980; Armstrong 1984; Dempson and Kristofferson 1987).

Growth

Length frequency data provide clear divisions of annual growth of juvenile bull trout from adfluvial stocks sampled from the Flathead River basin. Juvenile bull trout were approximately 50-70 mm at age 1, 100-120 mm at age 2, and 150-170 mm at age 3. Growth differed between tributaries in the North and Middle forks of the Flathead. Bull trout growth rate was slower in the Middle Fork, despite higher productivity and warmer water temperatures (Shepard et al. 1984). Although this seems inconsistent with trout culture, McPhail and Murray (1979) also found that bull trout fry grew to larger sizes at lower temperatures and grew largest at 4°C.

Migration

Juvenile bull trout migrate from natal streams to larger rivers or lakes throughout their range. In the Flathead, Pend Oreille, and Priest River basins, juvenile bull trout migrate downstream to a large lake (Shepard et al. 1984; Pratt 1985; Bjornn 1987) Oliver (1979) reports similar bull trout migration patterns in river basins. Allan (1980) describes a fluvial population in an Alberta river system.

Juvenile bull trout migrated from upper Flathead River tributaries primarily at age 2 (49%), with smaller percentages emigrating at age 1 or 3 (18 and 32%, respectively). Juvenile bull trout in Idaho and British Columbia also migrate from rearing areas in tributaries into larger lakes at age 1, 2, and 3 (Bjornn 1957; Oliver 1979; McPhail and Murray 1979). Oliver (1979) found that juveniles in Ram Creek, a small tributary to Wigwam River, in the Kootenay River drainage, British Columbia, migrated at age 1 and 2 (primarily age 2), while juveniles migrated from the Wigwam River primarily at age 2 and 3.

Juvenile bull trout may migrate during spring, summer, and fall from natal areas. Shepard et al. (1984) notes migration as early as May and continuing through the middle of July. Oliver (1979) reported that juvenile bull trout migrated continuously throughout the summer and fall in the Wigwam drainage, British Columbia. Using circumstantial evidence, McPhail and Murray (1979) suggested two migration periods for juvenile bull trout: (1) a spring migration of newly emerged fry, and (2) a fall migration of larger age 1+ and 2+ juveniles.

The rate of juvenile bull trout migration is not well documented. Shepard et al. (1984) speculate most juvenile migrants move quickly downstream along the stream margin to the main stem Flathead River or Flathead Lake. Juvenile bull trout may inhabit the partially regulated portion of the river throughout the year before moving into Flathead Lake.

Adult Life History

Food Habits and Distribution

Bull trout in lakes feed primarily on fish (Bjornn 1957; Jeppson and Platts 1959; Rieman and Lukens 1979; Shepard et al. 1984). Sculpins *Cottus* spp. were the principal prey of small bull trout (<300 mm) in Flathead Lake (Shepard et al. 1984). Larger fish consume whitefish *Prosopium williamsoni*, yellow perch *Perca flavescens*, kokanee *Oncorhynchus nerka*, and mysids (Bjornn 1957; Jeppson and Platts 1959; Rieman and Lukens 1979; Shepard et al. 1984).

Bull trout distribution in lakes seems to be related to water temperature. The vertical distribution of bull trout in the summer gill net catch corresponded with water less than 15°C in both Flathead Lake and Libby Reservoir (Shepard et al. 1984; Shepard 1985). As a thermocline develops in a lake, shoreline feeding declines and bull trout move into deeper, cooler waters.

Prey availability may also influence summer distribution of bull trout in lakes. However, during the fall bull trout continued eating whitefish even though other species were more abundant at the depth and temperature zone inhabited by bull trout (Shepard et al. 1984).

Migration

Migration into the main stem Flathead River from Flathead Lake begins in April and peaks during the high flows of May and June (Shepard et al. 1984). Bull trout spawners move upriver slowly, arriving at the North and Middle Forks in late June or July. Spawners enter the tributary streams from late July through September; the majority enter the tributaries in August. In the tributaries they hold in areas of cover (deep pools, log jams, undercut banks, etc.). Adult bull trout migrate primarily during the night in tributaries of the Flathead River, and tributaries to the Upper Arrow Lakes (McPhail and Murray 1979). After spawning, adults moved out of the tributaries and back down to the lower river and lake. Adult bull trout may begin to feed during their migration back down to the lake.

There are few comparative descriptions of bull trout spawning migration, and it may be less well-defined than the description above implies. For example, in the Flathead basin a spawner tagged in a tributary of the North Fork moved downstream, then upstream into the Middle Fork, through another large lake and was recaptured in a tributary to Lake McDonald. In the Pend Oreille system, large adult bull trout, assumed to be adfluvial fish, were found in a perennial reach of a stream upstream of intermittent areas. In these areas adfluvial bull trout must have migrated into spawning areas during the spring and early summer while a water corridor was present.

Arctic char and Dolly Varden migration patterns, even within a single basin, are complex and variable. Several migrations may occur within a single year and discrete stocks mingle during feeding and spawning migrations (Armstrong 1984; Gyselman 1984).

Spawning

Bull trout in the Intermountain West spawn in the fall, primarily in September and October (Heimer 1965; Leggett 1969; Oliver 1979; McPhail and Murray 1979; Shepard et al. 1984). The onset of spawning occurs as early as August in Oregon (Don Ratliff, Portland General Electric, personal communication, 1989). Water temperatures may influence the onset of spawning (Shepard et al. 1984; Weaver and White 1985). Water temperatures less than 9°C are reported for the spawning period of anadromous Dolly Varden and landlocked bull trout populations (Needham and Vaughan 1952; Blackett 1968; Leggett 1969; McPhail and Murray 1979; Shepard et al. 1984; Weaver and White 1985).

Typically bull trout spawn in large streams at sites with groundwater infiltration, particularly springs (Heimer 1965; Allan 1980; Shepard et al. 1984; Pratt 1985; Don Ratliff, Portland General Electric, personal communication, 1989). Aggrading areas of streams are also used. Where aggraded areas were intermittent, bull trout used pockets of suitable substrate in high gradient streams (Pratt 1985).The substrate is typically loosely compacted gravel and cobble (McPhail and Murray 1979; Shepard et al. 1984).

Descriptions of spawning sites have also included habitat unit, water depth and water velocity (Shepard et al. 1984). Runs or tails of pools with water 0.2-0.8 m deep may be used for spawning . Water velocities associated with redds were 0.2-0.6 m/s. Eggs are buried 100-200 mm in the gravel.

Adfluvial spawners average 440-600 mm (range = 300-875 mm) and are 4-9 years old in watersheds in the Intermountain West (Shepard et al. 1984; Pratt 1985). A portion of the spawning population are precocious males in the Flathead and Pend Oreille drainages (Shepard et al. 1984; Pratt 1985). Allan (1980) recorded the presence of bull trout that matured in their natal tributaries in the Clearwater River drainage, Alberta.

Detailed descriptions of bull trout spawning behavior are available (Needham and Vaughan 1952; Block 1955; Blackett 1968; Leggett 1969; McPhail and Murray 1979; Allan 1980). Generally, the female selected the spawning site and the male defended it. It is possible that spawning pairs form during the migration upstream (McPhail and Murray 1979). Bull trout seem to move upstream in tributary streams as pairs in MacKenzie Creek, British Columbia, and in the Flathead basin, Montana (McPhail and Murray 1979; Shepard et al. 1984).

Repeat and alternate year spawning occurs (Shepard et al. 1984). Allan (1980) reported that 27 percent of the adult bull trout tagged in Timber Creek, Alberta returned to spawn the following year.

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The Status of Bull Trout Populations in Oregon

DONALD E. RATLIFF
Portland General Electric Company
P. O. Box 710, Madras, Oregon 97741

PHILIP J. HOWELL
Oregon Department of Fish and Wildlife
850 SW 15th, Corvallis, Oregon 97333

Abstract. -- The range of bull trout *Salvelinus confluentus* in Oregon has been reduced to primarily the upper reaches of tributaries to the Columbia, Snake, and Klamath rivers. A total of 65 bull trout populations in 13 basins were classified into five categories of population viability based on an evaluation of information on abundance and factors limiting the population: 9 populations have a "low risk of extinction"; 13 are "of special concern"; 19 face a "moderate risk of extinction"; 12 a "high risk of extinction"; 12 are "probably extinct." Because of their requirements for pristine conditions, bull trout are particularly sensitive to habitat degradation. Other factors responsible for the decline or loss of bull trout populations include passage problems; interactions with other species, particularly hybridization and competition with introduced brook trout *S. fontinalis*; rotenone treatment projects; overharvest; and climate change.

Introduction

Bull trout *Salvelinus confluentus* are currently listed as a Category 2 candidate species under the federal Endangered Species Act. That designation means that further information is needed to determine the appropriateness of listing it as threatened or endangered. The Oregon Department of Fish and Wildlife (ODFW) has classified bull trout as a sensitive/critical species, for which listing may be appropriate if immediate conservation actions are not taken. Bull trout are also classified as a sensitive species in Region 6 (Oregon and Washington) of the U.S. Forest Service (USFS) and as a species of special concern by the American Fisheries Society (Williams et al. 1989).

Until recently little specific information on the status or biology of bull trout in Oregon was available. During the past several years there has been a concerted effort to find out more about this species. Since 1990 ODFW stream inventory crews have been documenting bull trout distribution and relative abundance. More intensive studies have been undertaken in the Metolius River system (e.g., Ratliff 1992) and by Fred Goetz (1989; unpublished) and others presented in this volume (Howell and Buchanan 1992).

This study provides a current assessment of the status of existing and extinct bull trout populations in Oregon and the factors that have reduced those populations.

Bull Trout Life History

In order to understand the status of Oregon bull trout populations and the factors affecting them, it is important to have a basic understanding of bull trout life history characteristics and habitat requirements. Adults usually spawn in late summer and early fall in the coldest headwater tributaries of a river system (Pratt 1992; Ratlifff 1992). Most of these are spring creeks and higher elevation streams fed by snowmelt and deep aquifers probably because these streams have enough flow in late summer for upstream migration of adults and low temperatures (<10°C) required for spawning, incubation, and rearing (McPhail and Murray 1979; Weaver and White 1985). In many of these streams bull trout are the only fish present.

Although some bull trout may spend their entire lives as residents in small streams, others migrate as juveniles downstream to larger waters, where they become more piscivorous and grow more rapidly. Fish that move downstream into a larger river are termed "fluvial"; those moving into a large lake or reservoir are termed "adfluvial". At age 4-6, most migratory bull trout mature and move back upstream to spawn. The upstream migration may vary from a short distance to many kilometers depending on the areas of the system used by adults.

The requirements of bull trout for very cold water, high quality habitat, and unrestricted interbasin migrations make them a valuable barometer of ecosystem integrity and health.

Methods

Information on the various populations in Oregon and the factors limiting those populations was obtained from biologists with the ODFW, the USFS, Indian tribes, Portland General Electric, and the Bureau of Land Management (BLM) and from stream surveys.

The populations identified in the various basins were considered to be reproductively isolated primarily on the basis of geographic separation of spawning/juvenile rearing areas, even if migrating adults from different populations mix in the lower reaches of a river system. Some populations are isolated by dams that prevent mixing and are thus artificially distinct (e.g., upper McKenzie River). In some cases distinct breeding populations may have been inadvertently lumped especially where spawning and rearing areas are currently poorly defined (e.g., North Fork John Day River). Almost no specific information on the range of breeding bull trout populations in Oregon is available. A recent genetics study of bull trout populations in the Columbia and Klamath basins (Leary et al. 1991), which included samples from the Metolius, John Day, Grande Ronde, Malheur, and Sprague River basins in Oregon, found that there was little genetic variation within them and substantial genetic differences among them. This suggests that there may be little interbreeding and genetic exchange among bull trout populations. Studies from other areas report mixed findings regarding homing of bull trout (McPhail and Murray 1979; Armstrong and Morrow 1980; Fraley et al. 1981). As we learn more about bull trout distribution in Oregon, more distinct populations will likely be identified.

Populations were placed in one of five status categories ranging from low risk of extinction to probably extinct. The status of each population was subjectively determined on the basis of relative abundance; the severity of factors suppressing the population, such as habitat conditions and the presence of brook trout; and the potential of the population to recover to a healthy condition (Table 1). The status categories are similar to those used by Nehlsen et al. (1991) for Pacific salmon stocks. It is hoped that with additional surveys bull trout will be located in areas where populations are listed as "probably extinct." These populations were also included to show where reintroductions after correction of problems may be possible.

The information presented was developed in consultation with and reviewed by the area biologists; however, the authors claim sole responsible for the contents of this paper. Because of the limited information available, we recognize that these results are not definitive but reflect the current knowledge concerning these populations. We hope that this paper stimulates increased attention toward improvement of the knowledge base for revising these determinations.

Results and Discussion

A total of 65 bull trout populations in 13 basins in Oregon were identified (Table 2, Figure 1) in the following categories:

Status Category	Number	Percentage
Low Risk of Extinction	9	14
Of Special Concern	13	20
Moderate Risk of Extinction	19	29
High Risk of Extinction	12	18
Probably Extinct	12	18

Two-thirds of the populations are considered to have at least a moderate risk of extinction. Surveys during 1990-91 failed to locate any pure bull trout in 4 of the 12 populations at high risk of extinction. The basins that have the most precarious populations are the Willamette, Hood, Klamath, and Powder rivers. Most of the healthiest populations are in northeastern Oregon.

TABLE 1.-- Bull trout status criteria.

Category	Abundance	Habitat[a]	Brook trout	Recovery potential
Low risk of extinction	High ↑	Excellent ↑	None ↑	--
Of special concern	↕	↕	↕	Very good ↑
Moderate risk of extinction	↕	↕	↕	↕
High risk of extinction	↓ Very low	↓ Poor	↓ High	↓ Major effort required
Probably extinct	No reports since 1980	--	--	--

[a] Present and projected

TABLE 2.--Status of bull trout populations in Oregon by river basin.

Basin	Subbasin / Population	Status	Supressing factors *a*	Available information *b*
Willamette River				
	M.F. Willamette R.	High Risk	CT,HD,BT,OH	1*c*,2*d*,3
	McKenzie R.			
	S.F. McKenzie R.	Moderate Risk	OH,PB,HD	1,2,3
	Anderson Cr.	Moderate Risk	OH,BT,PB,HD	1,3,4
	Trailbridge Reservoir	High Risk	PB,BT,OH	1,3,4
	Carmen Reservoir	Probably Extinct	PB,OH,BT	1,3
	Santiam R.			
	North Santiam R.	Probably Extinct	OH,BT,PB	2,3
	South Santiam R.	Probably Extinct	OH,BT	2,3
	Clackamas R.	Probably Extinct	OH,BT,PB	1*c*,2,3
Hood River				
	Middle Fork Hood R.			
	Clear Branch	High Risk	PB,DL,OH,HD	1,2
	West Fork Hood R.	Probably Extinct	OH,HD	1,2
Klamath River				
	Sprague R.			
	Boulder and Dixon crs.	High Risk	HD	1
	Deming Cr.	Moderate Risk	HD,PB	1
	Brownsworth Cr.	Moderate Risk	HD	1
	Leonard Cr.	Moderate Risk	HD	1
	Sycan R.			
	Long Cr.	Moderate Risk	BT,HD	1
	Coyote Cr.	High Risk	BT,HD	1*c*
	Upper Sycan R.	Probably Extinct	BT,HD	1
	Seven Mile Cr.	Probably Extinct	BT,HD	1
	Upper Klamath Lake			
	Cherry Cr.	High Risk	BT,HD	1*c*
	Sun Cr.	High Risk	BT,HD	1,4
Deschutes River				
	Odell Lake	High Risk	HD,OH,BT	1,3,5
	Upper Deschutes R.	Probably Extinct	PB,CT,BT,OH	2,3
	Crescent Lake	Probably Extinct	BT,OH,PB	3
	Metolius R.	Low Risk	OH,BT,HD	1,3,4
	Shitike Cr.	Low Risk	HD	1,2
	Warm Springs R.	Moderate Risk	HD,BT	1,2

TABLE 2.--Continued

Basin	Subbasin / Population	Status	Supressing factors *a*	Available information *b*
John Day River				
	Upper John Day R.	Moderate Risk	HD,BT	1,2,3
	Middle Fork			
	Upper Middle Fork	Probably Extinct	HD	1,2
	Granite Boulder Cr.	High Risk	HD	1,2
	Big Cr.	High Risk	HD	1,2
	North Fork	Of Special Concern	HD,OH	1,2,3,4
Umatilla River				
	North Fork Umitilla R.	Low Risk	-------	1
	South Fork Umitilla R.	Of Special Concern	HD	1,5
Walla Walla River				
	North Fork Walla Walla R.	Of Special Concern	HD	1,5
	South Fork Walla Walla R.	Low Risk	-------	1
	Mill Cr.	Low Risk	PB	1
Malheur River				
	North Fork Malheur R.	Of Special Concern	HD,DL,CT	1,4
	Middle Fork Malheur R.	High Risk	HD,DL,BT	1,4
Burnt River		Probably Extinct	BT,HD,PB	1,2
Powder River				
	Upper Powder R.			
	Silver Cr.	Moderate Risk	BT,HD	1
	Little Cracker Cr.	Moderate Risk	BT,HD	1
	Lake Cr.	Moderate Risk	BT,HD	1
	North Powder R.			
	Indian and Anthony crs.	Moderate Risk	BT,HD	1
	Eagle Cr.	High Risk	BT,HD,OH	1*c*
Pine Creek				
	North Pine Creek			
	Elk Cr.	Moderate Risk	BT,HD	1
	East Pine Cr.	Of Special Concern	HD	1
	Meadow Cr.	Moderate Risk	BT,HD	1
	Middle Fork Pine Cr.	Of Special Concern	HD	1
Grande Ronde River				
	Upper Grande Ronde R.			
	Clear Cr.	Moderate Risk	HD *e*	1,5
	Limberjim Cr.	Moderate Risk	HD *e*	1,5
	Indiana Cr.	Moderate Risk	HD	1

TABLE 2.--Continued

Basin	Subbasin / Population	Status	Supressing factors *a*	Available information *b*
	Catherine Cr.	Of Special Concern	HD	1
	Indian Cr.	Moderate Risk	HD	1
	Lookingglass Cr.	Of Special Concern	HD,PB	1,2
	Minam R.	Low Risk	-------	2
	Little Minam R.	Low Risk	-------	1
	Wallowa R.			
	Lostine R.	Moderate Risk	OH,BT,HD	1,2,3
	Bear Cr.	Of Special Concern	BT,HD	1,2
	Hurricane Cr.	Of Special Concern	BT,HD,PB	1
	Wallowa Lake	Probably Extinct	PB,OH *f*	3
	Wenaha R.	Low Risk	-------	2
Imnaha River				
	Imnaha R.	Low Risk	OH	1,2,3
	Big Sheep Cr.	Of Special Concern	PB,DL,HD	1,2
	Little Sheep Cr.	Of Special Concern	PB,DL,HD	1,2
	McCully Cr.	Of Special Concern	PB,DL	1,4

a Supressing factors include: passage barriers (PB), downstream losses (DL) of migrants, habitat degradation (HD), overharvest (OH), hybridization and competition with brook trout (BT), and chemical treatment projects (CT).

b Available information includes: (1) recent inventory, (2) anecdotal reports and habitat quality, (3) creel surveys, (4) research and management studies, (5) inference based on habitat conditions.

c Sampling efforts during 1990-91 failed to locate any bull trout.

d Two bull trout reported captured and released by knowledgeable anglers from Hills Creek Reservoir during 1990.

e Habitat degradation downstream

f Bull trout were intentionally trapped and eliminated from Wallowa Lake during the late 1930s and early 1940s.

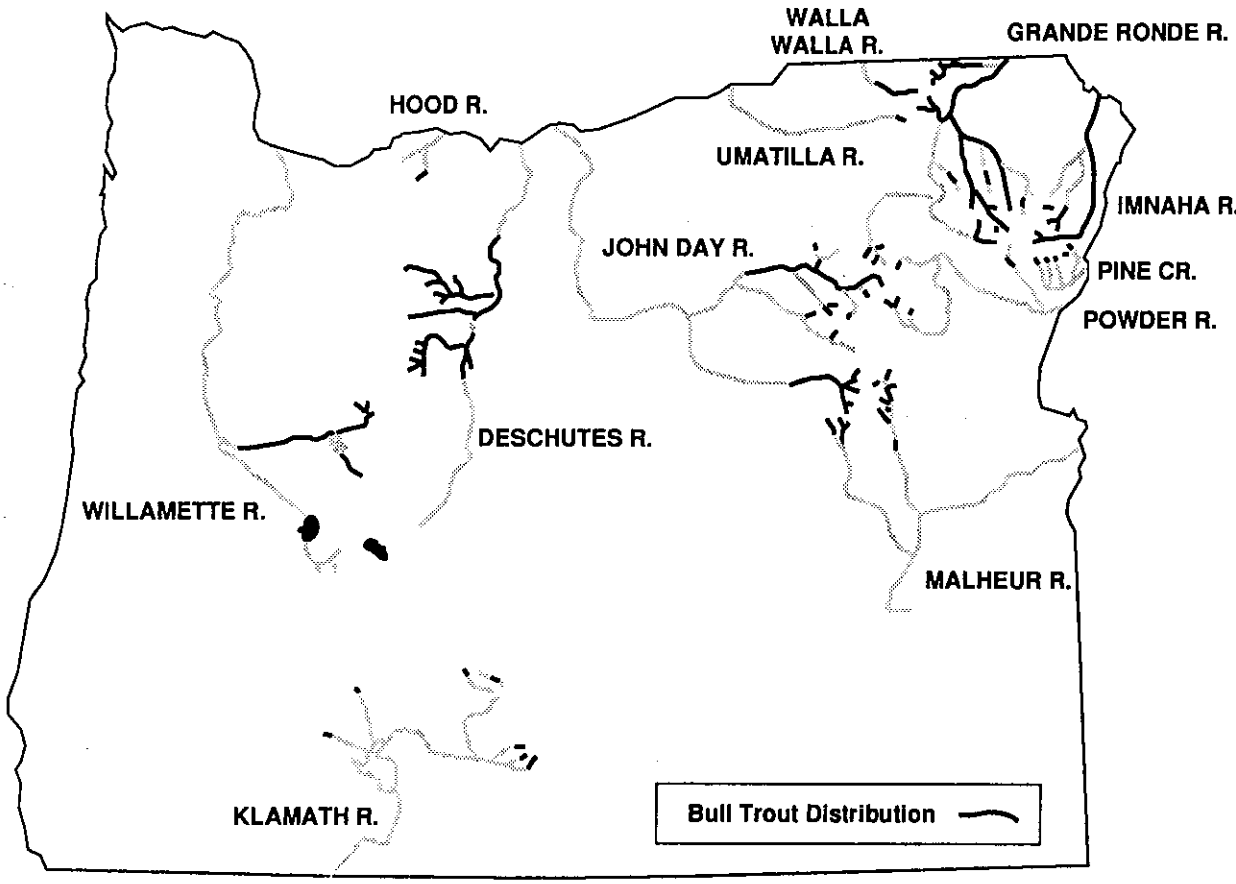

FIGURE 1.-- Bull trout distribution in Oregon.

The following factors have reduced and in some cases eliminated bull trout populations:

Habitat Degradation - Removal of riparian vegetation alters bull trout habitat in a number of ways, including reducing recruitment of woody debris and opening the canopy. Instream woody debris may be an important habitat feature for bull trout of all ages (Oliver 1979; Shepard et al. 1984a; Elliott 1986; Goetz 1989; Buckman et al. 1992). Opening the canopy increases solar radiation and can warm the stream above the temperature requirements of bull trout. Increased temperatures may increase competition with more temperature-tolerant species, such as rainbow trout *Oncorhynchus mykiss*, brook trout *S. fontinalis*, and brown trout *Salmo trutta*. Water withdrawals can also increase stream temperatures and reduce flows and available habitat. Removal of vegetation and roadbuilding in upland areas can alter runoff/infiltration and flow patterns and increase sedimentation (Bottom et al. 1985). Siltation of gravel reduces egg and fry survival (Shepard et al. 1984b). Effects of siltation in streams that are predominantly spring-fed are long-lasting because of they lack flushing flows that occur in more flashy, run-off streams. Habitat degradation of many main stem reaches make them unsuitable for juvenile migrants and adults.

Passage Barriers - Artificial barriers, such as dams, can block or substantially delay upstream migration of adults to spawning areas. Barriers also isolate populations and prevent genetic exchange that may contribute to the genetic diversity within the population. The location of a barrier relative to the spawning and juvenile rearing habitat is important. The closer the barrier is to the spawning area, the larger the percentage of the population impacted. Thus, a small dam with no upstream passage, relatively high in a system, will have a much larger impact than a high-head dam low in a system. A reservoir low in a system can increase production if it creates more productive adfluvial habitat (e.g., Metolius River/Lake Billy Chinook).

Downstream Losses - Some downstream migrating juvenile bull trout are lost to unscreened diversions and, in a few cases, to passage through dams.

Overharvest - Bull trout are aggressive by nature and readily take lures or bait, making them very susceptible to angling. Streams in the Willamette, Hood, Klamath, Malheur, Powder, and Pine Creek basins and the Metolius River are now closed to bull trout harvest, and the daily limit on bull trout was recently reduced to 1 fish in Lake Billy Chinook and to 2 fish in John Day, Umatilla, Walla Walla, Grande Ronde, and Imnaha basins.

Hybridization and Competition with Brook Trout - Introduced brook trout pose a serious threat to bull trout populations through hybridization (Leary et al. 1991; Markle 1992) and competition (Wallis 1948; Peters 1985). Brook trout mature at a younger age and are quite prolific compared to bull trout. Frequent production of sterile hybrids creates an unstable situation leading to the displacement of bull trout (Leary et al. 1991), especially when combined with other limiting factors, such as habitat degradation. In the Klamath Basin, for example, bull trout no longer occur in Sevenmile Creek and the upper Sycan River, where brook trout are now present (Table 2). In recent surveys of Coyote and Cherry creeks the only form of bull trout found was 1 hybrid in each streams. Brook trout are the major threat to the bull trout population in Sun Creek (Dambacher et al. 1992). In Long Creek a natural barrier that separates a portion of the bull trout population from the brook trout below has probably prevented the resident bull trout above the barrier from being displaced.

Interactions with Other Species - As previously suggested, habitat alterations of bull trout areas have favored other species. Brown trout have been introduced in some bull trout streams (e.g., Metolius River, Sprague River). As a piscivore, bull trout may also have been adversely affected by declines in prey species. For example, in the Powder, Burnt, Malheur, and Pine Creek systems above Hells Canyon Dam, where most populations are depressed, there is no longer any salmon and steelhead production.

Chemical Rehabilitation Projects - During the 1950s and 1960s, a number of Oregon streams were chemically treated with rotenone to remove fish thought to compete with or prey on game fish. Most of those treatments impacting bull trout populations were done to stop "rough fish" infestation of new reservoirs following dam construction. There was little concern at that time for bull trout, which were mainly considered to be predators of trout and salmon.

Climate Change - Oregon is near the southern fringe of bull trout distribution. Only an isolated population in the headwaters of the Jarbridge River in Nevada occurs further south. The population in the upper McCloud River in California is now extinct (Rode 1990). McPhail and Lindsey (1986) suggest that, as a species adapted to cool water, bull trout may be a remnant of preglacial cold water fish fauna. The reduction of bull trout in the southern portion of its range has been caused at least in part by the loss of cold water habitat following the retreat of glaciers and snowfields since the Late Pleistocene (Cavender 1978). This situation has been aggravated by human-caused habitat alteration. Global warming may further dim the prospects for bull trout.

As a result of these factors, populations have become largely fragmented and isolated in the upper reaches of the drainages. Although we have little information on migratory behavior of Oregon populations, it appears on the basis of the numbers and small sizes of fish sampled and reported that many of the populations are resident. The lower reaches of streams, which would be used by migratory fish are the portions of the drainages that in many cases have been altered the most by direct development as well as cumulative impacts from areas upstream.

Fragmentation and isolation can exacerbate problems of declining populations. Lack of genetic exchange between populations coupled with low population levels result in little genetic variation within the population. This, in turn, can lead to an inbreeding depression, further lowering productivity of the population.

The loss of fluvial and adfluvial life histories is a major concern for bull trout conservation. These larger fish have greater reproductive potential because of their increased fecundity and are probably less likely to hybridize with the smaller brook trout in spawning areas. Large bull trout also have considerable angling potential. A trophy bull trout fishery has developed in the Metolius River/Lake Billy Chinook system since that migratory population has been rebuilding.

Acknowledgements

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Distribution and Relative Abundance of Bull Trout in the Sprague River Subbasin, Oregon

JEFFREY S. ZILLER
Oregon Department of Fish and Wildlife
3150 E. Main Street, Springfield, Oregon 97478

Abstract. -- Populations of bull trout *Salvelinus confluentus* were studied in five tributaries of the Sprague River in the Klamath Basin to determine upper and lower distribution limits, changes in distribution and relative abundance since 1979, species richness in streams that contain bull trout, and key habitat parameters. Deming, Leonard, and Brownsworth creeks had small populations of bull trout (321, 207, and 240 fish per km, respectively) in a total of approximately 12 km of available stream habitat, similar to levels found in 1979. The population in Boulder Creek has declined to critically low levels (109 fish per km) in only 2.0 km of the stream. Long Creek bull trout populations were not completely assessed; however, cohabitation and hybridization with brook trout *S. fontinalis* were documented. Bull trout populations in all five streams appeared to be primarily resident and vulnerable to extirpation.

Introduction

Bull trout *Salvelinus confluentus* were first reported from the Klamath Basin by E. D. Cope (1879). Bull trout were collected in the Sprague River subbasin by Oregon Department of Fish and Wildlife (ODFW) personnel in the 1960s, but the data were not published (J. D. Fortune, ODFW, personal communication, January 1990). Surveys conducted by Long and Bond (1979) identified most of the streams that contained bull trout in the Sprague River subbasin and provided a rough estimate of relative abundance. They found bull trout in five streams in the subbasin: Boulder, Brownsworth, Deming, Leonard, and Long creeks. During 1987 one bull trout was found in Coyote Creek (Dave Buchanan, ODFW, personal communication, January 1990). These streams contain the only known populations of bull trout in the Sprague River subbasin.

This study was conducted as part of the 1989 bull trout workshop sponsored by the Oregon Chapter of the American Fisheries Society and ODFW. It was designed to obtain information about the status of these bull trout populations and, ultimately, to assist resource managers in conserving bull trout and their habitat. The objectives were to 1) determine the upper and lower distribution limits and estimate the size of bull trout populations in the Sprague River subbasin; 2) determine if changes in distribution and relative abundance of bull trout have occurred since 1979; 3) determine species richness and distribution in subbasin streams that contain bull trout; and 4) compare relative abundance of bull trout with key habitat parameters for three geographically similar streams

Study Area

The Sprague River drains approximately 1,600 square miles of land into the Williamson River near Chiloquin, Oregon. Our study was restricted to four tributaries of the North Fork and South Fork of the Sprague River near the Gearhart Wilderness Area and Long Creek, a western tributary to the Sycan River (Figure 1).

The headwaters of these streams begin flowing at an elevation of between 2,130 and 2,270 meters and have relatively steep gradients (5-20%) and cold (4-12°C) water.

Methods

Five streams in which bull trout had been found by Long and Bond (1979) were selected: Boulder, Brownsworth, Deming, Leonard, and Long creeks. Four crews of three to seven workshop participants sampled approximately 30 meters of stream in each of 33 sections, 0.4 km long. Fish were sampled using backpack electrofishing units of various makes. Smith-Root gas or battery powered electrofishing units were used most commonly. Generally, one thorough pass was made in each 30 meter section in an attempt to capture most of the fish present. Block nets were not used at the upper and lower ends; however, because the streams were

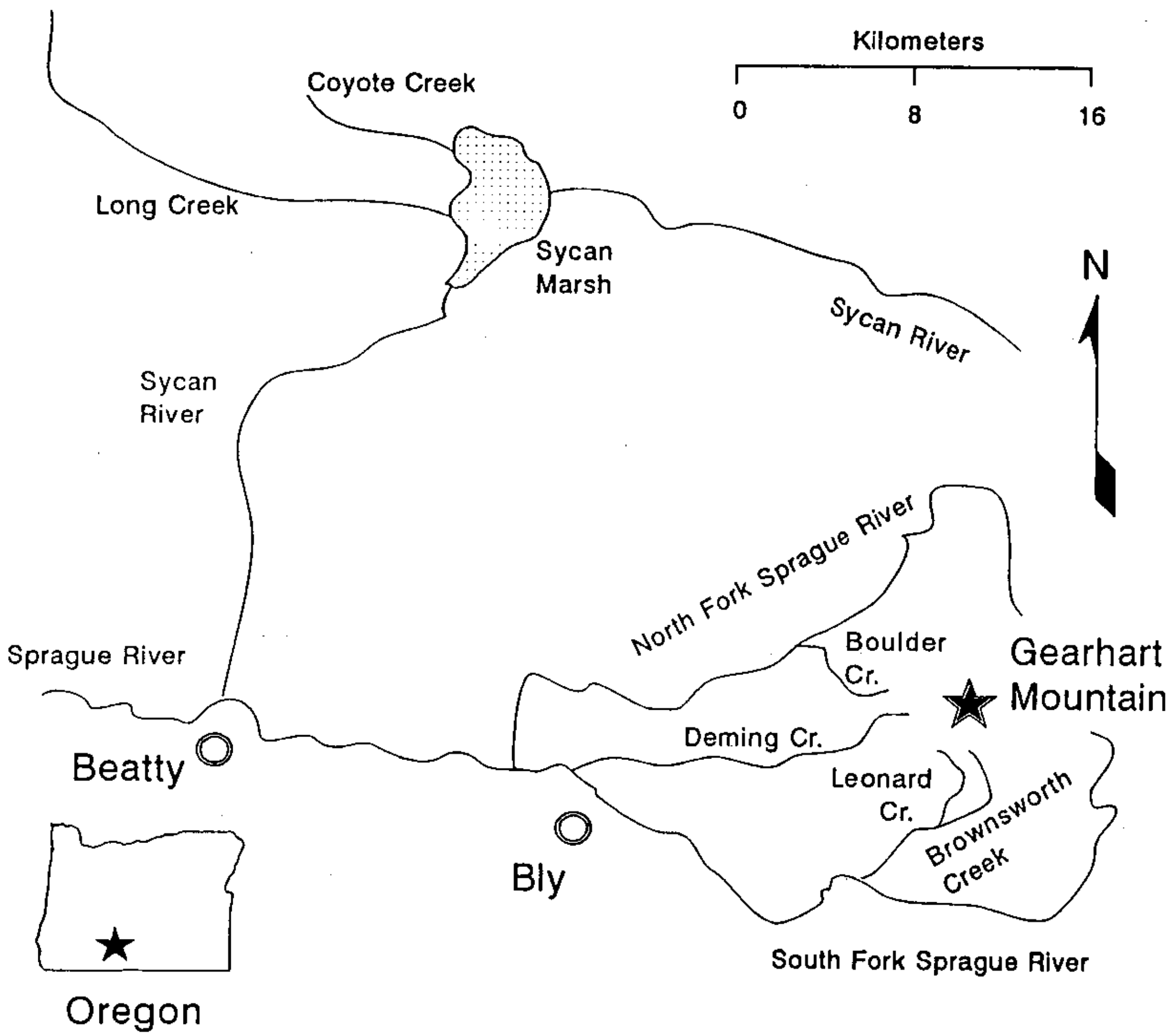

FIGURE 1.-- Upper Sprague River subbasin study area.

small, at low flow, and clear, and most fish resided in pools, we believe few fish were pushed out of the sampled sections. Captured fish were identified to species, measured for fork length, and released in the vicinity of the capture site. A sample of *Salvelinus* spp. captured in Long Creek that appeared to have characteristics intermediate between bull trout and brook trout *S. fontinalis* was preserved for further taxanomic study.

Elevations of sampling points were determined from U. S. Geological Survey quadrangles included in Fremont National Forest district maps and a 1981 map of the Gearhart Mountain Wilderness published by U. S. Department of Agriculture.

The upper limit of bull trout distribution was determined by spot sampling up the stream to a point where no fish were found. Approximately 100 meters of stream were sampled past this point to insure accuracy. The lower limit of bull trout distribution was not as accurate because occasionally fish could occur below that point. However, sampling indicated that the number of fish below the lower distribution limits identified was probably very small.

I estimated the abundance in each 0.4 km section by expansion of the number of trout per 30 meters to trout per 0.4 km. This data was extrapolated to unsampled sections by averaging the trout per 0.4 km above and below the unsampled sections. The abundance for the entire reach was made by adding both the expanded number of fish in each of the 0.4 km sections and the extrapolated number of fish in the unsampled sections. Because the 30 meter samples were not replicated, I was unable to calculate confidence intervals. Therefore, the results must be regarded as imprecise.

Fish habitat at each sample site was qualitatively evaluated. Parameters included gradient, water clarity, riparian condition, substrate, and instream cover. Parameter values were estimated using a survey similar to that of Hankin and Reeves (1988).

On 11 August 1989, Tempmentor recording thermographs were placed near the lower end of the sampling area on Deming, Boulder and Leonard creeks (8.4, 6.0, and 4.8 km from the source, respectively). On 29 August 1989, we placed two additional thermographs in upstream areas of Deming and Leonard creeks (1.0 and 1.2 km from the source, respectively). All five of the thermographs were recovered on 7 September 1989.

Results

Bull Trout Distribution

Upper and lower limits of bull trout distribution were found in Boulder, Brownsworth, Deming, and Leonard creeks (Figures 2-3). The elevation of the upper and lower limits were similar for all four streams (Table 1). We did not find an upper or lower limit of bull trout distribution in Long Creek (Figure 4).

Bull trout were found to inhabit approximately 14.0 km of Boulder, Brownsworth, Deming, and Leonard creeks (Table 1). In about 4.8 km of these streams, bull trout was the only fish species captured (Figures 2-3). It is possible that a few of the unsampled sections may also have contained only bull trout.

TABLE 1. Elevation of upper and lower bull trout distribution and total kilometers of stream containing bull trout for Boulder, Brownsworth, Deming and Leonard creeks, August 1989.

	Elevation (m)		
Stream	Upper limit	Lower limit	Km of stream with bull trout
Boulder Cr.	1,844	1,719	2.0
Brownsworth Cr.	2,021	1,725	4.0
Deming Cr.	2,048	1,676	4.0
Leonard Cr.	2,012	1,652	4.0

The few bull trout found in Long Creek were captured in the two sample locations that were highest in elevation (Figure 4). Brook trout were predominate in all except the highest sample site. Several fish that were tentatively identified as bull trout x brook trout hybrids were also captured at the highest sample sites.

Abundance

The estimated number of bull trout in Boulder, Brownsworth, Deming and Leonard creeks was 3,310 fish (Table 2). Boulder Creek had the lowest number of bull trout (219), whereas Deming Creek had the highest number of fish (1,293). The number of age zero fish are probably underestimated because their small size and habitat preferences make them less vulnerable to capture with electrofishing equipment than larger trout.

Densities of all trout combined averaged 368 fish per km and ranged from 259 to 461 fish per km (Table 2). Stream sections that contained bull trout averaged 219 bull trout per km and ranged from 109 to 321 bull trout per km.

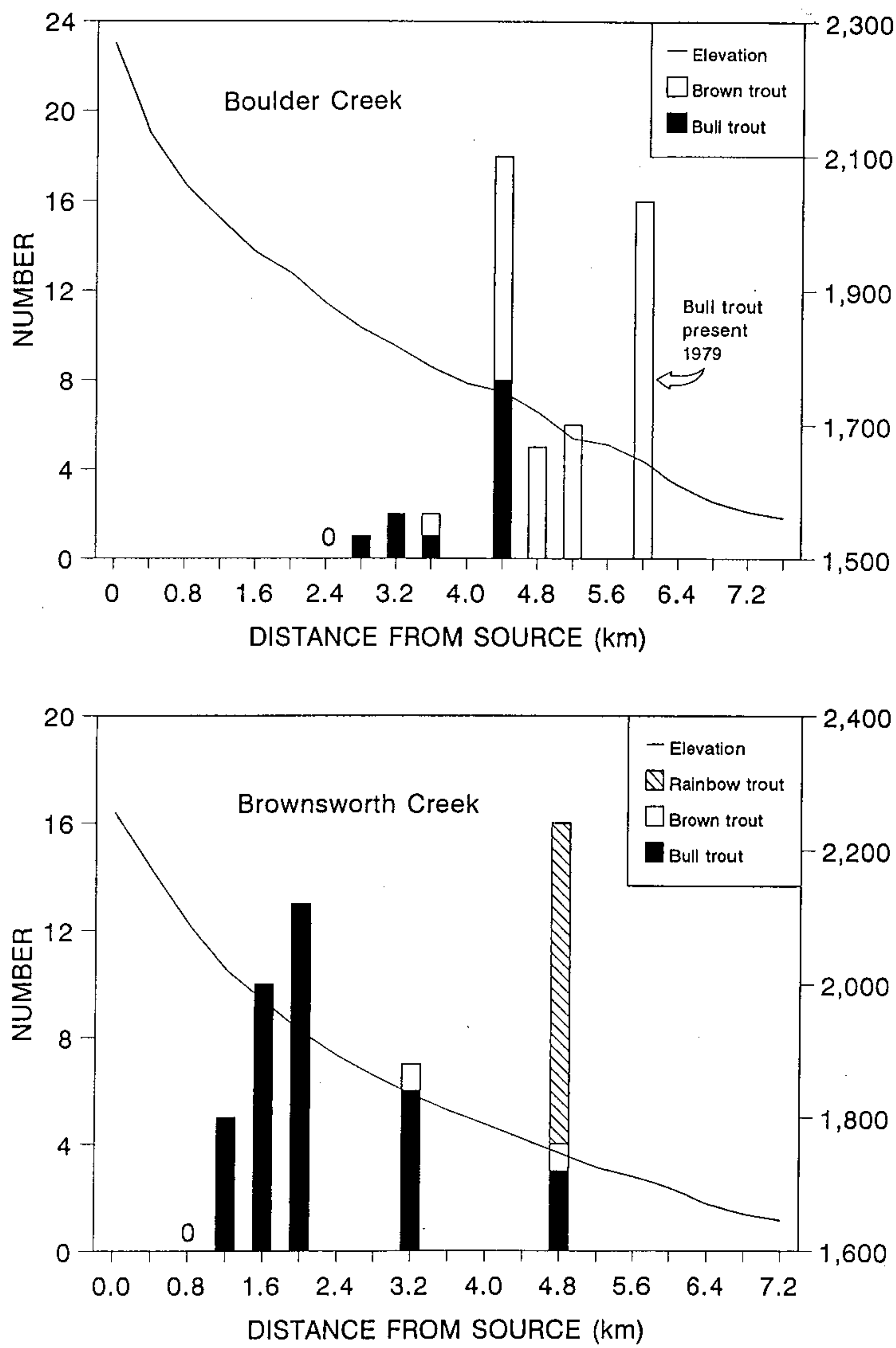

FIGURE 2. --Number of fish per 30 m captured with electrofishing equipment in Boulder and Brownsworth creeks, August 1989.

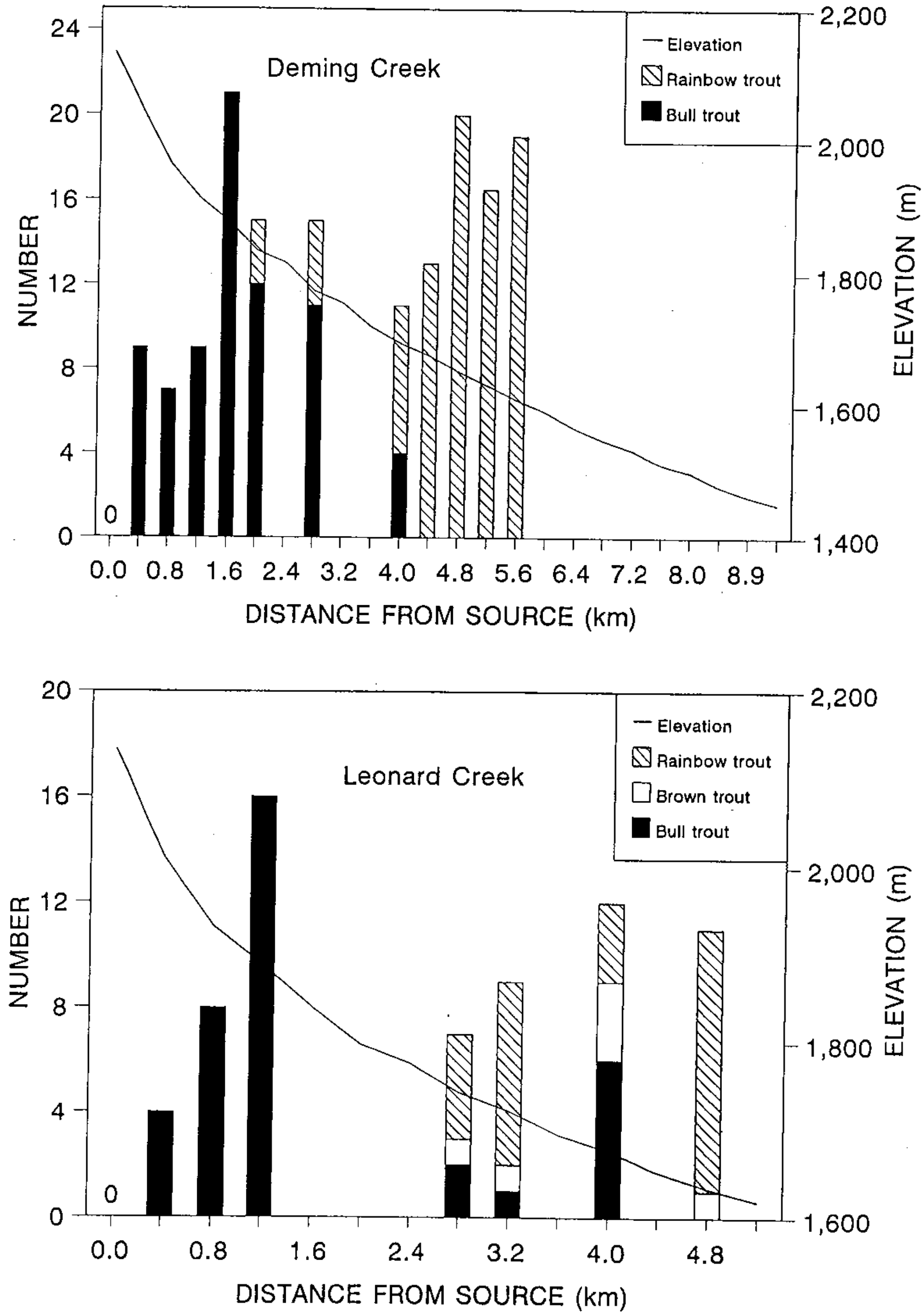

FIGURE 3. --Number of fish per 30 m captured with electrofishing equipment in Deming and Leonard creeks, August 1989.

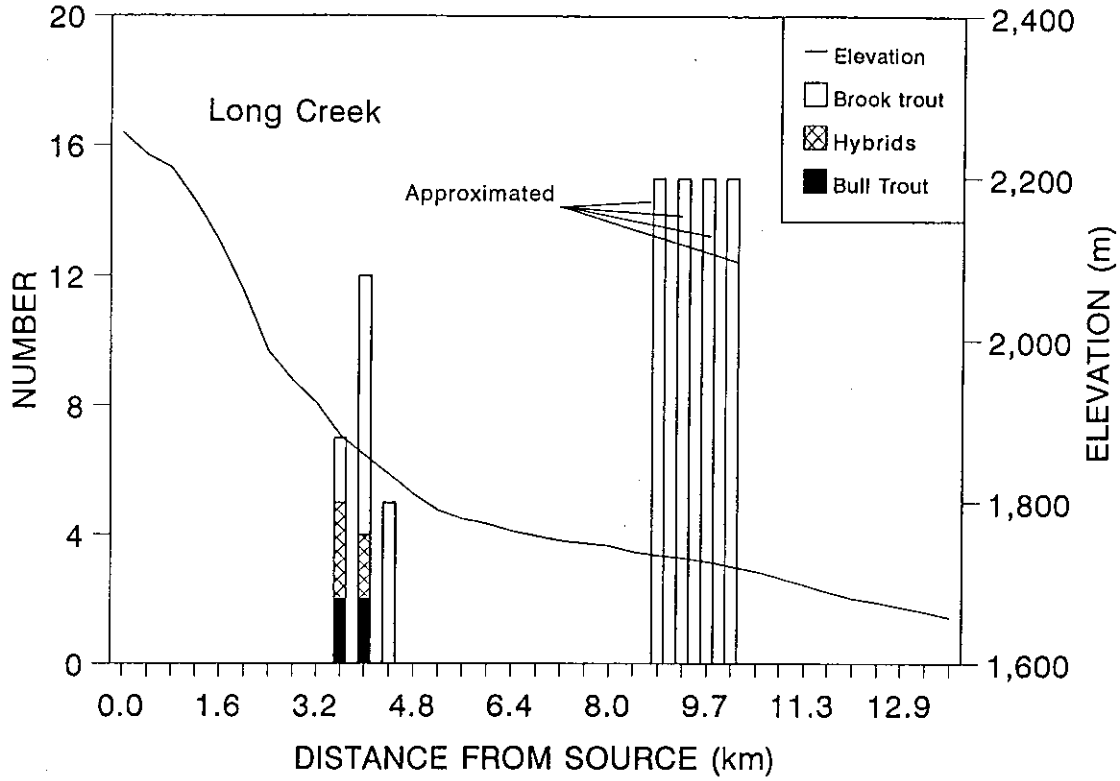

FIGURE 4. --Number of fish per 30 m captured with electrofishing equipment in Long Creek, August 1989.

TABLE 2. Abundance of trout in sections of Boulder, Brownsworth, Deming and Leonard creeks, August 1989.

Stream (km)[a]	Number: Bull trout	Number: All trout	Fish per km: Bull trout	Fish per km: All trout
Boulder Cr. (3.6)	219	937	109	259
Brownsworth Cr. (4.0)	964	1,393	240	346
Deming Cr. (5.6)	1,293	2,595	321	461
Leonard Cr. (4.0)	834	1,630	207	405

[a] Km of stream for which numbers of all trout were estimated.

Species Richness

Four species of trout were found in the streams sampled: bull trout, rainbow trout *Oncorhynchus mykiss*, brown trout *Salmo trutta*, and brook trout (Table 3). No other fish species were observed. In general, numbers of bull trout increased and numbers of other trout species decreased as elevation increased moving upstream (Figures 2-3). Long Creek was the only stream containing brook trout.

Bull Trout Length

The largest bull trout measured during the study was 218 mm and was captured in Deming Creek. The largest bull trout captured from the other three Gearhart Mountain streams were all less than 190 mm (Figures 5-6). The four bull trout captured in Long Creek ranged from 84 to 117 mm.

Of the 144 bull trout captured in this study, only 5 were identified as young of the year (less than 60 mm fork length). Six trout fry were not identified to species and may have been bull trout. The five young of the year positively identified as bull trout averaged about 45 mm and ranged from 40 to 49 mm.

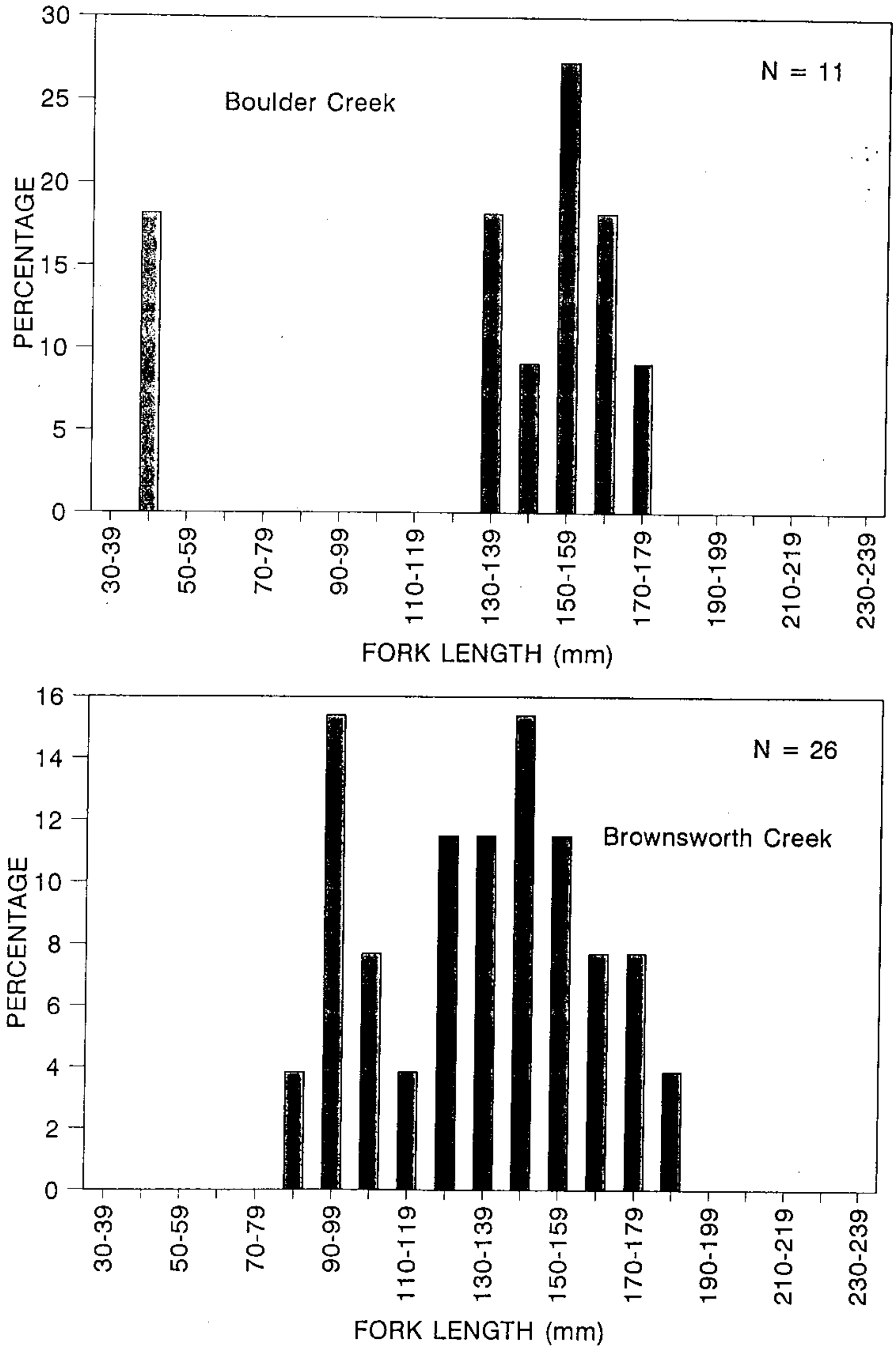

FIGURE 5.--Length frequency histograms for bull trout captured in Boulder and Brownsworth creeks, August 1989.

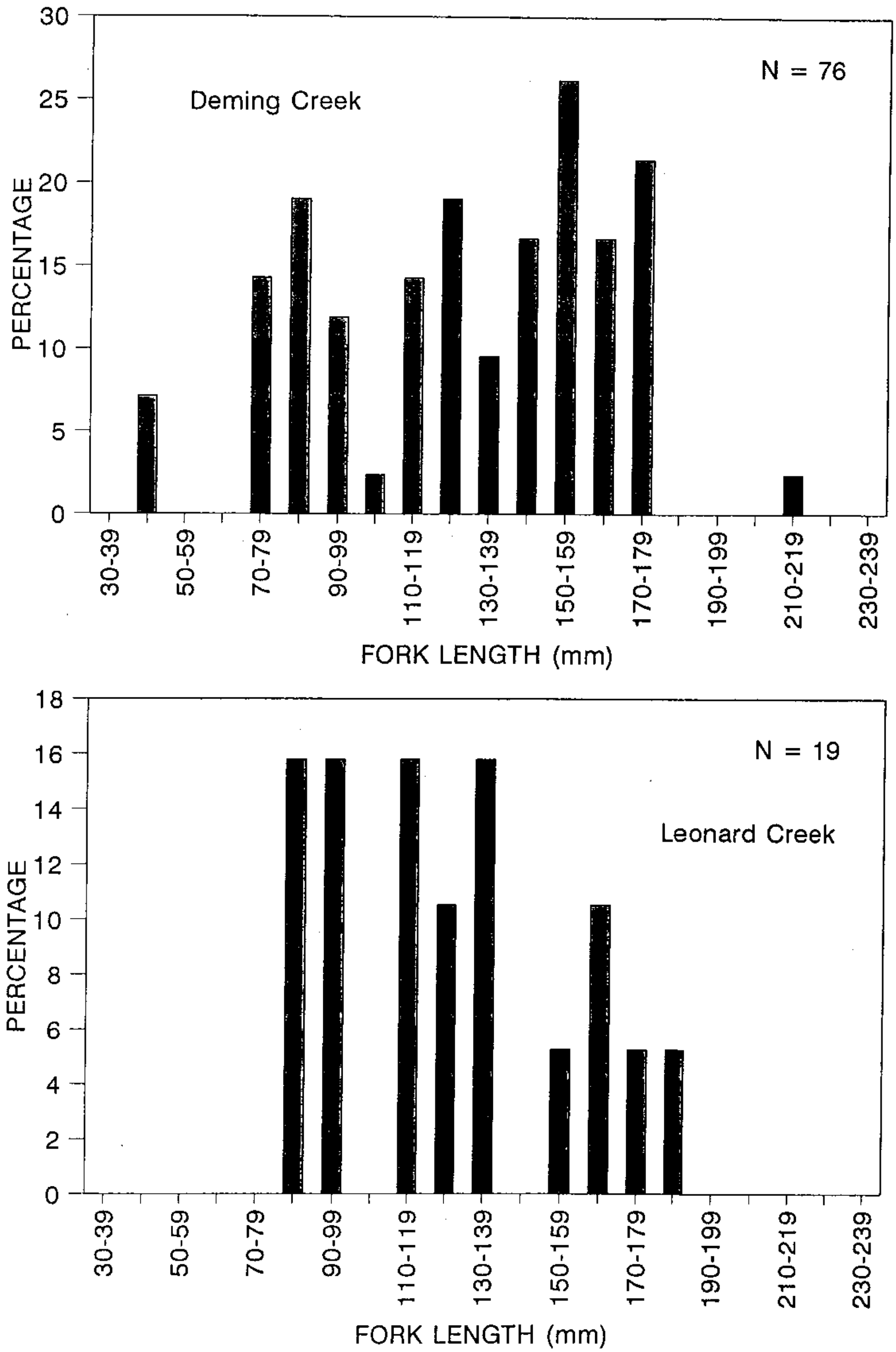

FIGURE 6.--Length frequency histograms for bull trout captured in Deming and Leonard creeks, August 1989.

TABLE 3. Fish species captured during electrofishing surveys of streams in the upper Sprague River basin, 1989.

Stream	Species present
Boulder Cr.	Bull trout, rainbow trout, brown trout
Brownsworth Cr.	Bull trout, rainbow trout, brown trout
Deming Cr.	Bull trout, rainbow trout
Leonard Cr.	Bull trout, rainbow trout, brown trout
Long Cr.	Bull trout, rainbow trout, brook trout

Bull Trout Habitat

The data collected in 1989 were summarized into three categories: stream sections with 100 percent bull trout, sections with no bull trout, and sections with both bull trout and other species. Bull trout were the prevalent species in reaches at higher elevations and with cooler water temperatures and steeper gradients (Table 4). Substrate and cover were similar for areas with bull trout. Areas with no bull trout generally had smaller substrates and overhanging vegetation for cover.

Water Temperature

The minimum water temperatures recorded in Boulder, Deming, and Leonard creeks from 11 August to 7 September 1989 were less than 5.0°C in areas with 100 percent bull trout (Table 5). Thermographs placed in areas where no bull trout were captured recorded minimum temperatures greater than 5.0°C. Maximum daily fluctuation and maximum temperatures are presented but are not comparable because all of the thermographs were not operating during the same time periods. During the period from 21 to 24 August 1989, an intense Pacific storm moved on shore causing water temperatures to drop sharply. Because the thermographs recording in 100 percent bull trout waters were installed after the storm, temperatures were lower than would be expected before the storm.

TABLE 5. Water temperatures of Boulder, Deming and Leonard creeks.

Stream	Temperature (°C)		
	Min.	Max.	Max. diff./d
Boulder Cr.[a]	6.1	10.0	3.0
Deming Cr. (Lower)[a]	5.5	15.0	6.8
Deming Cr. (Upper)[b]	3.5	11.5	7.1
Leonard Cr. (Lower)[a]	5.5	14.0	5.7
Leonard Cr. (Upper)[b]	4.8	11.0	5.7

[a]11 August through 7 September 1989
[b]29 August through 7 September 1989

TABLE 4.--Qualitative trout habitat data for Boulder, Brownsworth, Deming and Leonard creeks, August 1989.

Habitat parameter	Percentage of bull trout		
	100%	11-86%	0%
Elevation (m)	1922	1772	1653
Temperature (°C)	6.9	7.9	9.4
Gradient	steep (4-5%)	mod. (2-3%)	mod (2-3%)
Dominant substrate	rubble cobble	small boulder cobble	large gravel pea gravel
Dominant cover	turbulence woody debris	turbulence woody debris	woody debris overhang veg.

Discussion

The number of fish captured per 30 m by electrofishing equipment was compared between Long and Bond's (1979) study and this study (Table 6). In five of the seven sites bull trout numbers were essentially unchanged from 1979 to 1989. The greatest difference was in Boulder Creek, where no bull trout were found in 1989 for approximately 1.2 km upstream from the 019 Road, whereas there were 5-10 bull trout per 30 m in 1979. Brownsworth Creek, on the other hand, in 1989 had 3 bull per 30 m in the reach near USFS road 34, where no bull trout were found in 1979.

The information collected in this study shows that populations of bull trout in the Sprague River subbasin have a very small range near the headwaters of four streams in the Gearhart Mountain area. Further investigation of the Long Creek population did show a similar concentration of bull trout near the headwaters (Unpublished data, ODFW, 1991). Although the abundance estimates were roughly calculated without confidence intervals, I believe they indicate the populations in this subbasin are disturbingly small. These populations are apparently disjunct because of the natural drying trend that started about 10,000 years ago (Dicken 1980) and, more recently, habitat degradation and transfers of exotic trout into the basin.

Bull trout populations in the Gearhart Mountain area include many small, apparently mature fish, which are indicative of resident populations (Mike Rode, California Department of Fish and Game, personal communication, November 1989). Between 4 and 7 percent of the bull trout captured were young of the year--a pauperous number of fry when compared to the Metolius River tributaries, where a population of fluvial and adfluvial bull trout reside (Ratliff and Fies 1989). Although fluvial populations may still exist in the Gearhart Mountain area, we found no direct evidence that would support this theory. There have been unsubstantiated reports of "large Dolly Varden" captured by anglers in the canyon area of the North Fork of the Sprague River in the early 1970s (John Toman, ODFW, personal communication, November 1990); however, ODFW has not received any reports of large bull trout in the North or South forks of the Sprague River during recent years (Goetz 1989). The limited range, diminished status, and resident nature of these populations makes them vulnerable to even small environmental or biological changes.

There may be fluvial bull trout in Long Creek, where a fish approximately 51 cm total length was caught by an angler in during the spring of 1990. In addition a large bull trout was captured in Long Creek with electrofishing equipment in 1983 (Craig Bienz, Klamath Tribe, personal communication, January 1990).

It is probable that historic populations in the Sprague River and its tributaries were more extensive or fluvial. Movement of spawning fish within and between populations could have allowed for greater exchange of genetic material. The most recent isolation of individual stocks of bull trout has likely eliminated this transfer of genetic material and the theoretical implications of inbreeding suggest we are losing genetic variability in

TABLE 6. Comparison of trout densities for streams in the Sprague River subbasin, 1979 and 1989.

		Fish per 30 m			
		Bull Trout		Other trout	
Stream	Location	1979	1989	1979	1989
Deming Cr.	T36S, R15E, S1	15-20	9-21	0	0
Deming Cr.	T36S, R15E, S11	10-15	11	Scarce	4
Deming Cr.	T36S, R15E, S10	0	0	30-40	20
Boulder Cr.	T35S, R15E, S22	5-10	0	10-15	16
Brownsworth Cr.	T36S, R16E, S28	0	3	10-15	13
Brownsworth Cr.	T36S, R16E, S8	13-20	130	0	0
Leonard Cr.	T36S, R16E, S8	13-20	16	0	0

these stocks. This problem may be aggravated if populations are further reduced. Electrophoretic analysis indicated that the populations in the Sprague River tributaries are genetically and evolutionarily distinct from bull trout in the Columbia River Basin and would qualify as a separate "species" under the federal Endangered Species Act (Leary et al. 1991).

Over the past century, logging practices and livestock grazing have probably changed the quality and quantity of habitat available to bull trout in the Sprague River tributaries. Both of these activities generally lead to an increase in the amount of solar radiation that reaches the water surface, resulting in increased water temperature (Bottom et al. 1985). Cold water temperatures are very important to bull trout populations for egg incubation and juvenile rearing (Goetz 1989; Pratt 1992).

Habitat alterations from timber management may have helped brown trout gain a competitive advantage over bull trout. In the 10 years since Long and Bond conducted their field work, nearly all of the ponderosa pine has been harvested from private lands within the Boulder Creek drainage. Similar changes have occurred in Brownsworth and Leonard creek drainages, although they have not been as extensive. Further investigation is warranted to determine if the removal of the canopy was the cause of these shifts and, if so, what physical and biological mechanisms are involved.

Although much of the upper Leonard, Boulder, Deming and Boulder creek watersheds are in the Gearhart Wilderness, livestock grazing continues to be a permitted use of the wilderness. Fortunately, livestock grazing in the Gearhart Wilderness has been relatively light in the late 1980s. Long Creek and the lower portions of the other study streams have some areas of heavy grazing that may be contributing to higher water temperatures and, therefore, reduced bull trout habitat. Land managers should be informed about the effect of stream shade removal on bull trout habitat and make efforts to prevent increases in water temperatures.

Another immediate threat to many of the bull trout populations in the Klamath Basin is the encroachment of brook trout into bull trout waters (Dambacher et al. 1992). Numerous introductions of this exotic fish species have occurred in the basin (Unpublished data, ODFW). Apparently, brook trout are able to out-compete and hybridize with bull trout populations, eventually eliminating the bull trout (Markle 1992; Leary et al. 1991). This process may be occurring in parts of Long Creek as evidenced by the presence of brook trout x bull trout hybrids. Cavender (1978) also noted brook trout x bull trout hybrids in Long Creek. The few populations of bull trout in the Klamath Basin that do not appear to have declined during the past 10 years are in streams that do not have brook trout.

Bull trout in the upper Sprague River subbasin lead a very tenuous existence. Distribution limits obtained in this study will be invaluable for monitoring trends in bull trout populations. Because of the limited amount of habitat, one catastrophe such as a major forest fire or accidental chemical spill, could easily extirpate a population. All resource managers should strive to implement protection measures and expand the range of these unique fish.

Acknowledgements

I am very grateful to all of the enthusiastic workshop participants who assisted with this study in spite of the unseasonable weather. I am particularly grateful to Dave Buchanan, Jeff Dambacher, John Fortune, Rod French, Al Hemmingsen, and Doug Markle who guided individual groups on the field forays. I thank Dave Buchanan and Phil Howell for critically reviewing the manuscript.

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Distribution, Abundance, and Habitat Utilization of Bull Trout and Brook Trout in Sun Creek, Crater Lake National Park, Oregon

JEFFREY M. DAMBACHER
Oregon Department of Fish and Wildlife
4192 N. Umpqua Highway, Roseburg, Oregon 97470

MARK W. BUKTENICA
Crater Lake National Park, Crater Lake, Oregon 97604

GARY L. LARSON
Cooperative Park Studies Unit, College of Forestry,
Oregon State University, Corvallis, Oregon 97331

Abstract. --A survey of fish populations and instream habitat in Sun Creek, Crater Lake National Park, during the summer of 1989 revealed a remnant population of resident bull trout *Salvelinus confluentus* sympatric with introduced brook trout *S. fontinalis* in a 1.9 km reach near an upper edge of useable habitat. Bull trout and brook trout used similar habitat. Both preferred pools over other habitats, and the channel margin over other channel positions. Hybridization and potentially competition with exotic brook trout appear to threaten this bull trout population with a high risk of extinction.

Introduction

Once found in most major drainages in the Pacific Northwest and Canada, bull trout *Salvelinus confluentus* are currently experiencing a reduction in abundance and local extinction (Goetz 1989; Roberts 1987). Habitat degradation and the introduction of non-native fishes are believed to be primary causes. In a number of Oregon waters hybridization and competition with introduced brook trout *S. fontinalis* is implicated in depressing native bull trout populations to extinction or near extinction (e.g., Upper Sycan River, Coyote Creek, and Cherry Creek in the Klamath Basin) (Ratliff and Howell 1992). Where bull trout have persisted together with brook trout, there appears to be a barrier or mechanism separating bull and brook trout spawners. For example, in some headwater streams resident populations of bull trout have survived above impassable barriers (e.g., Long Creek and Cracker Creek) (Oregon Department of Fish and Wildlife (ODFW), unpublished data). In several tributaries of the Metolius River, cold water temperatures may exclude brook trout from bull trout spawning areas (Ratliff 1992). Bull trout populations with large adfluvial or fluvial adults may prevail in sympatry with brook trout by virtue of their avoidance of smaller brook trout when choosing spawning partners.

Bull trout were probably the only fish native to Sun Creek, a tributary of the Wood River in the Klamath River Basin within Crater Lake National Park (N.P.) (Figure 1). The Sun Creek population likely had a fluvial life history component. In 1938 bull trout as large as 380 mm were caught by angling in the Wood River downstream of Sun Creek (E.H. "Polly" Rosborough, Chiloquin, Oregon, personal communication, November 1991).

Approximately 45,000 brook trout fry and 7,000 rainbow trout *Oncorhynchus mykiss* fry were introduced into the Sun Meadow section of Sun Creek (Figure 1) between 1931 and 1940 (Wallis 1948). An additional 230,000 brook trout fry and 50,000 rainbow trout fry were stocked in Sun Creek between 1926 and 1971, probably at a road crossing 7.5 km downstream of the park boundary (ODFW, unpublished data).

A comprehensive survey of stream fishes in Crater Lake N.P. in the summer of 1947 showed that Sun Creek was inhabited by bull trout, brook trout, and rainbow trout (Wallis 1948). Bull trout, 130 to 220 mm, were described by Wallis (1948) as being "well distributed" downstream from a falls 0.7 km below Vidae Creek (Figure 1). Brook trout were found in

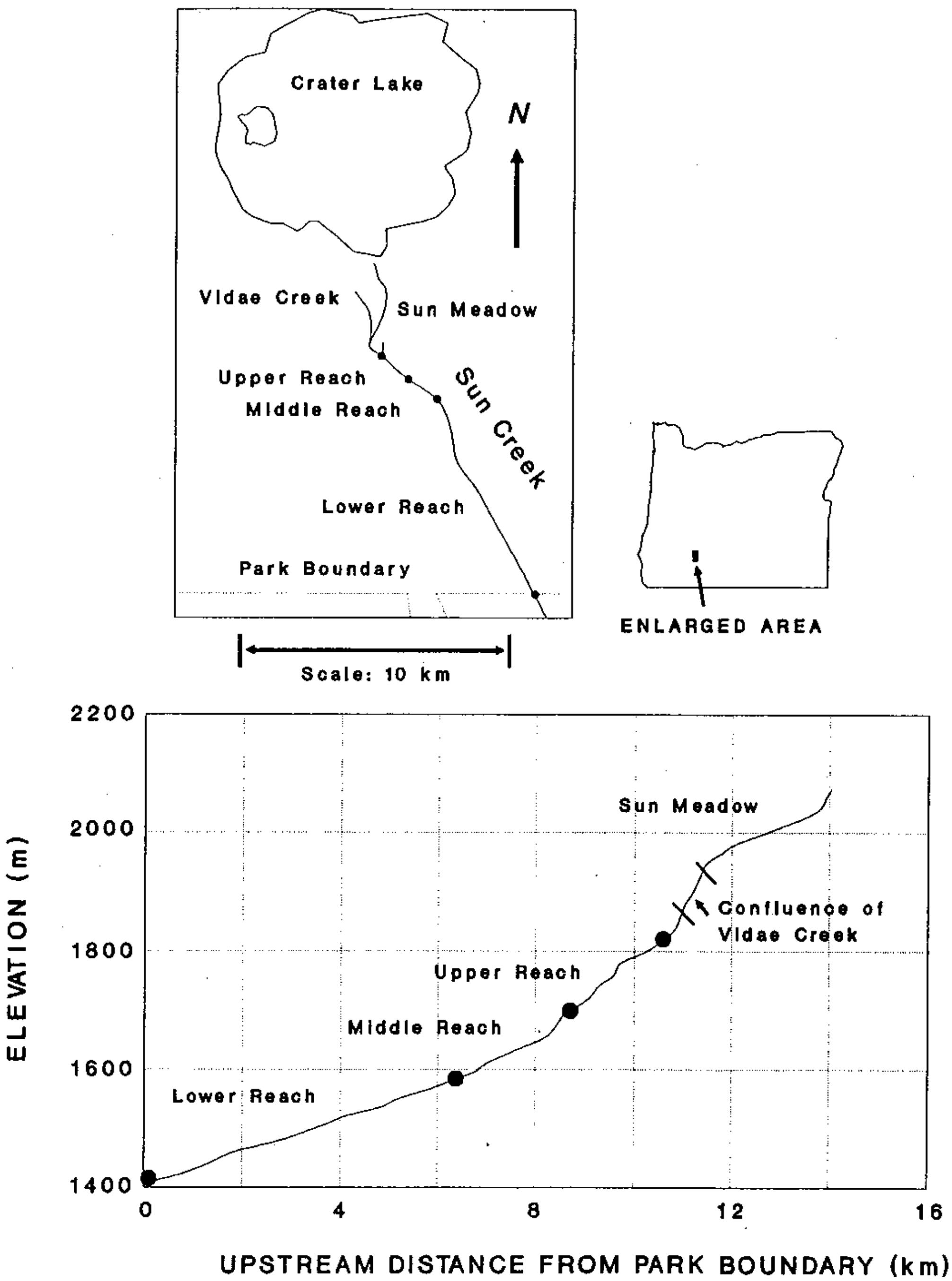

FIGURE 1.-- Map of Sun Creek, Crater Lake National Park, Oregon. Filled circles denote reach boundaries, cross lines denote impassable falls.

greater numbers than bull trout, and rainbow trout were scarce. Park streams in the Klamath Basin were surveyed again in the summer of 1989 with the objectives of documenting the present distribution, abundance, habitat, and habitat utilization of stream fishes. This paper reports the results from the survey of Sun Creek.

Study Area

Sun Creek (Figure 1) is a second order stream (Strahler 1957). It increases from a width of about 1.5 m in Sun Meadow to a width ranging from 3 to 6 m near the park boundary. Sun Creek is incised into a 25,000 year-old glacial valley (formed during the Pleistocene epoch) filled with pumice ash deposits from the eruption of Mount Mazama 6,800 years ago (Bacon 1983). Within the Park the Sun Creek basin ranges in elevation from roughly 1,400 to 2,200 m above sea level. The channel actively erodes the base of adjacent hill slopes, which stand near their angle of repose and supply large amounts of pumice sediment. Sand-sized and finer sediments are actively transported even during seasonal low flow in October. Virtually all substrate crevices are filled with pumice sediment. Cover for fish consists of stream bank undercuts and woody debris.

The Sun Creek basin is forested by old growth ponderosa pine *Pinus ponderosa*, mountain hemlock *Tsuga mertensiana*, and shasta redfir *Abies magnifica*; alder *Alnus* spp. thickets dominate the riparian canopy below approximately 1,600 m elevation. The majority of channel structure in Sun Creek consists of pieces of woody debris that are abundantly supplied by trees that fall into the active channel. Most breaks in channel gradient, pools, and scour pockets are formed by woody debris.

A heavy snow pack covers Sun Creek during winter. Peak stream flow occurs during the spring thaw from late June to early July. Stream flows at the Park boundary in August and September 1990 decreased from 0.31 to 0.25 $m^3 s^{-1}$, respectively. In September of 1989, conductivity increased from 40 mMhos cm^{-1} at 1,800 m elevation to 56 mMhos cm^{-1} at 1,400 m elevation at the park boundary, and alkalinity increased from 15 mg to 21 mg $CaCO_3 l^{-1}$, respectively. In mid-August 1989 water temperature ranged between 5.6°C and 10.0°C (1000 and 1600 hrs, respectively) at 1,650 m elevation.

Methods

Fish numbers were estimated by direct observation during snorkel diving in 11 km of Sun Creek upstream from the park boundary during August and September of 1989. Fish were counted by a single diver in approximately 10 percent of riffles and glides and 20 percent of pools. Fish population estimates were calculated by increasing dive counts by the proportion of units censused in each habitat type (Hankin and Reeves 1988). The snorkel survey progressed upstream from the park boundary. Habitat units were approached from the downstream end with the diver carefully moving upstream and counting fish. A flashlight was used to illuminate undercut banks and clumps of woody debris. Because we had no reliable estimate of dive count error, fish abundance estimates were not adjusted and should be considered as minimum estimates only. Single pass electrofishing without blocknets was used to determine the relative abundance of fish in reaches of stream that were either too small to effectively snorkel dive (e.g., Sun Meadow section of Sun Creek) or where fish densities recorded while snorkeling were near zero (e.g., Vidae Creek, and Sun Creek from 11 km above park boundary to Sun Meadow).

During the snorkel survey each species of fish was counted and classified as to age on the basis of body size. Fish less than 60 mm were classed as age 0, fish between 60 and 100 mm were classed as age 1, and fish greater than 100 mm were classed as age 2 and older. The stream channel position of each fish was described as: midchannel without cover, midchannel downstream of cover, or channel margin. Cover was considered as any obstruction to flow, such as woody debris or larger than average substrate.

Brook and bull trout hybrids were identified by spots on their dorsal (Markle 1992) and caudal fins and often by weak tricoloration (slight or no orange cast with a black stripe next to a white leading edge) of their pectoral and pelvic fins (Cavender 1978). Bull trout had clear dorsal fins and lacked body vermiculations; their pectoral and pelvic fins were either clear or had an orange cast and a white leading edge. Brook trout had prominent tricoloration of their pectoral and pelvic fins, as well as body and dorsal fin vermiculations. Brook trout as small as 50 mm were discernable from bull trout by their dorsal fin vermiculations.

Stream habitat was inventoried in the 11 km reach upstream of the park boundary that was snorkel surveyed. The stream channel was classified into habitat units of pools, glides, and riffles (Bisson et al. 1982), and the area of each habitat unit was visually estimated. Estimates of habitat area were verified by direct measurement in approximately one-tenth of all habitat units. Verifications were used to calculate calibration factors that corrected visually estimated area (Hankin and Reeves 1988).

Results

Fish Distribution and Abundance

The surveyed portion of Sun Creek (the lower 11 km within the park) was divided into three reaches (lower, middle, and upper) based on differences in the relative numbers of brook and bull trout (Table 1, Figure 2). No rainbow trout were found in Sun Creek within the Park. Brook trout were observed in relatively high numbers in the lower reach and in

TABLE 1.--Numbers of brook and bull trout, and brook x bull trout hybrids estimated by snorkel diving in three reaches of Sun Creek, Crater Lake National Park, summer 1989.

				Habitat area		Trout[f]	Brook trout		Bull trout		Hybrids	
Reach	Habitat	n[d]	N[e]	m^2	Percent	Age 0	Age 1	Age ≥2	Age 1	Age ≥2	Age 1	Age ≥2
Upper[a]	Pool	9	51	810	11	0	0	0	0	0	0	5
	Glide	1	8	280	4	0	0	0	0	0	0	0
	Riffle	4	49	6,500	85	0	0	0	0	0	0	0
	Total	14	108	7,590	15	0	0[g]	0[g]	0	0	0	5
Middle[b]	Pool	8	36	940	15	0	0	9	9	22	0	4
	Glide	2	8	430	7	0	0	4	0	9	0	0
	Riffle	4	37	4,900	78	0	0	0	19	74	0	0
	Total	14	81	6,270	13	0	0	13	28	105	0	4
Lower[c]	Pool	45	248	10,400	29	231	264	644	0	0	22	0
	Glide	12	126	9,300	26	63	241	273	0	0	0	0
	Riffle	12	138	16,200	45	138	276	390	0	0	0	0
	Total	69	512	35,900	72	432	781	1,307	0	0	22	0
Grand total		97	701	49,760		432	781	1,320	28	105	22	9

[a] 8.5 km to 10.8 km upstream of park boundary.
[b] From 6.6 km to 8.5 km upstream upstream of park boundary.
[c] 6.6 km upstream of park boundary.
[d] Number of habitat units censused by snorkel diving.
[e] Total number of habitat units.
[f] Probably brook trout.
[g] A few brook trout were found by electrofishing, but none by snorkel diving in the upper reach.

low numbers in the middle and upper reach. Bull trout were observed only within the 1.9 km long middle reach. Small numbers of hybrids were observed in all three reaches; however, their distribution extended only a few kilometers upstream and downstream of the middle reach.

A series of falls blocks upstream migration between the upper reach and Sun Meadow. Within this section a few brook trout were caught by electrofishing. In the Sun Meadow section brook trout were judged to be moderately abundant based on single pass electrofishing. No fish were found by electrofishing in Vidae Creek.

Approximately 2,300 age 1 and ≥2 fish were observed in the lower, middle, and upper reaches of Sun Creek (Table 1). Brook trout made up about 93 percent, bull trout 6 percent, and hybrids 1 percent of that total. The abundance of brook trout in the lower reach was much greater than all fish combined in the middle or upper reaches (Table 1, Figure 2). A few hybrids were the only fish observed in the upper reach while snorkel diving, although a small number of brook trout were captured while electrofishing in that section.

Age 0 fish were observed only in the lower reach,

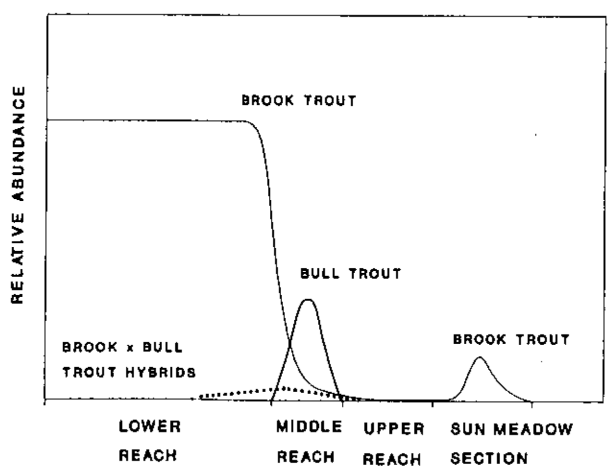

FIGURE 2. --Distribution and relative abundance of age 1 and ≥2 fish in Sun Creek, Crater Lake National Park, Oregon, 1989; estimated by snorkel diving in the lower, middle, and upper reaches and by electrofishing in the Sun Meadow section.

despite careful searching in the middle and upper reaches while snorkel diving. Age 0 fish were difficult to identify as to species, although all that were observed in the lower reach appeared to be brook trout. Similarly only a single age 0 fish was captured by electrofishing in the middle reach, whereas age 0 fish were frequently captured in the lower reach.

Although the estimated number of brook trout and hybrids were low in the middle reach (based on snorkel diving), numbers could have been greater, as rare fish can be poorly represented in a subsample of habitat units. A 0.5 km section was sampled by single pass electrofishing without blocknets to give another appraisal of the relative proportion of brook trout and hybrids to bull trout in the reach. Of 29 fish captured, 16 were bull trout, 8 were brook trout, and 5 were hybrids. This suggests that the ratios of brook trout to bull trout, and hybrids to bull trout could have been higher than the estimates made by snorkel diving. In the lower and middle reaches, the largest bull trout and hybrids captured by electrofishing were roughly 200 mm in fork length; the largest brook trout was 230 mm.

Habitat Characteristics and Utilization

Of the roughly 50,000 m^2 of habitat inventoried in Sun Creek, 72 percent was in the lower reach, 13 percent in the middle reach, and 15 percent in the upper reach (Table 1). The middle and upper reaches were progressively steeper (Figure 1), and the proportion of riffle habitat increased as channel gradient increased (Table 1).

Bull and brook trout utilized habitat similarly at the habitat unit and the microhabitat scale. Both fishes preferred pools over other habitat types (Table 2). Age ≥2 brook trout occurred more frequently in pools than did age 1 fish. At the microhabitat level, all age classes of brook and bull trout maintained positions predominantly at the channel margin (Figure 3). Age 0 char positioned themselves exclusively at the channel margin, while occupancy of mid-channel positions increased with age. When together in the same pool, brook trout appeared to dominate the head of the pool, while bull trout were behind or at the channel margin. When only one species was present in a pool, the largest individual of the species dominated the head of the pool.

Discussion

A remnant population of bull trout is restricted to a 1.9 km long reach of Sun Creek. This population is now considered to be purely resident since there are no recent records indicating fluvial bull trout in lower Sun Creek or Wood River. Channelization and heavy cattle grazing have greatly impacted lower Sun Creek and adjoining streams below the park boundary, which may have contributed to the loss of this life history component. Competition and hybridization with brook trout appear to have reduced the remaining resident bull trout population near to extinction.

Brook and bull trout used similar habitat types and microhabitats, and brook trout appeared to dominate pool inlets. If bull trout are excluded from their preferred habitat by brook trout, then they may suffer a diminished ability to feed and grow. This may adversely affect their survival and reproduction.

Survival to emergence of bull trout fry in Sun Creek may be low due to the great amount of fine pumice sediment in the stream bed. Bull trout egg-to-emergence survival drops off sharply in substrate with greater than 30 percent fines (<6.4 mm); nearly zero survival has been recorded when fines were about 45 percent (Shepard et al. 1984). Estimated numbers of age 0 and 1 fish observed in all reaches were particularly low in comparison to age ≥2 fish. Although this could be indicative of an inverted age class structure, we believe that younger fish probably were counted less by snorkel diving.

Considerable hybridization was evident during this study and in museum specimens collected in Sun Creek in 1950, where out of 9 fish, 4 were classed as hybrids and 5 as bull trout by Markle (1992). Previous research (Leary et al. 1983) has found brook and bull trout hybrids to be infertile males. However, one of five hybrids collected from the middle reach of Sun Creek was a female with a developed ovary (Markle 1992). It is not known if the hybrids in Sun Creek are capable of producing offspring.

TABLE 2. Habitat electivity E (Ivlev 1961) of brook and bull trout in Sun Creek, Crater Lake National Park, Oregon, summer 1989; where E = (% use - % area)/(% use + % area). E has a possible range of -1 to +1; negative values describe avoidance, positive values describe preference, values near zero indicate neutral selection.

	Brook trout/ Lower reach		Bull trout/ Middle reach
Habitat	Age 1	Age ≥2	Age 1 and ≥2
Pool	+0.08	+0.26	+0.21
Glide	+0.09	-0.11	0.00
Riffle	-0.12	-0.20	-0.05

It is interesting that bull trout still exist in Sun Creek since there is no separation of brook trout and bull trout spawners (Figure 2). To date bull trout have maintained higher densities than brook trout in the middle reach although recruitment may be low. This at

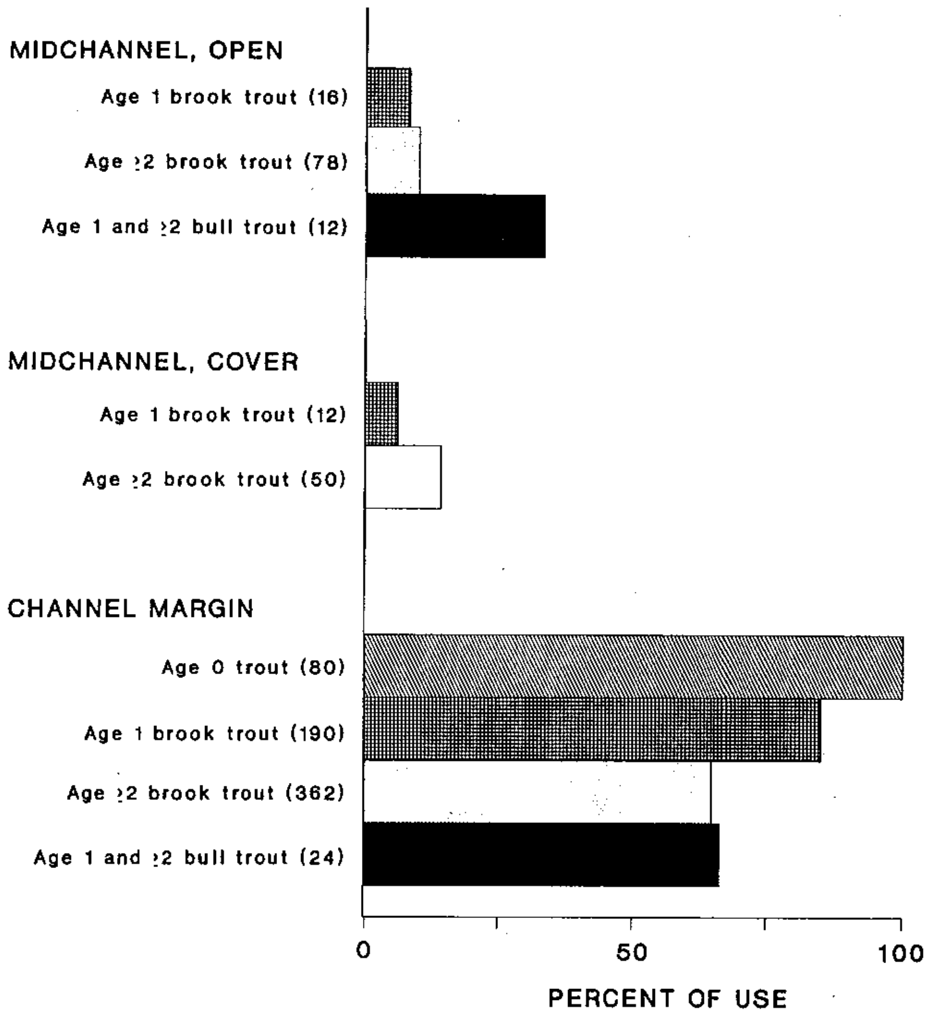

FIGURE 3. --Frequency of microhabitat use by bull trout and brook trout in Sun Creek, Crater Lake National Park, Oregon, as observed by snorkel diving, summer 1989. The number of observations is in parentheses.

least temporarily affords a numerical advantage to bull trout in pairing up with other bull trout spawners. The exact cause of their higher density is unknown, but the middle reach does have some unique characteristics. Within the middle reach heavy influxes of groundwater more than double the flow. Adult bull trout are known to concentrate spawning in reaches influenced by groundwater (Graham et al. 1984). Also, floculated ferric hydroxide associated with the groundwater input completely covered the stream substrate. The relative density of aquatic insects on the flocculent-covered substrate is very low compared to other reaches. This might create chemical or biological conditions for which this bull trout population is better adapted.

Progressing from the middle to the upper reach of Sun Creek, numbers of both brook trout and bull trout decline to near zero, and pools, the preferred habitat of both species, are of limited availability. This suggests that bull trout in Sun Creek are surviving at the upper edge of useable habitat below the falls.

The status of the Sun Creek bull trout population appears precarious given their small population size and the effects of hybridization and competition with brook trout. Natural variations in population size as great as 400% are common to many stream fishes (Hall and Knight 1981). A population of 133 fish is probably incapable of surviving even a moderate decrease in population size. Also, a small population may not be able to withstand abrupt environmental change and may not have the genetic diversity to adapt to gradual, long-term environmental change. For example, increasing water temperature from 4°C to 8°C during incubation can greatly reduce Dolly Varden *S. malma* egg-to-emergence survival (McPhail and Murray 1979). Such increases in temperature are predicted by some theorists of global warming (Smith 1990).

Crater Lake N. P. is initiating a bull trout recovery program for Sun Creek within the park boundary. The goal of the program is to reestablish a self-sustaining resident population of bull trout by eliminating all brook trout and building a barrier to prevent their reinvasion from downstream.

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Bull Trout Investigations in the Metolius River-Lake Billy Chinook System

DONALD E. RATLIFF
Portland General Electric Company
P. O. Box 710, Madras, Oregon 97741

Abstract. -- Bull trout *Salvelinus confluentus* populations in the Metolius River-Lake Billy Chinook system of central Oregon have been studied since 1985. Spawning of adults and initial juvenile rearing (ages 0-1) is limited to cold (~4.5°C) spring-fed tributaries to the Metolius River. Bull trout are the only fish utilizing upper Jack, Roaring, Candle, and Jefferson creeks. Young bull trout disperse from these tributaries during their second and third year and move to other waters in the system. Those which rear in Lake Billy Chinook grow exceptionally fast, about 1.4 cm per month, likely preying on the large kokanee *Oncorhynchus nerka* population. Spawning commences in July and extends through October, with a peak of activity during early September. Redd counts have increased steadily from 27 in 1986 to 149 in 1989. This recovery is probably a result of the angling regulation change which required the release of all wild trout and char in the Metolius River since 1982.

Introduction

The bull trout *Salvelinus confluentus* was originally found throughout most of the Deschutes River drainage of Oregon (Goetz 1989). However, the completion of Crane Prairie Dam in 1920 and Wickiup Dam in 1947 cut off access for adult bull trout migrating to most upper Deschutes River spawning areas. In addition, inundation of some juvenile rearing areas, rotenone poisoning to remove non-game species, competition with introduced salmonids, and overharvest apparently eliminated bull trout populations in the upper Deschutes River above Steelhead Falls (Ratliff and Howell 1992). The last account of bull trout in the upper Deschutes River was in 1951 from Wickiup Reservoir (Borovicka 1951).

Today, bull trout are found in the Metolius River system, in the Deschutes River from about Sherars Falls (river kilometer (RK) 70.6) upstream to Steelhead Falls (RK 205.6) including Lake Simtustus (Pelton Reservoir) and Lake Billy Chinook (Round Butte Reservoir), and in Shitike Creek and the Warm Springs River (Ratliff and Howell 1992). A small isolated population also occurs in the Odell Lake system.

A study of bull trout in the Metolius River-Lake Billy Chinook system was initiated in 1985. Cooperators in the study include Portland General Electric Company (PGE), the Oregon Department of Fish and Wildlife (ODFW), the Deschutes National Forest, and the Confederated Tribes of the Warm Springs Reservation. We hope that populations can be enhanced to create a significant trophy fishery by taking advantage of abundant prey species in Lake Billy Chinook. This study proposes to learn more about the life history characteristics, population status, and limiting factors for this native stock. This paper summarizes information to date on distribution, growth, movements, and spawning.

Study Area

Lake Billy Chinook, created by the construction of Round Butte Dam in 1964 at RK 177 on the Deschutes River in central Oregon, is a reservoir which has a surface area of 1,619 hectares and is located in the canyons of the Metolius, Deschutes, and Crooked Rivers (Figure 1). The Deschutes and Crooked River arms run parallel, north and south, whereas the Metolius arm extends to the west. Lengths of these arms are 13, 10, and 19 km, respectively. There is currently no upstream fish passage over Round Butte Dam.

The Metolius River heads as a large spring near the base of Black Butte and flows north and then east around Green Ridge approximately 41 km into Lake Billy Chinook. A number of tributaries enter the Metolius River from the west. Progressing downstream these are Lake, Spring, First, Jack, Canyon, Abbot, Candle, Jefferson, and Whitewater creeks (Figure 1). Of these, Spring, Jack, Canyon, Abbot, Candle, and Jefferson creeks are greatly influenced by springs. Whitewater Creek is a glacial stream originating on the east slope of Mt. Jefferson. Squaw Creek is a west-side tributary to the Deschutes River 4.8 km above Lake Billy Chinook.

Other native fish in the Lake Billy Chinook system include rainbow trout *Oncorhynchus mykiss*, chinook salmon *O. tshawytscha*, kokanee salmon *O. nerka*,

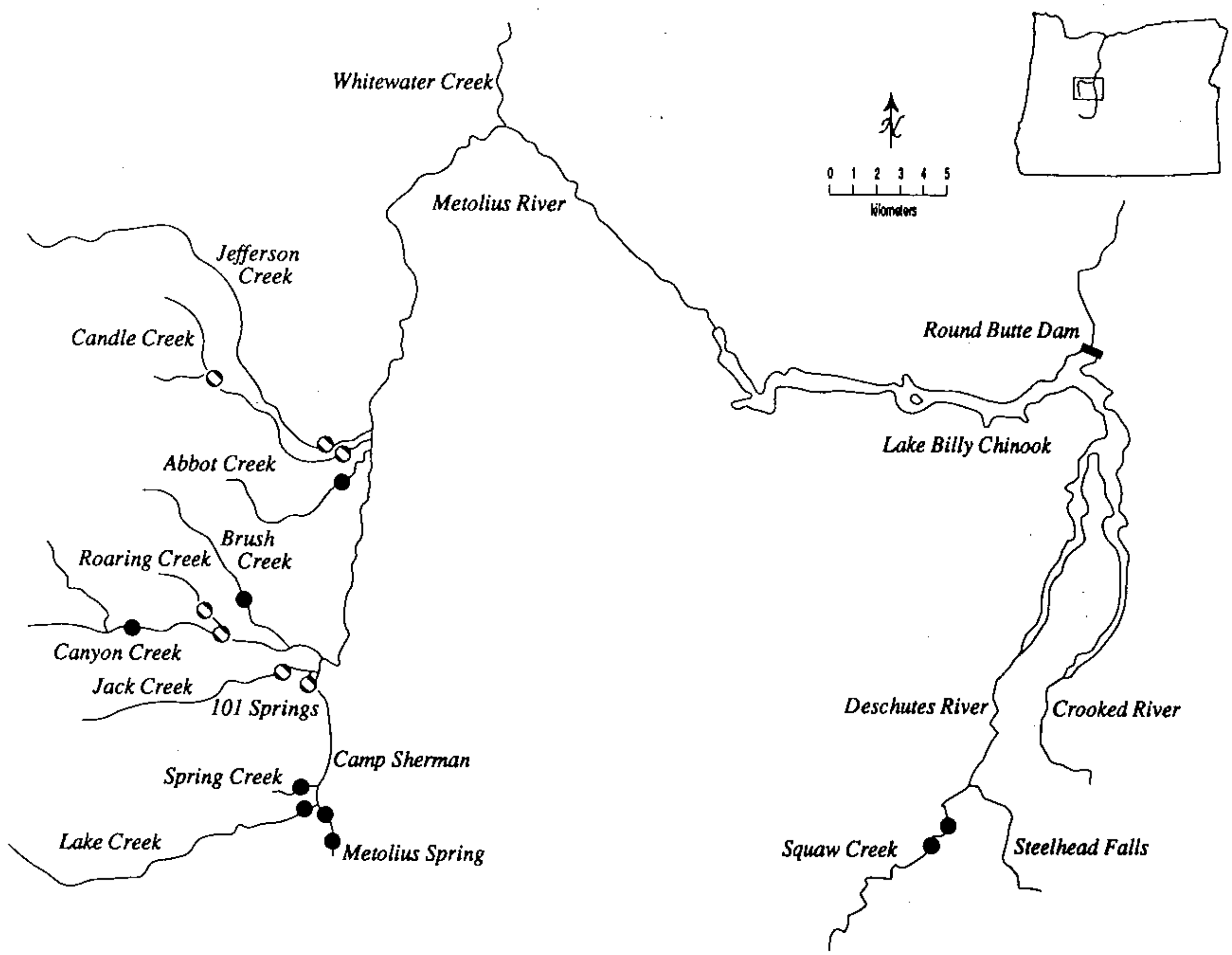

FIGURE 1.-- Bull trout study area and sampling locations for juvenile bull trout distribution studies, 1985 and 1986. Open circles indicate where age-0 bull trout were found.

mountain whitefish *Prosopium williamsoni*, largescale sucker *Catostomus macrocheilus*, bridgelip sucker *C. columbianus*, longnose dace *Rhinichthys cataractae*, northern squawfish *Ptychocheilus oregonensis*, chiselmouth *Acrocheilus alutaceus*, shorthead sculpin *Cottus confusus*, torrent sculpin *C. rhotheus*, slimy sculpin *C.cognatus*, and mottled sculpin *C. bairdi* (Fies and Robart 1988). Introduced species include brown trout *Salmo trutta*, brook trout *Salvelinus fontinalis*, largemouth bass *Micropterus salmoides*, smallmouth bass *M. dolomieui*, and goldfish *Carassius auratus*.

Methods

Distribution

To determine the distribution of young bull trout in the system, juvenile fish were captured using backpack electro-shocking equipment. The Metolius headwater spring, the Metolius River at Riverside Campground, and all major tributaries except Whitewater Creek were electrofished. Squaw Creek, a tributary to the Deschutes River above Lake Billy Chinook, and Alder Springs, a tributary to Squaw Creek were included also. Fish captured were identified, enumerated, measured, and released. Water temperature at each sampling location was recorded.

Growth

Juvenile bull trout were captured and measured from Metolius River tributaries during April, July, and October of 1986 and 1987. Length-frequency histograms were constructed to delineate the lengths of age-0 and age-1 bull trout. Scale samples were collected to determine the ages of larger, older fish and as a reference for tributary growth rates on adult scales. Scale samples were also taken from bull trout checked during creel surveys and captured during tagging efforts. Growth information was gathered from individual bull trout tagged and then later recaptured.

Movement

Bull trout were captured, tagged, and released in the Metolius River above Camp Sherman and in the Metolius Arm of Lake Billy Chinook to learn more about their movements. A raft electroshocker was used to capture fish in the Metolius River, while a combination of both hook-and-line and trap nets were used in the Metolius Arm. Bull trout were also tagged during trout inventories in the Metolius River above Camp Sherman during May and September, 1983 and 1984, before this study formally began (Fies and Robart 1988). Bull trout were tagged in the same area in 1985 and 1988 and at the head of the Metolius Arm during 1986-90. Most tagging in Lake Billy Chinook was done during the spring from March through May. Each fish larger than about 15 cm received an individually numbered floy tag. Signs alerting anglers to the presence of tagged fish were posted at each major boat launching and moorage area. In addition to the fishery, tagged fish were recovered in the trap nets and observed in the spawning areas.

Spawning

The tributaries where young juvenile bull trout were found during distribution surveys were surveyed each fall during 1985-90 to determine spawning locations and to count redds. Initial efforts in 1985 were concentrated on determining where adult bull trout had access. During fall (Oct.-Nov.) of 1986-1990, Jack Creek, Candle Creek, Jefferson Creek, Canyon Creek, and its tributary Roaring Creek were surveyed to get a total redd count. In 1987 Roaring Creek was surveyed three times during the late summer and fall to better define the spawning period.

Results and Discussion

Distribution

Young bull trout (age 0 and 1, <100 mm) were found most consistently in the coldest, spring-influenced tributaries in the Metolius basin: Jack Creek, Candle Creek, Jefferson Creek, Canyon Creek and its tributary Roaring Creek (Figure 1). Larger bull trout (age $\geq$ 2, >100 mm) were found in the Metolius River, upper Canyon Creek, Brush Creek, and Lake Billy Chinook. No bull trout were seen in Spring, Lake, or Abbot creeks (Table 1). No young bull trout (age 0-1) were observed in the Deschutes River, Squaw Creek, or Alder Springs during these studies, although large bull trout are occasionally captured in these locations by anglers.

Bull trout were the only species observed in Roaring, Candle, and Jefferson creeks during electrofishing surveys in 1985 and 1986 (Table 1). In lower Jack Creek some sculpins and rainbow trout werealso captured. No bull trout were captured in Squaw Creek and Alder Springs where the temperatures measured during the sampling period were 16.5°C and 11.0°C, respectively. Present distribution of young bull trout appears to coincide with the coldest water temperatures in the system.

Historic information suggests a loss of range for bull trout in the Metolius system. Large bull trout migrating upstream apparently to spawn were captured in Abbot Creek (Foster 1957) and were observed in Spring Creek (Len Mathisen, ODFW retired, personal communication, 1981) and ascending Lake Creek to Suttle Lake (D. Frey, unpublished field notes, Deschutes River System Lake Creek Tributary Metolius River, June 22, 1942). A combination of overharvest, barriers, habitat change, and the invasion of introduced brook and brown trout likely eliminated the bull trout from these three streams. These factors have been implicated in the reduced distribution and losses of other Oregon bull trout populations (Dambacher et al. 1992; Ratliff and Howell 1992). The streams where bull trout presently spawn are only slightly cooler than Spring Creek and Abbot Creek. However, this slight temperature difference (~2°C) may have prevented invasion by brook trout.

Growth

Newly emerged bull trout fry (22-24 mm) were observed in Jack and Candle creeks the first week of April 1986. Young-of-the-year bull trout averaged 32.7, 48.1, and 60.8 mm in the tributaries when sampled April 29, July 21, and October 8, 1987, respectively (Figure 2). In April 1987, mean lengths for ages 0+, 1+, and 2+ bull trout in Metolius River tributaries were 32.7, 70.4, and 106.8 mm, respectively (Figure 2). Growth of young bull trout appears to be quite slow during their residency in these cold tributaries.

Although scale samples have yet to be analyzed, individual growth rates for some larger bull trout have been determined from information based on tag returns. Growth rates for bull trout tagged and recaptured more than one year later showed considerable variation probably due to differences in rearing habitat and associated prey abundance (Table 2). Bull trout tagged and recaptured in Lake Billy Chinook grew very rapidly averaging 1.4 cm increase per month.

Movement

Sampling of juvenile bull trout in the cold tributaries suggests most juveniles disperse from these streams during their second and third years. Comparison of length-frequency histograms from samples taken during April, July, and October of 1987 shows a reduction of age 2+ fish during the early portion of the summer and some loss of yearling fish before October (Figure 2). Few fish <100 mm were captured from the Metolius River above Camp Sherman

TABLE 1.--Fish captured during sampling of various tributaries to the Metolius and Deschutes rivers, 1985-86.

Stream	Bull trout		Brook trout	Other salmonids	Non-salmonids	Total bull trout	Percent bull trout	Mean water temp. (C)		
	< 100 mm	> 100 mm						@ sampling	month	July[a]
Upper Metolius R.	0	0	1	26	25	0	0	8.3	Oct	--
Lake Cr.	0	0	0	8	1	0	0	6.7	Apr	18.2
Spring Cr.	0	0	1	29	5	0	0	7.2	Oct	--
Jack Cr.	34	6	0	8	3	40	78	3.3	Apr	8.2
101 Springs	1	4	0	5	0	5	50	5.0	Apr	--
U. Canyon Cr.	4	2	1	4	3	6	43	6.1	Oct	--
Roaring Cr.	23	5	0	0	0	28	100	4.4	Oct	6.1
Brush Cr.	0	3	0	7	60	3	4	8.3	Jul	--
Abbot Cr.	0	0	3	3	28	0	0	6.1	Oct	--
Candle Cr.	49	7	0	0	0	56	100	4.4	Oct	5.7
Jefferson Cr.	21	1	0	0	0	22	100	5.0	Oct	7.2
Squaw Cr.	0	0	0	7	10	0	0	16.7	Jun	--
Alder Springs (East)	0	0	0	16	1	0	0	11.1	Jun	--

[a] Mean July (1988) water temperatures. July is the warmest month of the year for these streams.

or Lake Billy Chinook (Figure 3).

Bull trout recaptured after more than 1 year have shown a variety of movement patterns. Of five fish recaptured after being tagged in the Metolius River above Camp Sherman, three were recaptured up to 4.5 years later near Camp Sherman, one was recaptured 1.5 years later in Lake Billy Chinook, and another was recaptured 5 years later while spawning in Jack Creek. Four bull trout tagged in Lake Billy Chinook were later observed spawning in tributaries: one each in Jack, Jefferson, Roaring, and Canyon creeks. One fish tagged at the head of the Metolius Arm was captured 13 months later by an angler in the Deschutes River just below the mouth of Squaw Creek. It appears that young bull trout disperse from the cold Metolius tributaries to forage in other accessible waters in the system before returning to their natal stream to spawn.

Spawning

Approximately 25.1 km of four Metolius River tributaries (Jefferson, Candle, Canyon, and Jack creeks) were identified as spawning reaches for bull trout (Figure 4). All four are cold, spring-fed streams where age-0 bull trout were found during juvenile electrofishing surveys. In addition, bull trout spawning was documented in the 101 Springs area where large cold springs emerge and travel a short distance into the Metolius River at the mouth of Jack Creek. Also, bull trout spawning has been reported in the Metolius River near the mouth of Jack Creek. No bull trout were observed or reported spawning in the upper Metolius River, Spring Creek, or Lake Creek. However, as noted earlier, there are historical records of adult bull trout using Spring and Lake creeks.

In all the spawning tributaries except Jefferson Creek, upstream distribution of redds was limited only by barriers to access. In Jefferson Creek, the steep gradient of the stream and poor spawning gravels near the upstream barriers apparently limited spawning. Although Whitewater Creek was not surveyed, it is believed that the very high gradient and glacial silt during the spawning season limit spawning success.

Total redd counts in the four tributaries increased steadily from 27 in 1986 to 149 in 1989 and decreased slightly in 1990 (Table 3). The apparent recovery of this population is probably the result of increased survival after an angling regulation change requiring the release of all wild trout and char in the Metolius River since 1982.

Roaring Creek was surveyed three times in 1987 to determine the peak spawning period. Counts were made August 7, September 8, and October 22. Adults were observed on redds during the August and September counts. No adults or new redds were observed during the October count. In 1988 weekly observations indicated that peak spawning activity occurred approximately the first week of September. In 1989, although peak spawning activity again occurred in early September, total activity was more protracted. A pair of bull trout was observed spawning in Canyon Creek July 13, and a number of spawning adults were observed in Jack Creek October 2, but the majority of redds were no longer occupied.

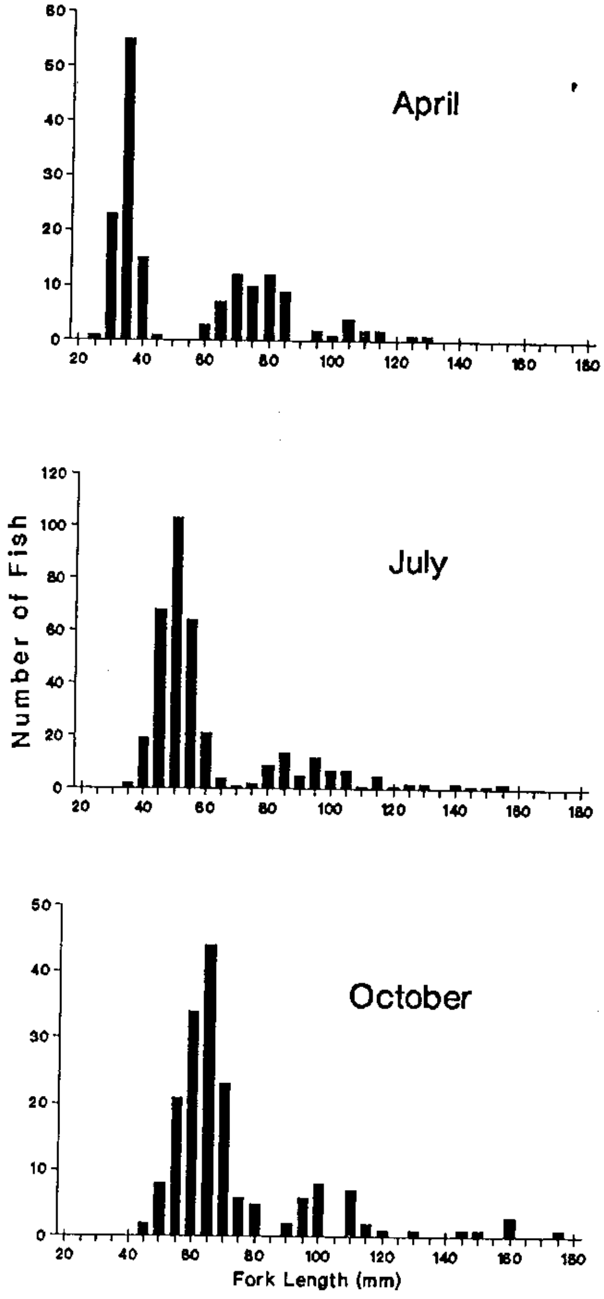

FIGURE 2.-- Lengths of juvenile bull trout sampled in Metolius River tributaries, April 29, July 21, and October 8, 1987.

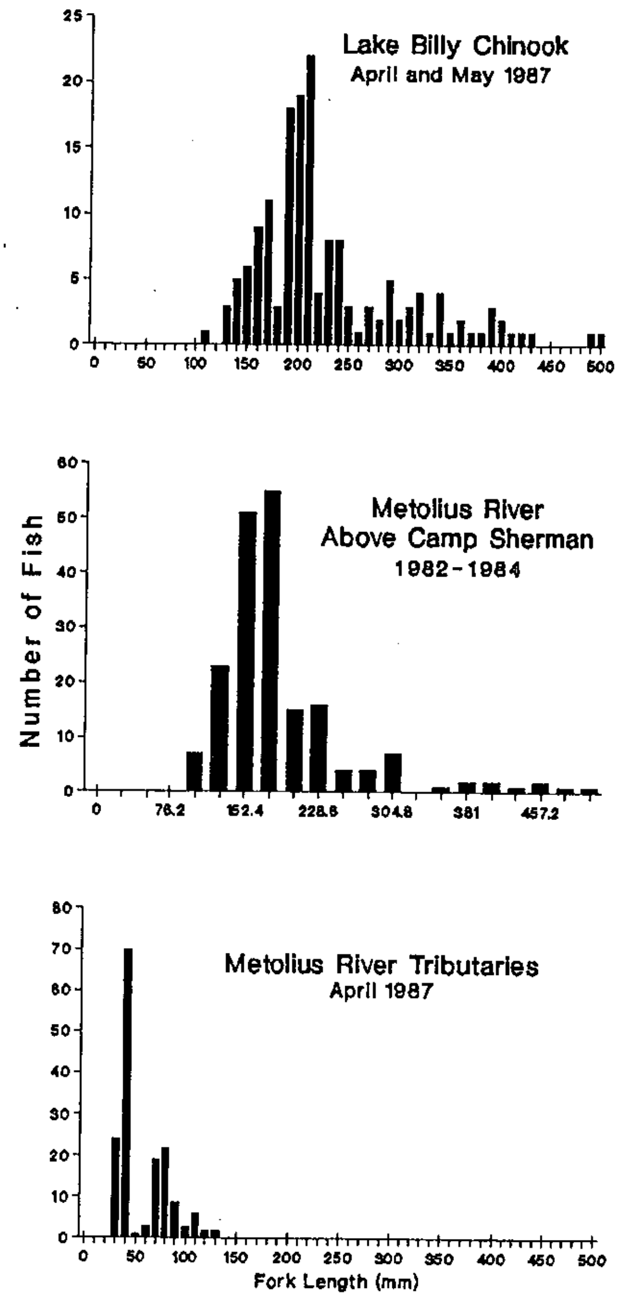

FIGURE 3.-- Lengths of bull trout sampled in Lake Billy Chinook, the Metolius River above Camp Sherman, and in tributaries of the Metolius River.

TABLE 2.--Increases in fork length (cm) for individual bull trout tagged and recaptured at various locations in the Metolius River-Lake Billy Chinook system.

Location	Fork length at tagging	Fork length at recapture	Months to recapture	Increase per month	Increase per year
Tagged-Metolius R.	15.7	51.3	54.0	0.7	7.9
Recovered-Metolius R.	16.0	55.2	60.0	0.7	7.8
	30.5	50.8	33.0	0.6	7.4
			Mean	0.6	7.7
Tagged-Metolius R. Recovered-L. Billy Chinook	15.5	37.8	18.5	1.2	14.4
Tagged-L. Billy Chinook	31.5	51.3	13.5	1.5	17.6
Recovered-L. Billy Chinook	29.0	66.3	25.5	1.5	17.6
	17.8	33.0	12.0	1.3	15.2
	24.6	50.0	21.5	1.2	14.2
	18.5	40.6	15.5	1.4	17.1
	19.8	57.1	24.0	1.6	18.7
			Mean	1.4	16.7
Tagged-L. Billy Chinook Recovered-Deschutes R.	30.5	40.6	13.0	0.8	9.3

TABLE 3.--Number of bull trout redd in Metolius River tributaries, 1986-90.

Stream	Distance km	Redds 1986	1987	1988	1989	1990
Jefferson Cr. mouth to falls	4.7	6	9	27	36	29
Candle Cr. mouth to trail head	6.6	6	8	8	17	16
Canyon Cr. mouth to Roaring Springs	6.4	12	20	31	39	48
Jack Cr. mouth to headwater springs	7.4	3	11	30	50	49
House of Metolius Springs mouth to headwater springs	0.3	------no count------			7	3
TOTAL	25.4	27	48	96	149	145

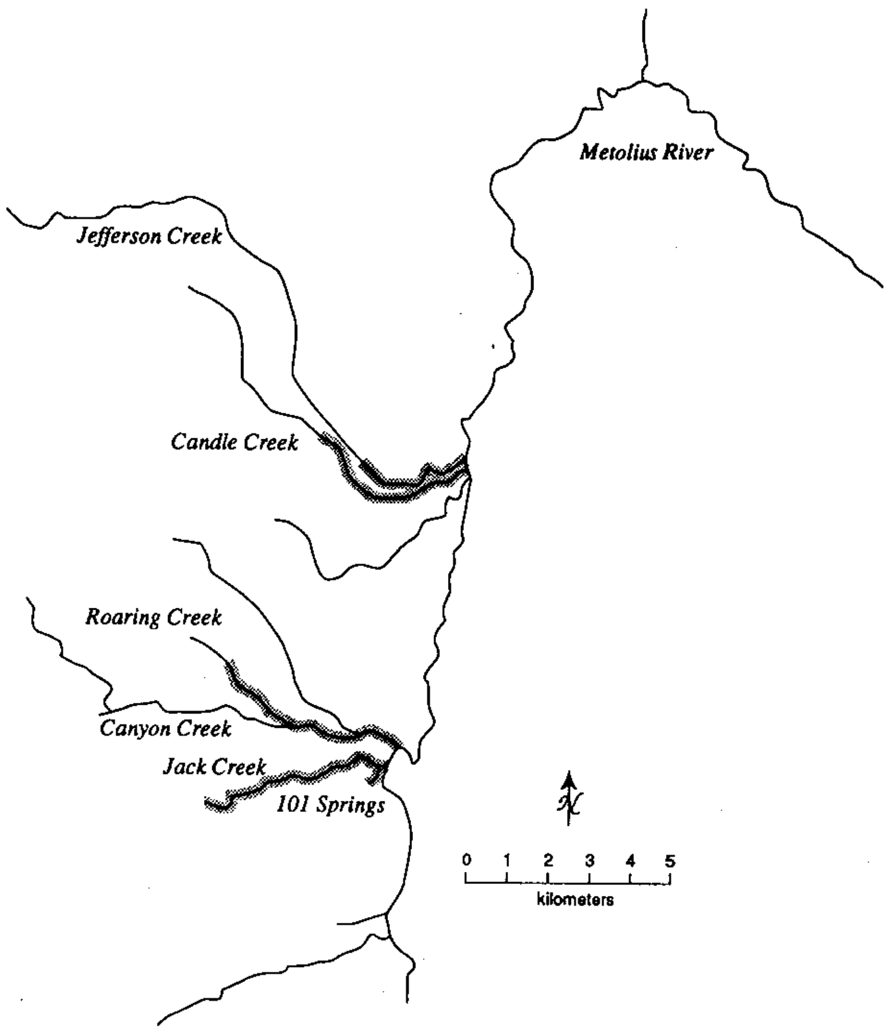

FIGURE 4.-- Spawning areas of bull trout in the Metolius River System.

Some spawning kokanee from Lake Billy Chinook used the lower reaches of Canyon, Candle, and Jefferson creeks. This may have obliterated some bull trout redds, especially in 1988 when kokanee were especially abundant. Peak kokanee spawning activity seemed to occur approximately 2 weeks later than peak bull trout spawning during 1988. Although there was considerable overlap in spatial distribution between the two species, in general bull trout spawned higher in the tributaries than kokanee.

Acknowledgments

This work would not have been possible without the close cooperation between personnel from PGE, ODFW, the U.S. Forest Service, and the Confederated Tribes of the Warm Springs Reservation of Oregon. Numerous volunteers participating in the ODFW Salmon-Trout Enhancement Program (STEP) from the Central Oregon Flyfishers, the Deschutes River Chapter of Trout Unlimited, and the Camp Sherman community also helped. Thanks to Len Mathisen of Bend who researched old files and newspapers to provide the historical information on bull trout distribution in the Deschutes River basin. Special thanks also to Ted Fies, ODFW District Biologist, who did early fish tagging in the Metolius River, provided valuable guidance for these studies, coauthored a progress report, and provided critical review of this manuscript. Thanks to Milton Hill, ODFW, for providing the maps.

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Malheur River Bull Trout Investigations

ROBERT C. BUCKMAN
Oregon Department of Fish and Wildlife
Hamlet Rt., Box 360, Seaside, OR 97138

WILLIAM E. HOSFORD
PAM A. DUPEE
Oregon Department of Fish and Wildlife
P. O. Box 8, Hines, Oregon 97738

Abstract. -- Bull trout *Salvelinus confluentus* populations and habitat in the North Fork and Middle Fork Malheur River were surveyed in 1989 and 1990. Bull trout were found in Little Crane, Elk, Sheep, and Swamp creeks and main stem of the North Fork system and Lake and Big creeks and Meadow Fork of Big Creek in the Middle Fork system. No bull trout were found in the Little Malheur drainage. Brook trout *S. Fontinalis* were widely distributed in the Middle Fork streams where bull trout occur. Tributaries containing bull trout had very cold water averaging about 45°F during summer, forested watersheds, and abundant instream woody debris. Only 4 bull trout were observed during creel surveys. Threats to these populations include land and water management activities, primarily unscreened water diversions, timber harvest, and grazing; loss of larger adults in main stem reaches; interactions with brook trout in the Middle Fork system; and potential increases in water temperatures and reduced future recruitment of woody debris as a result of forest fires.

Introduction

Bull trout *Salvelinus confluentus* in the continental United States have been the subject of increasing concern in recent years because of susceptibility of their habitats to human influence. This concern is particularly acute in the Malheur drainage because it is near the southern periphery of bull trout distribution and because of the intense land management activities occurring in the Malheur National Forest that threaten their habitat.

Historically, the Malheur River drainage contained indigenous bull trout in both the upper North and Middle forks. The populations in the two forks have been isolated from each other since dam construction in the early 1900s and are thus managed and considered as separate populations. Although the Little Malheur may have had bull trout historically, there is very little evidence that they persisted after settlement of the area. Larry Bisbee, Hines District Fish Biologist, Oregon Department of Fish and Wildlife (ODFW), during 1954-1971, and Cecil Langdon, Ontario District Wildlife Biologist, ODFW, during mid-1950s-1976, were unaware of any bull trout in the Little Malheur drainage.

Bull trout are a Category II species under the Endangered Species Act, which means more information is needed on this species before a determination of threatened or endangered status can be made. Bull trout are also on the review list for Oregon threatened and endangered species compiled by the Oregon Natural Heritage Data Base (1987), the ODFW sensitive species list, and the U.S. Forest Service (USFS) (Region 6, Oregon and Washington) sensitive species list. According to the USFS Manual (U.S. Forest Service 1986), an analysis of effects of proposed forest management activities on sensitive species and their habitat is required, and special management considerations will be given to them. U.S. Bureau of Land Management (BLM) policy directs protection and enhancement of the habitat for Category II species to prevent them from becoming listed as threatened or endangered (BLM 1988).

The Malheur National Forest Plan designated bull trout as an indicator species for non-anadromous fish and riparian habitat on the Forest (USFS 1990). The assumption is that management activities that affect bull trout will affect a variety of other species in the same or similar habitat. Likewise, measures to protect the indicator species will protect other species as well.

Prior to 1989, fish resources and habitats in the Malheur drainage had only been partially inventoried. The best information available came from physical and biological surveys of the North Fork Drainage in 1972 (ODFW unpublished) and an ODFW survey of the fish populations in the main stem of both the North and Middle forks in 1982-83 (Pribyl and Hosford 1985). While this information is very useful, it is not sufficient to make current assessments of the status of bull trout populations and management decisions that will assure their continued existence.

This paper provides the results of inventories undertaken in the summers of 1989 and 1990 to provide better information on Malheur bull trout populations.

Specific information collected in 1989 includes:

1) Fish population surveys and habitat inventories for possible bull trout habitat in tributaries to both the North and Middle Forks of the Malheur River,
2) Fish population surveys in areas of the North Fork and Middle Fork main stems that could potentially contain bull trout,
3) Physical and biological surveys in the upper Middle Fork drainage to complete baseline surveys for this drainage,
4) A creel survey designed to get general descriptive information on fisheries in the upper Malheur River drainage.

In 1990 physical and biological surveys were completed for the Little Malheur drainage above Forest Road 16. Irrigation diversions in the upper Malheur drainage were also sampled.

This paper also describes forest fires that occurred in 1989 and 1990 in the upper Malheur River basin and their potential effects on bull trout habitat.

Description of Area

The Malheur River contains bull trout habitat in the drainages of the North Fork Malheur River above Beulah Reservoir and the Middle Fork Malheur River above the Drewsey Valley (Figure 1). These areas cover about 500 square miles and represent about 10 percent of the entire Malheur River basin.

The North Fork Malheur River headwaters originate in the Blue Mountains about 160 river miles upstream from the confluence of the Malheur and Snake rivers. Several spring-fed tributaries with very cold water enter the main stem creating habitats suitable for bull trout in the upper 20 miles of the drainage. The main stem North Fork Malheur is free flowing downstream to Beulah Reservoir, about 40 miles below the headwaters.

Water quality in the main stem North Fork Malheur is maintained to some extent by the spring-driven tributaries, but it is negatively impacted by diversion of water to streamside meadows for livestock forage production. Low summer flows in the upper North

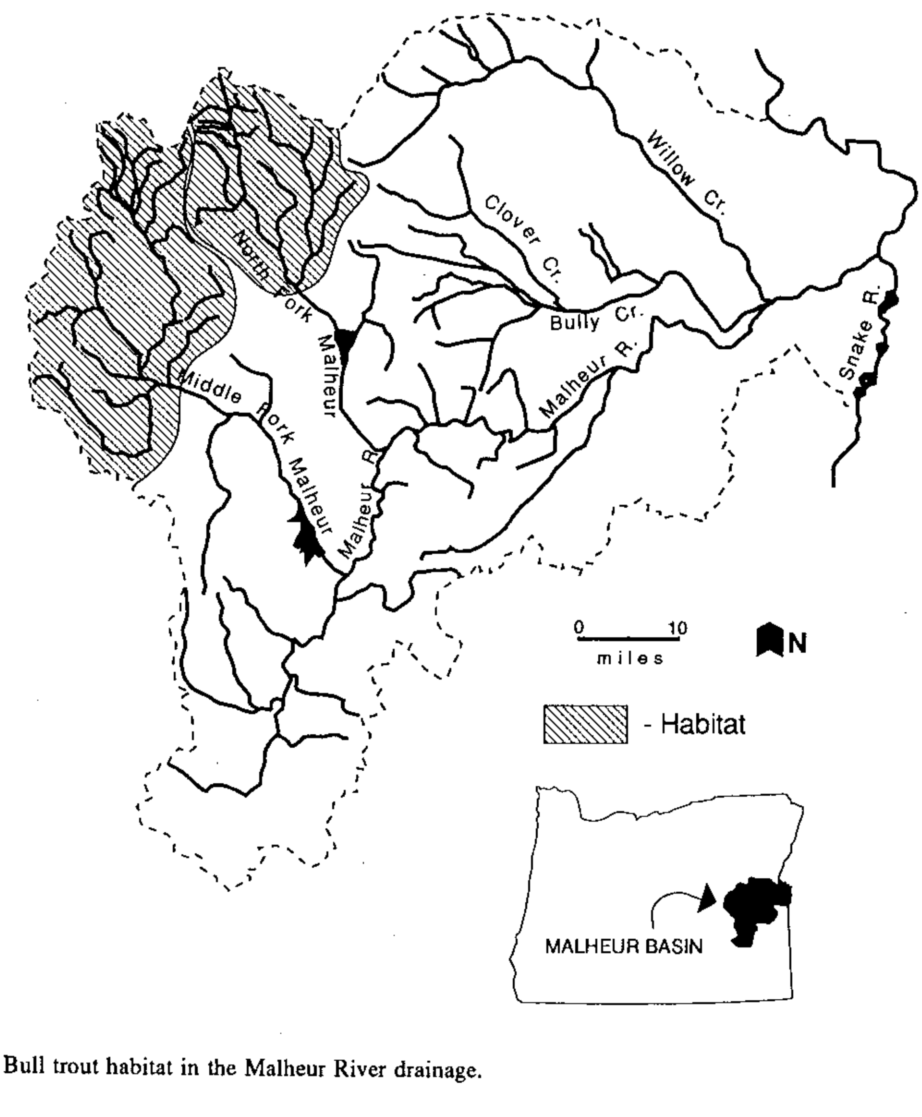

FIGURE 1. Bull trout habitat in the Malheur River drainage.

Fork tributaries are typically an estimated 1 to 5 cubic feet per second (cfs) in most areas suitable for bull trout. The upper main stem North Fork Malheur has low summer flows of 20 cfs near the Forest Road 16 bridge crossing (river mile (RM) 53) and 35 cfs below the mouth of Crane Creek (RM 44).

The Little Malheur River flows south from headwaters in the Monument Rock Wilderness for approximately 29 miles before it enters the North Fork Malheur (RM 29) 8 miles above Beulah Reservoir. The upper 9 miles (RM 20-29) of the drainage are within the wilderness. The river is spring-fed by several tributaries above the USFS boundary at USFS Rd 16 crossing (RM 18). Summer flow was measured at 2.3 cfs at the crossing in 1990. Much of the lower 20 miles of the Little Malheur is diverted for hay production on private land. Overall, streamflow decreases in downstream areas due to increasing numbers of diversions, thus lowering water quality and quantity and reducing habitat for coldwater fish.

The Middle Fork Malheur River headwaters are located on the south slope of the Strawberry Mountains, about 200 RM upstream from the Snake River. A series of tributary streams (McCoy, Big, Lake, and Bosenburg creeks) flow south from the Strawberry Mountains before converging at the southern edge of Logan Valley where they become the main stem Middle Fork Malheur. In the forested areas above Logan Valley, these tributaries are generally pristine with cold water the entire year because of a heavy groundwater contribution to the flow. As the tributaries pass through Logan Valley, the water quality deteriorates rapidly because of irrigation withdrawals, livestock use, and poor riparian habitat. The main stem continues south from Logan Valley for about 20 miles through forest and rangeland without substantial change before it enters the Drewsey Valley where heavy irrigation withdrawals reduce flow and increases in water temperature make the stream unsuitable for bull trout. Summer flow measured at Dollar Basin on the Middle Fork Malheur River is 20 cfs.

The USFS manages most of the land in the Malheur drainage where bull trout habitat occurs. The exceptions include some private holdings in high elevation meadows such as Logan Valley, Summit Prairie, and Crane Prairie, and a mix of BLM and private ownership on the North Fork Malheur for the 15 miles of river immediately above Beulah Reservoir. The principal land uses in the area include timber harvest, livestock production, and recreation.

Major forest fires occurred in the drainages containing bull trout in the upper Malheur River system during 1989 and 1990. The fires occurred after survey work for both years was completed. The Glacier Complex fire in 1989 burned 12,000 acres in portions of Sheep and Swamp creek drainages (North Fork Malheur drainage). The Sheep Mountain fire in 1990 burned an additional 11,302 acres in the headwaters of Sheep, NF Elk, SF Elk, and Little Crane creeks (North Fork Malheur drainage). Most of the burned area was above the known distribution of bull and redband trout *Oncorhynchus mykiss*. However, the fires have the potential to significantly impact the water quality within these stream systems through increased temperature and sedimentation.

The Snowshoe Fire burned 12,026 acres in the Big Creek watershed (Middle Fork Malheur drainage) in 1990 but did not burn with the intensity of the Sheep Mountain fire. It is anticipated that Big Creek water quality will be impacted similarly because of the loss of vegetative cover.

Methods

Fish Population Inventories

Surveys in 1989 were designed to describe the distribution and population characteristics of bull trout throughout the Malheur River drainage. Streams were surveyed that were thought to be possible bull trout habitat based on a review of previous inventories and an assessment of the suitability of the habitat for bull trout.

Sampling techniques were dependent on the size of the stream. Most tributaries streams were small enough to allow sampling with a backpack electroshocker. Larger tributaries and the main stems were too large to be effectively electrofished using the backpack units, so snorkeling was used to inventory the fish populations.

Throughout the areas to be sampled with backpack electrofishing gear, specific sample sites were systematically placed at intervals between 0.7 and 1.0 miles. At each sample site a stream segment (usually 100 yards) was cordoned off with blocking seines. One pass was then made through the section going in an upstream direction with a Coffelt 700 volt backpack electrofishing unit. Species and fork length were recorded for all fish that could be captured.

In the main stems, snorkeling sample sites were selected in habitat throughout the possible bull trout distribution. The sites were not spaced evenly because it was felt more intense sampling was needed in some areas than others. Below Crane Creek, the North Fork is relatively homogeneous for about 8 miles so only two sites were sampled in this area. Above Crane Creek the North Fork is more variable and hatchery trout are present so it was necessary to have more sample sites. At each sample site, stream lengths between 0.25 and 1.0 miles were snorkeled while moving in an upstream direction. For all fish observed, species were identified and lengths estimated. All snorkeling was conducted during daytime hours.

In 1990 the Little Malheur River drainage and irrigation diversions in the upper Malheur River drainage were sampled with a Dirigo 1000 volt backpack electroshocker without blocknets. Segments of stream, each with similar physical attributes (i.e., constraint, land-use, gradient, riparian condition, etc.)

were sampled. Within each stream segment or reach, a single pass was made in each of at least three fast water and slow water habitats. Samples were taken while going in an upstream direction. Numbers and sizes of each species captured were recorded.

Habitat Inventories

At each backpack electrofishing site in the 1989 survey a series of habitat measurements were made in conjunction with the fish sampling (Table 1). In addition, at each of the electrofishing sample sites several 35mm slides were taken of the stream channel and streamside vegetation.

In 1990 quantitative habitat surveys were conducted on the upper Little Malheur River and its tributaries above RM 18 using a methodology modified from Hankin and Reeves (1988).

TABLE 1.--Habitat characteristics collected for each electrofishing site in the upper Malheur River drainage in 1989.

Habitat Characteristic	Criteria
Length of section	Measured at thalweg
Stream width	Average at transect
Elevation	From USGS maps
Maximum depth	Average max. at transect
Water temperature	Measured at time of survey
Streamflow variation	Binns method
In-stream wood number	Index value
In-steam wood size	Index value
Gradient	Index Value
Streamside vegetation	
Percent trees	Based on visual estimates
Percent shrubs	Based on visual estimates
Percent forbes	Based on visual estimates
Percent grass	Based on visual estimates
Percent none	Based on visual estimates
Stream substrate	
Percent cobble	Based on visual estimates
Percent gravel	Based on visual estimates
Percent silt	Based on visual estimates

Creel Survey

Sufficient manpower was not available to conduct a full statistical creel so effort was directed at sampling anglers during peak use periods. Anglers were sampled both when in the process of fishing and while at camping areas near the stream. The species, number, and size of fish in the catch were recorded along with amount of effort expended, gear used, and place of residence.

Results

North Fork Malheur

Fish Populations: In the North Fork drainage, 35 sites on tributary streams were sampled for fish populations and corresponding habitat characteristics. An additional 11 sites on the main stem were sampled for fish populations only.

Bull trout were found in five separate tributary streams in addition to the main stem (Table 2, Figure 2). Four of the five tributaries containing bull trout (Little Crane, Elk, Sheep, and Swamp creeks) all had multiple age classes and populations distributed over at least a mile of stream. These four streams probably serve as the only bull trout spawning and juvenile rearing areas in the system. Flat Creek, the other tributary containing bull trout, had only two fish at the lowermost sample site. These fish may have moved into this stream from other locations rather than resulting from spawning in this stream. Bear Creek was the only major tributary not sampled based on a consideration of bull trout habitat needs.

The main stem of the North Fork Malheur had only a scattering of larger size bull trout that were found in the vicinity of tributaries used by bull trout for spawning. These main stem habitat may be selected because of cooler temperatures. No bull trout were observed in the main stem downstream from the mouth of Crane Creek. This was in contrast to the 1982-83 inventory, which showed moderate bull trout abundance in these locations (Pribyl and Hosford 1985).

The size distribution of bull trout in tributaries and the main stem is shown in Figure 3. It appears that bull trout spawn in the tributaries where they rear for some time before moving into the main stem. It is not known if all bull trout migrate downstream into the main stem or if a component of the population residualizes and completes its entire life history in the tributaries.

Redband trout were the most widely distributed fish species encountered in the areas inventoried. They were found in all areas with the exception of some of the tributaries headwaters.

Limited numbers of hatchery legal-sized rainbow trout from the stocking in the main stem one month earlier were still present. Most of these fish were observed around the upstream fringe of the stocking area rather than in the main stocking location at North Fork Campground.

No brook trout *S. fontinalis* were found in the North Fork drainage. Whitefish *Prosopium williamsoni* were abundant throughout most of the main stem North Fork Malheur but were absent from all of the tributaries with the exception of lower Crane Creek. Most of these fish were between 12 and 16 inches in length. No brook trout *S. fontinalis* were found in the North Fork drainage. Whitefish

TABLE 2.-- Summary of fish observations in the North Fork Malheur River drainage during the summer of 1989.

Location	Sample sites	Number observed[a]							
		BUT	RBW	RBH	WF	COT	SU	D	RSS
Swamp Cr.[b]	5	37	4	0	0	26	0	0	0
Cow Cr.	2	0	4	0	0	12	0	0	0
Sheep Cr.	3	17	6	0	0	0	0	0	0
Elk Cr.[c]	4	18	4	0	0	2	0	0	0
Little Crane Cr.	7	13	29	0	0	10	0	0	0
Crane Cr.	8	0	103	0	4	148	0	0	0
Flat Cr.	3	2	30	2	0	55	0	0	0
Spring Cr.	3	0	42	0	0	34	0	0	0
Upper NF main stem above FS rd 16	5	3	136	16	30	50	0	0	0
Middle NF main stem (RM 422--50)	6	1	100	7	316	4	3	10	0
Lower NF main stem	1	0	109	0	162	8	250	30	275

[a] BUT - bull trout; RBW - redband trout; RBH - hatchery rainbow trout; WF - mountain whitefish; COT - cottid; SU - sucker; D - dace; RSS - redside shiner.
[b] Does not include sampling from after the burn.
[c] Includes the north and south forks of Elk Creek.

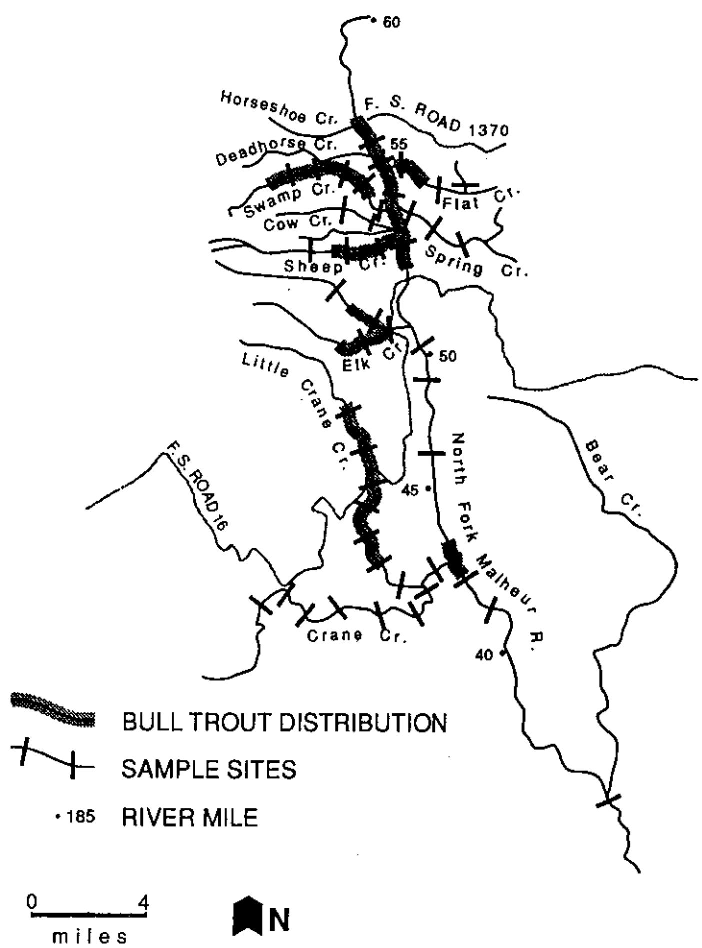

FIGURE 2. -- Distribution of bull trout in the upper North Fork of Malheur drainage based on sampling observations, summer 1989.

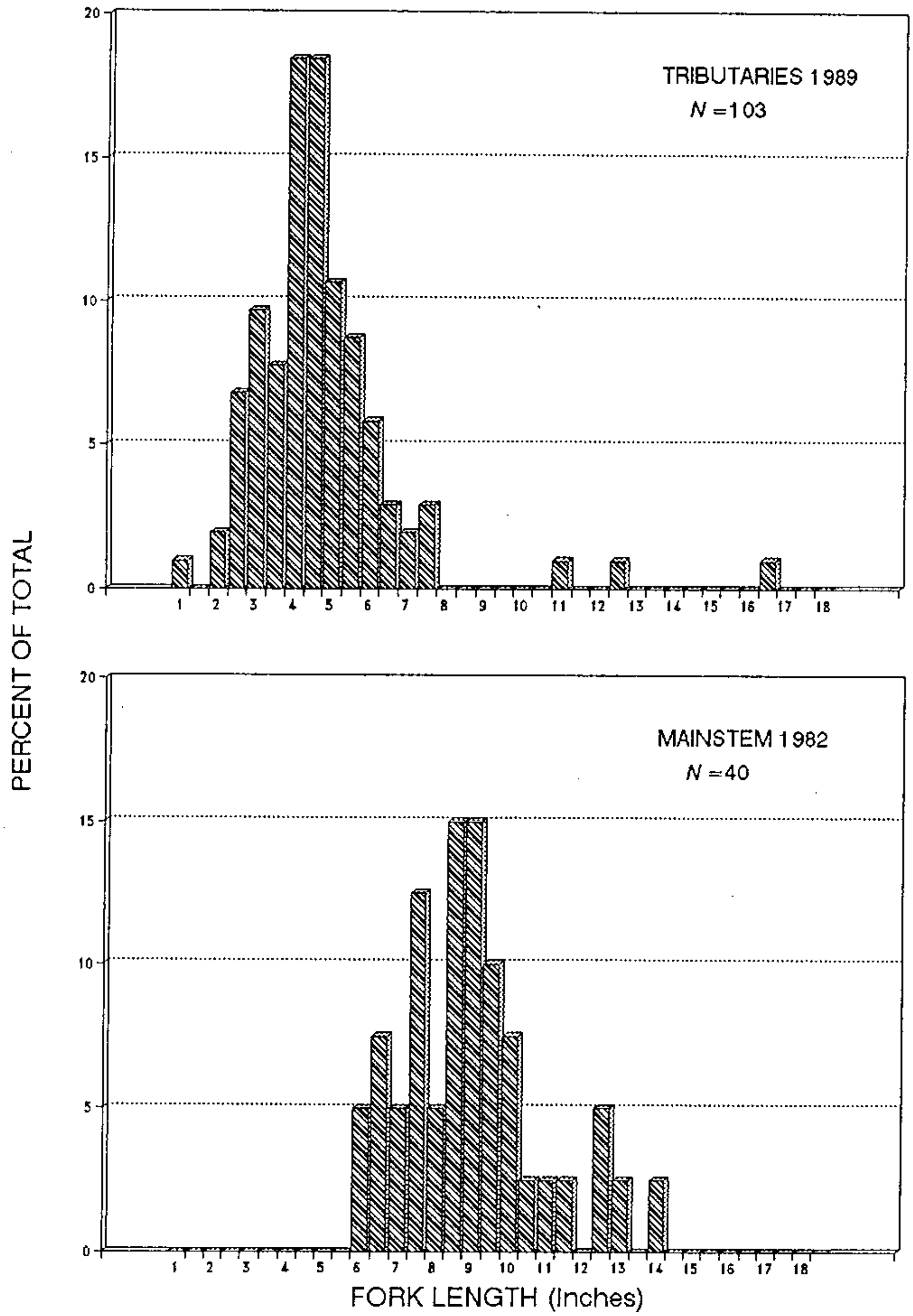

FIGURE 3. -- Length-frequency distribution of bull trout in the North Fork Malheur drainage, 1982 and 1989.

Prosopium williamsoni were abundant throughout most of the main stem North Fork Malheur but were absent from all of the tributaries with the exception of lower Crane Creek. Most of these fish were between 12 and 16 inches in length.

Nongame fish other than cottids *Cottus* spp. were not observed in any of the tributaries or main stem sample sites above the mouth of Crane Creek. The only location where nongame fish were abundant was the lower main stem site, where dace *Rhinichthys* spp., shiners *Richardsonius* spp. and suckers *Catostomus* spp. were numerous.

Habitat Inventory: The habitat measurements taken at each fishery backpack electrofishing site can be used to characterize the tributary streams where bull trout were present and to contrast these locations with areas where bull trout were absent (Tables 3 and 4). The tributary sites with bull trout had significant groundwater base flows in forested settings, an abundance of in-stream woody debris, very cold water, and excellent water quality.

TABLE 3.-- Average and range of values for habitat characteristics at 13 tributary sample sites containing bull trout in the North Fork Malheur drainage.

Habitat characteristics	Average	Minimum	Maximum
Width (ft)	10.0	6.4	15.1
Max. depth (ft)	0.94	0.7	1.3
Elevation (ft)	5,554	4,960	6,200
Water temp. (°F)	46	41	51
Streamside vegetation			
Percent trees	19	5	30
Percent shrubs	27	5	40
Percent forbes	26	15	40
Percent grass	21	10	40
Percent none	7	5	15
Stream substrate			
Percent boulder	19	5	40
Percent cobble	33	18	40
Percent gravel	30	18	50
Percent silt	18	10	43

The main stem habitat was not quantitatively inventoried, but general observations were made during the course of fish sampling. Most notable was an apparent enrichment of the stream in the stretch of about 10 miles from the Forest Road 16 crossing downstream to a few miles below Crane Creek. In this area the stream bottom was covered by an algal layer and water clarity was reduced. The algal layer appeared to reduce aquatic insect production as evidenced by the low abundance of insects among the boulder and cobble substrate. The source of the enrichment in this area may have been the livestock grazing in the irrigated streamside meadows. Other observations on main stem habitat supported previous assessments that pool habitat was lacking (Pribyl and Hosford 1985).

Spot checks in recent years indicate peak summer water temperatures of more than 70°F in the areas below Forest Road 16 crossing. Complete information needed to profile water temperatures in the upper North Fork Malheur is not available.

Creel Inventory: Only 1 bull trout was reported in the catch of 63 anglers checked on the upper North Fork Malheur main stem during 1989 (Table 5).

TABLE 4.-- Characteristics of streams with and without bull trout at sample sites on tributaries to the North Fork Malheur River sampled during the summer of 1989. Average values are shown except for wood.

Stream characteristic	Bull trout present	Bull trout absent
Width (ft)	10.0	10.0
Maximum depth (ft)	0.9	0.8
Water temperature (F)	46	52
Wood index--number of pieces[a]	4.0	3.0
Wood index--size[b]	2.3	1.8
Other salmonids present (number)	2.7	8.5

[a] 1 = none, 2 = 1 - 5, 3 = 6 - 10, 4 = 11 - 15, 5 = 16 - 50, 6 = > 50.

[b] 1 = 0 - 5 inches, 2 = 6 - 10 inches, 3 = > 10 inches.

TABLE 5.-- Summary of creel checks on the Upper North Fork Malheur River and the Little Malheur River, 1989.

Location	Anglers checked	No. of fish caught: BUT	RBW	RBH	WF	Total
NF Malheur R.	63	1	39	128	0	168
Little Malheur R.	22	0	8	34	0	42

Little Malheur River

Fish Populations: In the upper Little Malheur drainage, 18 sites on Camp, Larch, South Bullrun, and Rock creeks, an unnamed tributary to the Little Malheur, and 14 sites on the main stem were sampled by backpack electroshocker. Canteen and Lunch creeks were dry. Bull trout were not found in any of the sample sites.

Habitat Inventory: An evaluation of the habitat showed that the present habitat is probably not sufficient to support bull trout in the Little Malheur River main stem nor its tributaries. Midday water temperatures were marginal to high (>52°F), streamflow was low (2.3 cfs) in the lower river, and exposure to sunlight was considerable (approximately 50%) for most of the river and variable for the tributaries(30-70%). Pool habitat was lacking, maximum water depth was low (1.8 feet), and the river and tributaries were narrow (about 9 feet and 3-6 feet, respectively). The entire drainage is accessible to livestock. The lower 5.5 miles and the upper 1.5 miles of the Little Malheur (above Rock Creek) and all of Camp Creek are heavily grazed.

Middle Fork Malheur Drainage

Fish Populations: In the Middle Fork Malheur drainage, 37 tributary sample sites were electrofished, four tributary sites were snorkeled, and two main stem sites were snorkeled. Lake and Big creeks and Meadow Fork of Big Creek were the only streams that contained bull trout (Table 6, Figure 4).

Redband trout were widely distributed in the upper Middle Fork Malheur and its tributaries and were small in size. Redband trout were absent were in the downstream sections of Big Creek, Lake Creek, and McCoy Creek. These areas are all in the southern end of Logan Valley where habitat is badly degraded by heavy diversion of water for irrigation and lack of riparian vegetation from livestock use.

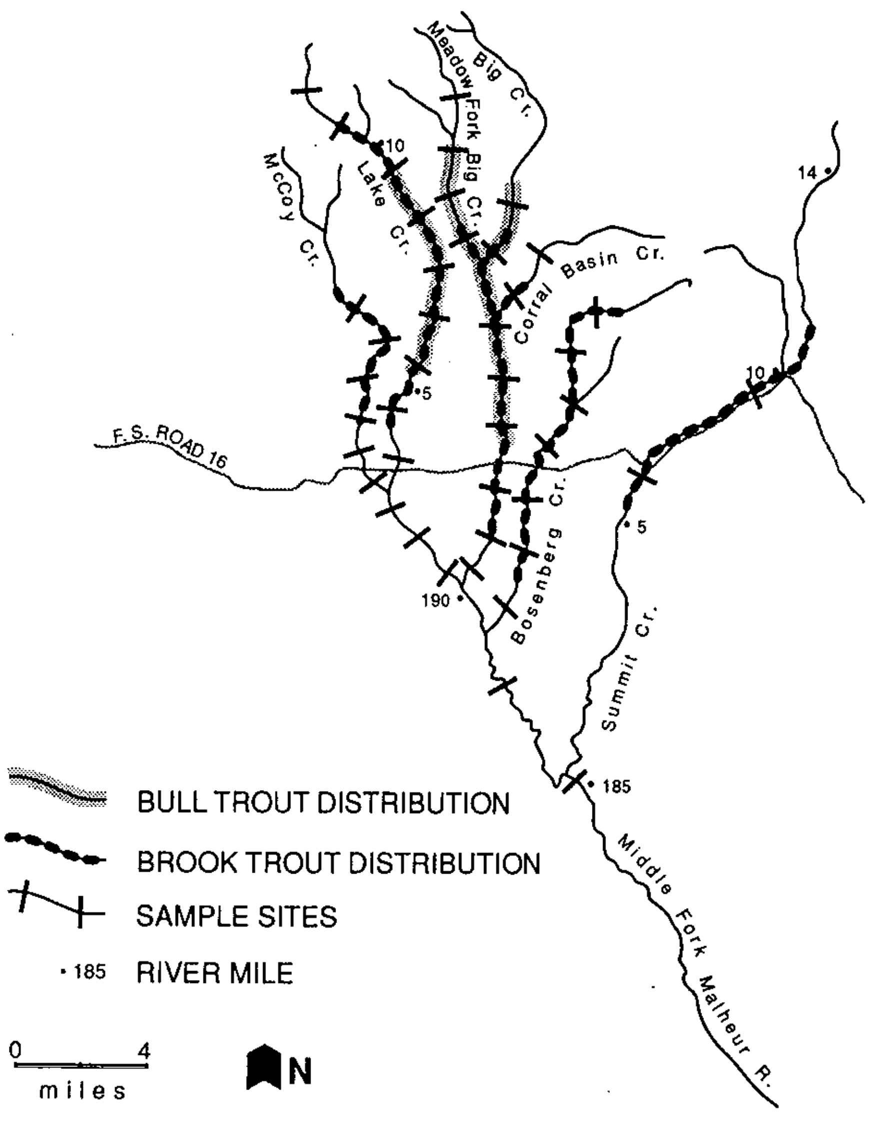

FIGURE 4. -- Distribution of bull trout and brook trout in the Middle Fork Malheur River. Estimates based on sampling observations during the summer of 1989.

TABLE 6.-- Summary of fish observations in the Middle Fork Malheur drainage, summer 1989.

Location	Sample sites	Number of fish								
		BUT	RBW	RBH	BT[a]	WF	COT	D	SU	RSS
McCoy Cr.	6	0	22	0	95	0	113	307	7	42
Lake Cr.	12	5	9	0	138	0	176	188	5	132
Big Cr.	8	30	124	0	191	12	61	10	0	0
Meadow Fork	4	46	6	0	4	0	13	0	0	0
Corral Basin Cr.	2	0	2	0	6	0	6	0	0	0
Bosenberg Cr.	7	0	18	0	105	0	88	229	7	34
Summit Cr.	2	0	16	0	22	0	0	35	5	4
Main stem RM 185-188	2	0	36	15	0	35	1	1,331	0	143

[a]Brook trout

Introduced brook trout were also widely distributed in the middle section of all tributary streams sampled (Figure 4). The only areas that contained bull trout but not brook trout were the upper site on Big Creek and the upper three sites on the Meadow Fork of Big Creek. This absence of brook trout may be due to the very cold water or natural velocity barriers. The other area devoid of brook trout was the lower end of Logan Valley probably because of poor water quality. The only stream where bull trout were abundant and were not outnumbered by brook trout was the Meadow Fork of Big Creek. In this stream, good bull trout populations existed within 2 to 3 miles of habitat. The size of bull trout was uniformly small, with the exception of a single site on Big Creek that had large beaver ponds (Figure 5). Brook trout up to nine inches in length were found in the upper Middle Fork Malheur in 1989.

In Lake Creek, Big Creek, and Meadow Fork of Big Creek where brook trout and bull trout populations overlap, apparent bull trout x brook trout hybrids were observed. Samples of these fish from the Meadow Fork of Big Creek were verified to be hybrids (Markle 1992).

The only tributary site with whitefish was on Big Creek near the campground. Whitefish were also observed at both sample sites on the main stem Middle Fork Malheur.

Nongame fish were the only fish present at the sites in the southern part of Logan Valley where water quality is apparently unsuitable for salmonids.

Habitat Inventory: The habitat observations at each electrofishing site showed that bull trout habitat in the upper Middle Fork Malheur tributaries is generally similar to that in North Fork tributaries (Tables 7 and 8). Locations with bull trout had cold water, heavy groundwater inflow, steep gradients, forested settings, and an abundance of in-stream woody debris. The bull trout also were more abundant at locations where other fish species were less numerous and were completely absent at all sites with dace, shiners, or suckers. The

TABLE 7.-- Average and range of values for habitat characteristics at seven tributary backpack electrofishing sites containing bull trout in the upper Middle Fork Malheur drainage, 1989.

Habitat characteristic	Average	Min.	Max.
Width (ft)	14.7	12.1	18.3
Max. depth (ft)	0.9	0.6	1.1
Elevation (ft above MSL)	5,749	5,200	6,080
Water temperature (°F)	44	39	52
Streamside vegetation			
Percent trees	25	15	30
Percent shrubs	21	10	30
Percent forbes	27	20	40
Percent grass	19	10	30
Percent none	6	0	10
Stream substrate			
Percent boulders	18	5	30
Percent cobble	41	35	50
Percent gravel	31	30	50
Percent silt	10	5	20

TABLE 8. Characteristics of streams with and without bull trout at sample sites on tributaries to the Middle Fork Malheur sampled in 1989. Average values are shown except for wood (See Table 4).

Stream characteristic	Bull trout present	Bull trout absent
Width (ft)	14.7	9.9
Maximum depth (ft)	0.9	0.8
Water temperature (°F)	44.1	53.9
Wood--index for no. of pieces	5.1	2.9
Wood size--index value	2.3	1.4
Other salmonids present (number)	9.5	13.0

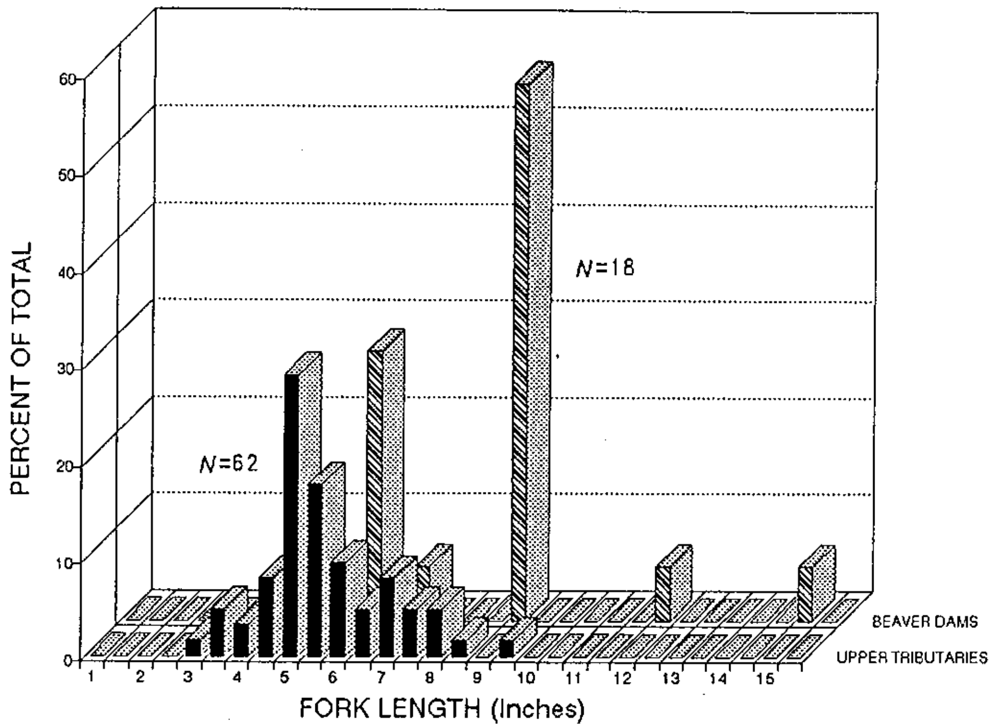

FIGURE 5. -- Length-frequency distribution of bull trout in the tributaries of the Middle Fork Malheur drainage, 1989.

stream reaches where nongame fish were abundant had poor riparian vegetation and had almost no in-stream woody debris or boulders.

Creel Inventory: A total of 57 anglers were checked on the Middle Fork and its tributaries (Table 9). Hatchery rainbow were the predominant fish in the catch. The only bull trout observed were three small fish caught by a single angler in the Meadow Fork of Big Creek.

Evidence of angler activity observed in the course of fish population sampling indicated that some angling occurred in the tributary areas occupied by bull trout. This was not surprising because of the larger size of Lake and Big creeks, the easy access, and the proximity of these streams to campgrounds, which make these areas attractive to anglers.

TABLE 9.-- Summary of creel checks on the upper Middle Fork Malheur River during 1989.

		Number of fish caught				
Location	Anglers checked	BUT	RBW	RBH	WF	BT
Main stem	38	0	92	70	4	0
Tributaries	19	3	8	33	0	12

Irrigation Diversions

Eight irrigation diversions were sampled in Logan Valley (Middle Fork drainage) and on the North Fork Malheur River. These diversions were unscreened and diverted by heavy plastic or burlap, averaged 0.75 miles in length, and had flows year-round. Bull trout were found in the Swamp Creek diversion (Table 10). In Logan Valley, one 6-inch bull trout was found in Big Creek diversion #1. Brook trout were the most numerous and widely distributed trout species occurring in the diversions in Logan Valley.

Flows were measured in each of the eight diversions and in the streams from which they were diverted (Table 11). The amount of streamflow diverted varied from 7% to 95%.

Discussion

North Fork Malheur

The fish resources of the North Fork drainage have been substantially altered by a variety of human influences including the loss of anadromous chinook salmon *O. tshawytscha* and steelhead trout *O. mykiss*. The North Fork Malheur bull trout population is of concern because of habitat loss. The long term prognosis for the stock is unclear. The existence of bull trout in four separate tributary streams with multiple age classes over at least a mile of habitat in each stream provides some assurance against any single

TABLE 10.--Number of fish sampled from irrigation diversions on the North Fork and Middle Ford Malheur River in 1990.

Diversion	Species[a]									
	RBW	BUT	BT	FRY	SD	LND	COT	RSS	BSU	SU
Middle Fork Malheur										
Big Cr. #1	0	1	227	0	3	0	3	0	0	1
Big Cr. #2	0	0	5	1	4	0	4	0	0	0
Big Cr. #3	0	0	15	0	0	0	5	0	0	0
Lake Cr. #1	1	0	17	0	37	3	10	1	0	0
McCoy Cr. #1	0	0	4	0	188	0	0	181	3	0
North Fork Malheur										
Swamp Cr. #1	1	2	0	0	0	0	0	0	0	0
NF Malheur #2	3	0	0	4	0	0	0	0	0	0
NF Malheur #3	17	0	0	0	0	0	66	0	0	0

[a] FRY - trout fry; SD - speckled dace; LND - longnosed dace; BSU - bridgelip sucker.

TABLE 11.-- Flows (cfs) of diversions in the North Fork and Middle Fork Malheur drainages sampled in 1990.

Location	Flow	Percentage of stream diverted
Middle Fork Malheur		
Lake Cr. #1	0.59	32
McCoy Cr. #12	0.61	78
Big Cr. #1	3.81	95
Big Cr. #2	0.29	7
Big Cr. #3	3.20	54
North Fork Malheur		
Swamp Cr. #1	0.79	48
Main stem#2	2.60	18
Main stem #3	1.52	8

natural or human-caused degradation of habitat totally eliminating the populations in the future.

The main stem adult bull trout habitat is essential to maintain something close to the size and age structure of a fluvial bull trout population. The main stem habitat is moderately degraded by the effects of cattle grazing and irrigation withdrawals. The elimination of bull trout in the lower main stem habitats between the 1983 and 1989 sampling could be attributed to habitat degradation as well as the 1987-88 drought. Temperatures in the main stem are probably near the upper limits for bull trout in a normal or wet year and above them in a dry year. Adult bull trout would benefit from land management that will prevent any additional stream temperature increases and remedy factors presently contributing to elevated water temperatures.

A major unanswered question concerning bull trout biology in the North Fork Malheur is the importance of main stem rearing to the viability of the population. If tributary streams can function independently, then priorities for habitat maintenance would be focused in these areas. Dependence on main stem-reared adults would shift priorities toward the main stem where more habitat degradation has already taken place. A migration study is needed to answer questions of the importance of main stem rearing for healthy populations of bull trout.

Some juvenile bull trout moving from the tributaries to the main stem and possibly some adults going back upstream are lost because of unscreened irrigation diversions. The extent of this mortality is not known, but it may be significant in areas such as lower Swamp Creek, where almost all the water is diverted out of the stream.

The fish habitat in several spring-fed tributaries was excellent prior to recent forest fires. These streams are in heavily forested country, have a steep gradient, a lot of woody debris, and extremely cold water. A cooperative effort by USFS and ODFW will be undertaken during the summer of 1991 to re-inventory sample sites to assess the fire's impact on the aquatic communities.

Future habitat alterations in tributaries containing bull trout are a concern. In the downstream areas of several tributaries inhabited by bull trout, habitat potential for bull trout appears good, but the predominant fish species is redband trout. The dominance of redbands in these areas where water is only slightly warmer suggests an increase in water temperature in areas where bull trout are still the principal species could shift the balance toward redbands.

Other indigenous fish species in the upper North Fork Malheur, including redband trout, whitefish, and cottids, are all widely distributed. Management for preservation of bull trout in both the main stem and tributaries will help assure the continued existence of healthy populations of these other species.

Subsequent to the 1989 findings, the stocking of legal-sized rainbow trout was reduced by half and confined to the North Fork Campground (ODFW 1990). It is believed that stocking trout only at the campground, where residualism of the hatchery rainbow was low due to a high harvest rate, will prevent the significant competition between the hatchery trout and bull trout and satisfy angler demand by continuing an established fishery . It will also confine increased fishing pressure created by the release of hatchery trout to a short section of stream.

Elsewhere on the main stem, the creel survey indicated that anglers catch very few bull trout, but the population is sparse so the removal of only a few fish may be unwarranted. As a result of the 1989 investigations and concern about the status of bull trout, the Malheur Basin has been closed to the harvest of bull trout by anglers since March 1991.

Little Malheur

Instream and riparian habitat conditions appear to be unsuited for bull trout in the Little Malheur drainage. Naturally low flows result in high or marginal water temperatures for bull trout. Livestock access throughout the drainage may be further impacting the integrity of the watershed by causing the deteriorating of bank stability, riparian habitat, and water quality.

Middle Fork Malheur

The fish resources of the upper Middle Fork Malheur River drainage have been substantially altered by a variety of human influences. Fish populations have changed due to the loss of anadromous chinook salmon and summer steelhead and the introduction of brook trout, which have become the most common salmonid in the upper basin. Habitat changes include those induced by cattle grazing and irrigation withdrawals. Streams that have lost riparian vegetation have lower summer flows and warmer water temperatures.

Land management activities in Logan Valley have probably eliminated bull trout throughout much of the valley in downstream areas. The last verified observation of bull trout in areas below Logan Valley was in 1960. While angling in the main stem within the first mile below Dollar Basin, Al Polenz caught two or three bull trout, 12 to 14 inches in length, on each of several fishing excursions (Al Polenz, ODFW, Roseburg, personal communication, January 26, 1990).

The future of bull trout populations in the Middle Fork Malheur drainage is precarious. They are found in only three tributary streams, and in two of these they were outnumbered by brook trout. The only areas where bull trout were the dominant fish species were at the uppermost site on Big Creek and in the Meadow Fork of Big Creek.

The composition of fish species undergoes a transition in Logan Valley from exclusively salmonids to predominantly nongame fish. The degradation of habitat in lower Logan Valley and downstream probably eliminated most of the habitat where adult bull trout were historically able to rear to a larger size. The only area in the Middle Fork Malheur drainage where larger adults were found was in Big Creek in and around a series of beaver dams.

Brook trout were widely distributed and may be expanding in their distribution. Brook trout are a major concern because they will interbreed with bull trout and may compete with them for food and space. Every effort should be made to prevent brook trout from becoming established in the areas now occupied exclusively by bull trout. Velocity barriers or dams to keep brook trout downstream would be a consideration except that adult bull trout and other native species migrating upstream would also be blocked.

The hatchery trout releases in the Middle Fork Malheur are made downstream from current bull trout habitat. The releases that have sometimes been made at the Forest Road 16 crossing of Big Creek will be relocated downstream to the main stem where bull trout are not present, as directed in the Malheur Fish Management Plan (ODFW 1990). Since bull trout can no longer be kept by anglers, signs explaining the difference between bull trout from brook trout and showing color photographs of both species have been posted.

In forested areas above Logan Valley, the tributaries occupied by bull trout were in good condition in 1989 prior to the Snowshoe Fire, but the fire may impact these habitats. Extreme care will be needed in the future in this area to prevent any warming of the water and any loss in instream woody structure.

Most of the sections of the large tributaries in the Middle Fork Malheur drainage occupied by bull trout are readily accessible to anglers. The creel survey did not indicate a large catch of bull trout, but the population is small so any removal may be excessive.

Much of the streamflow in the upper Middle Fork subbasin is diverted for irrigation in Logan Valley. The resulting mortality of bull trout and other species is not known, but these losses may be high in areas such as lower Lake Creek and Big Creek. The natural flow of water throughout this area has been altered. Most of the diversions have been used for years, and in many cases it is difficult to distinguish which is the original stream and which is the diversion. If these diversions continue to be used, they must be screened to prevent fish losses.

Recommendations

1. Improve protection of bull trout habitat by reviewing existing timber sales that have not yet been cut and in planning future sales and salvage logging and recovery measures in forest fire areas.

2. Increase consideration of fish resources before developing additional access on USFS land, particularly along the main stem of the North Fork.

3. Reduce fish losses from water diversions on public and private lands.

4. Determine the importance of main stem habitat.

5. Investigate the interaction between bull trout and brook trout in the Middle Fork Malheur and determine methods to prevent detrimental effects on bull trout.

6. Develop standard surveys to assess trends in bull trout populations.

7. Monitor the effects of an angling regulation prohibiting the retention of bull trout.

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Proceedings of the Gearhart Mountain Bull Trout Workshop
Oregon Chapter of the American Fisheries Society, 1992

Evidence of Bull Trout x Brook Trout Hybrids in Oregon

DOUGLAS F. MARKLE
Department of Fisheries and Wildlife
Oregon State University, Corvallis, Oregon 97331

Abstract. -- Specimens from Washington and Oregon were examined to find characters of use in the field identification of Dolly Varden *Salvelinus malma*, bull trout *S. confluentus*, brook trout *S. fontinalis*, and bull trout x brook trout hybrids. No Dolly Varden were found from Oregon. Dolly Varden from northern Washington differ from bull trout in a number of morphological and meristic features, including shorter head and jaw lengths, more prominent parr marks, and a higher, more arched back. In Oregon these forms of *Salvelinus* could be placed into three groups based on dorsal fin color pattern: banded in brook trout, solid in bull trout, and spotted in putative bull trout x brook trout hybrids. Multivariate analyses of morphometric and meristic data supported the three groups, and several univariate observations were consistent with the identification of hybrids. The continued existence of some small relict populations of bull trout may be seriously threatened by the presence and continued introduction of brook trout.

The bull trout *Salvelinus confluentus* (Suckley 1858) is listed as a category 2 species by the U.S. Fish and Wildlife Service (Federal Register 50:37958-37967) and of special concern by the American Fisheries Society (Williams et al. 1990). Category 2 indicates that a proposal to list the species as threatened or endangered may be appropriate, but that current evidence is inconclusive. Two taxonomic aspects of the bull trout's category 2 status are considered here: identification of the species and hybridization with brook trout *S. fontinalis* in Oregon.

At least part of the inconclusive nature of current evidence is simple confusion caused by misidentification with Dolly Varden *S. malma*. Cavender (1978) clarified the very unsatisfactory state of *Salvelinus* taxonomy in western North America by showing that there were three species in the Arctic char complex (Arctic char *S. alpinus*, Dolly Varden *S. malma*, and bull trout). Subsequent chromosome studies by Cavender (1984) and Phillips et al. (1989) have shown that Dolly Varden and Arctic char are probably each other"s closest relatives and that bull trout is a more distant relative (their sister taxon). Despite the long phylogenetic separation implied, bull trout and Dolly Varden are superficially similar and each species is morphologically variable. Consequently, there is considerable confusion in the minds of field biologists about identification of these species. In addition, Cavender (1978), who examined few samples from Oregon, indicated that the distribution of Dolly Varden included California and Washington but not Oregon. Thus, there has been uncertainty regarding the presence of one or two species of native *Salvelinus* in Oregon. The first goal of this study was to determine if there was any evidence of Dolly Varden in Oregon.

A category of evidence often used to list a threatened or endangered species is "natural or manmade factors affecting the continued existence of the species." Hybridization, especially with introduced congeners, often contributes to a species' decline. Hybrids between brook trout and bull trout have been reported from Alberta (Paetz and Nelson 1970), Oregon (Cavender 1978), and Montana (Leary et al. 1983). Leary et al. (1983) used 10 isozyme and 10 meristic characters to identify hybrids and showed that hybrids were more common than previously recognized. Two "possible hybrids" between Dolly Varden and bull trout from British Columbia were also identified by Cavender (1978). Hybrids between lake trout *S. namaycush* and either bull trout or Dolly Varden are not known.

Although hybrids are generally assumed to be intermediate in characters between the parent species, hybrid fishes are often not uniformly intermediate (Neff and Smith 1979). In fact, Leary et al. (1983) reported that hybrid bull trout x brook trout had consistently high, not intermediate, meristic counts. Mean values for nine of ten meristic characters of bull trout x brook trout hybrids were equal to or greater than that of the parent species with the higher value (Leary et al. 1983; 1985). Hybrids could be identified by just two characters: high numbers of pyloric caecae (like brook trout) and high numbers of vertebrae (like bull trout). The second, and primary, purpose of this study was to provide evidence for the existence of bull trout x brook trout hybrids in Oregon and to find characters and distributional information that might be useful for field biologists interested in identifying bull trout and bull trout x brook trout hybrids.

Methods

Standard ichthyological procedures (Hubbs and Lagler 1947) were followed unless noted. Characters selected were based on previous work by Cavender (1978) and Leary et al. (1983) and on the ease with which characters could be unambiguously recorded from radiographs and specimens.

The sex and twelve morphometric characters were recorded: standard length; head length; snout to posterior margin of orbit; upper jaw length; head width at pectoral fins; caudal peduncle depth; and six triangulation measurements: snout to dorsal fin origin; dorsal to pelvic origin; snout to pelvic fin origin; dorsal to anal fin origin; anal to caudal fin base; and dorsal to caudal fin base. Pigmentation of the dorsal and caudal fins were described qualitatively, as discussed in the next paragraph, and the number of spots below the lateral line and between the head and pelvic fin origin were counted. Twelve meristic characters were recorded: pyloric caecae; precaudal, caudal, and total vertebrae (including ural centra); dorsal, anal, pectoral, and pelvic fin rays; upper and lower procurrent caudal fin rays; branchiostegal rays on the right side; and left and right mandibular pores.

Specimens of Dolly Varden from Washington were identified using characters in Cavender (1978) and verified using a discriminant function (Haas and McPhail 1991). Specimens of bull trout, brook trout, and their putative hybrids from Oregon and Washington were identified using color patterns of the dorsal and caudal fins. Specimens with uniformly colored dorsal and caudal fins were classified as bull trout; those with dark and light banding in the dorsal fin were considered brook trout; and specimens with a spotted dorsal fin and, at sizes greater than about 140mm SL, a spotted caudal fin were classified as putative hybrids (Figures 1 and 2). The distinction between bull trout and hybrids was not always well defined. Some nominal bull trout

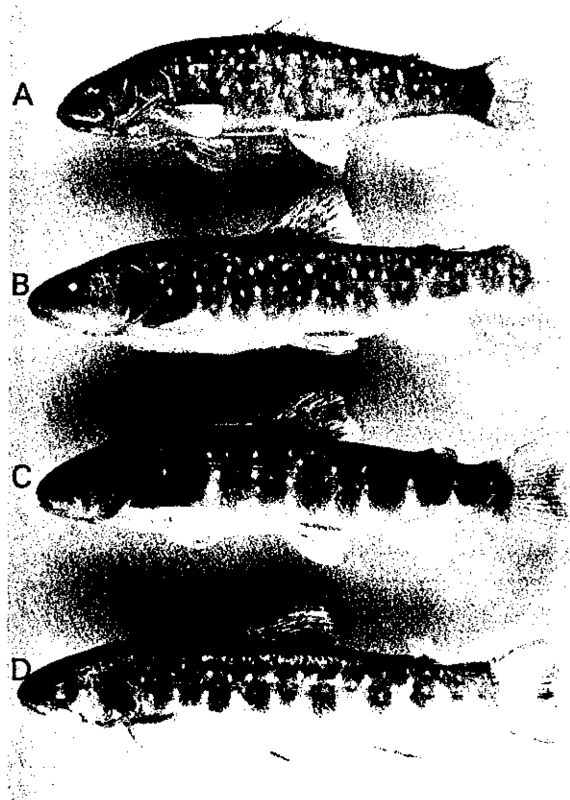


FIGURE 1. -- A. Bull trout, OS 12453, 80.5 mm SL, Malheur River. B. and C. Bull trout x brook trout hybrids, OS 12451, 92.2 and 89.0 mm SL, Klamath R., Long Creek. D. Brook trout, OS 124548, 87.4 mm SL, Klamath R., Long Creek.

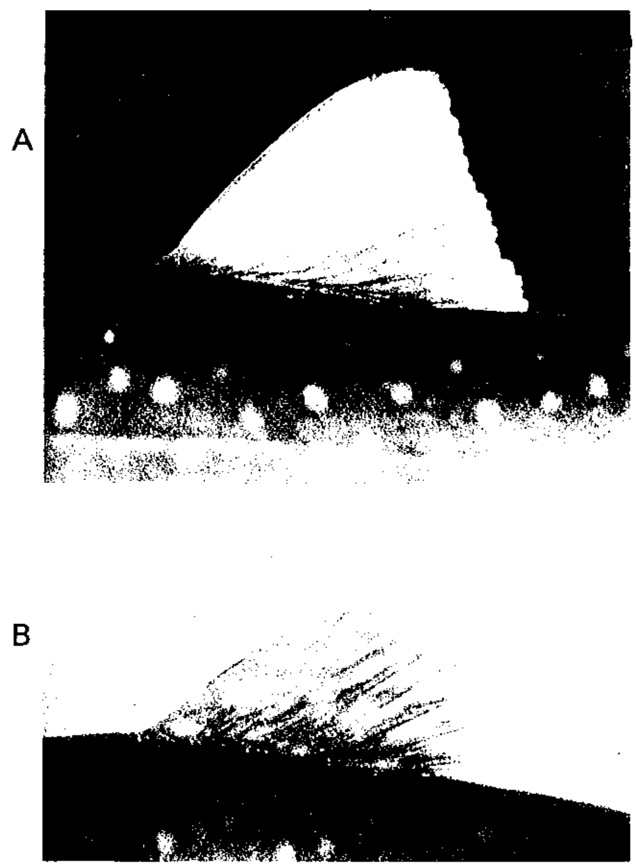


FIGURE 2. -- A. Solid colored dorsal fin of bull trout, OS 12459. 129 mm SL, Metolius R., Jefferson Creek. B. Spotted dorsal fin of bull trout x brook trout hybrid, OS 12452, 144 mm SL, Malheur River.

may have spotting at the fin bases, especially at the fleshy base of the dorsal (for example, CRLA uncataloged, collected 2 Sept., 1989). The analytical approach was to determine if there were other morphological features that would corroborate this classification.

Multivariate analyses were performed on the covariance matrix for morphometric data and on the correlation matrix for meristic data. Principal components analysis (PCA) was used as a descriptive tool, without the assumption of a single multivariately normal population, and, therefore, without statistical inference. The sensitivity of PCA for identification of hybrids depends on "the total variation within the hybrid population (i.e., the width of the hybrid cluster) relative to the distance between the parental species' clusters (Neff and Smith 1979). Discriminant function analysis of three groups (both parents and putative hybrids) was also used as a descriptive tool, despite arguments against its use in hybrid studies. The criticism is based on a problem of circular logic encountered when putative hybrids are based on intermediacy of characters and then confirmed using the same characters (Neff and Smith 1979). In this study, *a priori* group assignments are based on three different dorsal fin color patterns, not on intermediacy of the characters used in the multivariate analysis. The discriminant function analysis provides a function of the original characters that maximizes between group variance relative to within group variance and thus may serve to corroborate *a priori* groups.

The biological interpretation of those groups, whether as species or hybrids, requires additional evidence. The best corroborations for hybridization are laboratory rearing (Neff and Smith 1979) or detection of heterozygosity at loci diagnostic for the parent species (Leary et al. 1983; Campton 1987). Neither approach was possible in this study, rather the multivariate analyses were performed on two data sets, meristic and morphometric, and the *a priori* groups evaluated based on corroboration of both data sets. Analyses were performed using Statgraphics and SAS/STAT.

Total numbers of specimens examined were as follows (number of specimens x-rayed is given in parentheses): 101(41) bull trout, 45(45) brook trout, 23(23) Dolly Varden and 11(11) putative bull x brook trout hybrids. The number of specimens used in the analyses was less than the number examined because of missing data in some data sets. Locations and museum catalog numbers for the materials examined are given below. Museum abbreviations are OS - Oregon State University Fish Collection and CRLA - Crater Lake National Park. Number of specimens in each lot is given in parentheses.

Bull Trout

Oregon: Klamath R.-- Long Cr. OS 12455 (2), OS 6990 (10), Deming Cr. OS 6907 (6), OS 6987 (4), OS 12460 (4), Brownsworth Cr., OS 6988 (6), Leonard Cr., OS 6989 (5), Boulder Cr., OS 6991 (2), Cherry Cr., OS 6992 (1), OS 10008 (1), Sun Cr. OS 10772 (5), CRLA 322 (5), CRLA 6459 (1), CRLA uncataloged (2); Malheur R.-- Big Cr., OS 12453 (4); Willamette R.--McKenzie R., Anderson Cr., OS 12457 (6); Deschutes R.-- Odell Lake, Trapper Cr. OS 12456 (5), Metolius R., Jefferson Cr. OS 12459 (2), Lake Billy Chinook OS 11382 (1), Candle Cr. OS 11458 (5), Jack Cr. OS 12465 (3), Roaring Cr. OS 12466 (18).

Washington: N. Fork Lewis R., OS 12454 (3).

Bull Trout x Brook Trout Hybrid

Oregon: Klamath R.-- Long Cr. OS 12451 (2), Sun Cr., OS 10772 (1?), CRLA 322 (4), CRLA uncataloged (3); Malheur R.-- Big Cr. OS 12452 (1).

Brook Trout

Oregon: Klamath R.-- Long Cr. OS 12458 (12), OS 12461 (5), Sun Cr. CRLA 322 (1), CRLA 323 (5), CRLA 6460 (2), CRLA 6461 (17); Malheur R.-- Big Cr., OS 12464 (3).

Dolly Varden

Washington: Nooksack R. OS 12462 (13), OS 12463 (10).

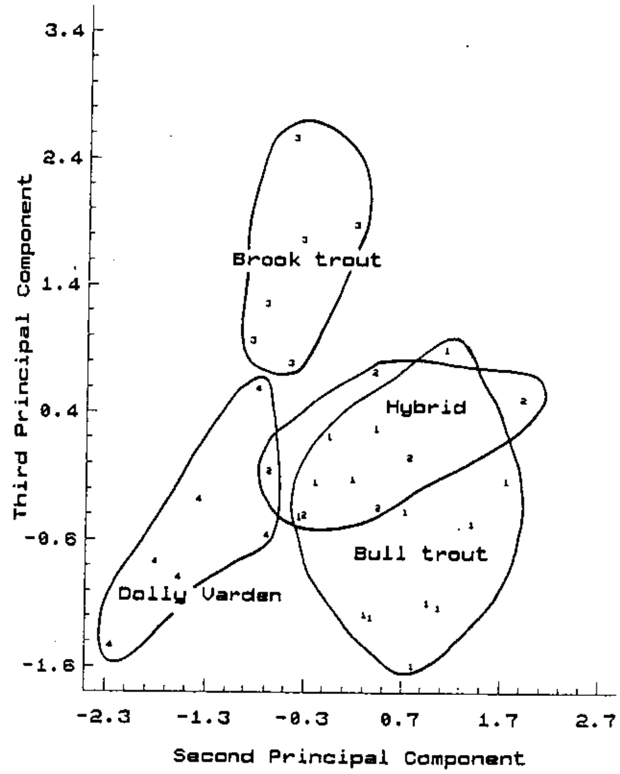
Results

Variable loadings of log transformed morphometric data on the first four axes of the PCA are given in Table 1. The first axis clearly represents size since all loadings are positive and of similar value. A scatterplot (Figure 3) illustrates the distribution of observations on the second and third principal component axes. Head length, upper jaw length, and the distance from the snout to the back of the orbit load most positively, while the dorsal origin to pelvic origin and anal origin to caudal distances load negatively on the second principal component axis. Upper jaw length, caudal peduncle depth, and dorsal origin to pelvic origin distance load most positively while snout to pelvic origin and dorsal origin to caudal distances load most negatively on the third principal component axis. The three species tend to occupy non-overlapping space and the putative hybrids occupy a subset of the bull trout space (Figure 3).

The discriminant function analysis of log transformed morphometric data correctly classified all *a priori* designated Dolly Varden, brook trout and hybrids, and 93% of bull trout. One bull trout was misclassified as a hybrid. The first two functions (Figure 4) were significant ($P < 0.0001$) and accounted for 91% of the variance. The group centroid of hybrids was approximately intermediate between those for bull trout and brook trout.

Univariate summaries of meristic data are presented in Table 2. Relative to presumed parents, hybrids had the highest mean for one character (caudal vertebrae) and

FIGURE 3. -- Scatter plot using second and third principal component axes from log transformed morphometric data. Symbol abbreviations: 1 = bull trout, 2 = hybrids, 3 = brook trout, and 4 = Dolly Varden.



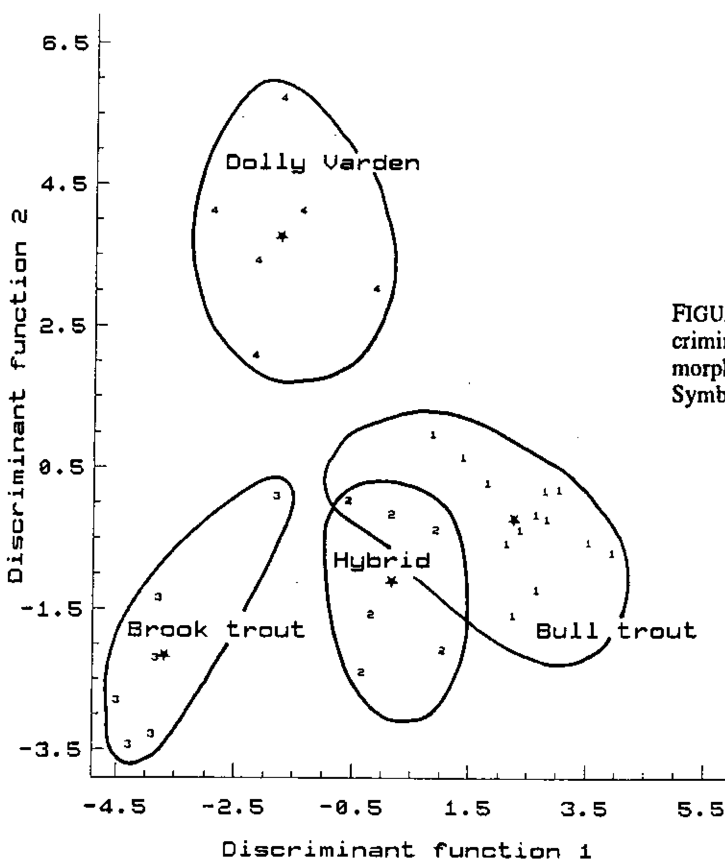


FIGURE 4. -- Scatter plot using first two discriminant function axes from log transformed morphometric data. Stars indicate group centroids. Symbol abbreviations as in Fig. 3.

TABLE 1.-- Loadings of log transformed morphometric variables on principal components axes from the covariance matrix. Variance percentage is in parentheses.

Variable	PCI (95.4)	PCII (2.0)	PCIII (1.2)	PCIV (0.5)
Standard length	0.298442	-0.026954	-0.286672	-0.072242
Head length	0.258712	0.411540	-0.191595	-0.104466
Upper jaw length	0.282903	.0.530382	0.443127	-0.092204
Snout to posterior margin of orbit	0.249920	0.297049	0.107021	0.057809
Head width at pectoral fins	0.287464	0.040663	0.010336	0.900583
Caudal peduncle depth	0.266637	-0.230770	0.459669	0.065665
Snout to dorsal fin origin	0.302099	0.115133	-0.240048	-0.159943
Dorsal to pelvic origin	0.313339	-0.300250	0.460132	-0.277389
Snout to pelvic fin origin	0.288978	0.179132	-0.292042	-0.195886
Dorsal to anal fin origin	0.306361	-0.244148	0.010992	-0.113210
Anal to caudal fin base	0.293833	-0.380733	-0.146980	-0.018289
Dorsal to caudal fin base	0.307615	-0.255729	-0.292466	0.051134

the lowest mean for three characters (mandibular pores, and upper and lower procurrent caudal fin rays). Hybrids were basically intermediate for the other meristic data.

Variable loadings of meristic data on the first four axes of the PCA are given in Table 3 and data for the first two axes shown in Figure 5. Right branchiostegal rays, precaudal and total vertebrae load positively and pyloric caecae load most negatively on the first principal component axis. Caudal vertebrae, anal fin rays, and upper and lower procurrent caudal fin rays load most positively, and mandibular pores and pyloric caecae load most negatively on the second principal component axis. Brook trout occupy a unique space, whereas bull trout, Dolly Varden, and the hybrids show various amounts of overlap (Figure 5). Somewhat less overlap is obtained when the first and third axes are examined, and hybrids occur in a clearly intermediate space between bull trout and Dolly Varden.

When meristic data are analyzed for bull trout and Dolly Varden only, differences between the two species are apparent in the first two axes of the PCA (Figure 6). High positive loadings on the first axis are made by precaudal vertebrae (0.41), right branchiostegal rays(0.38), total vertebrae (0.33), and mandibular pores (0.30), and high negative loadings made by caudal vertebrae (-0.32) and anal fin rays (-0.30). Highest positive loadings on the second axis are made by upper (0.62) and lower procurrent caudal fin rays (0.48), and highest negative loadings made by pyloric caecae (-0.29). Within the bull trout samples, there appears to be a cline, especially along the second axis. The Dolly Varden, which are from a more northerly site than any of the bull trout, are not part of the apparent cline in bull trout.

The discriminant function analysis of meristic data correctly classified all specimens. The first two functions (Figure 7) were significant ($P < 0.0001$) and accounted for 99% of the variance. The group centroid of hybrids was much closer to bull trout than to brook trout.

Discussion

Dolly Varden and Bull Trout

The distinction between bull trout and Dolly Varden was confirmed in this study. At similar sizes, differences in mouth size, head size and head shape are readily apparent (Figure 8). In addition to these characters used by Cavender (1978), Dolly Varden and bull trout appear to differ in parr mark retention and anterior profile. Specimens of Dolly Varden (ca. 75-200 mm SL) examined during this study have lightly colored sides and visible parr marks; whereas, bull trout of similar size have darkly colored sides and parr marks which, although visible, are qualitatively less distinct (Figure 8). Dolly Varden also tend to have an arched, relatively high back with a straight ventral profile, whereas bull trout have more symmetrical dorsal and ventral anterior contours and a blunter profile (Figure 8).

No specimens of Dolly Varden from Oregon were found. The two suspected specimens of Dolly Varden from California (Cavender 1978) are deposited at the Smithsonian Institution and are so badly disintegrated that they can not be removed from their storage bottle without completely falling apart (S. Jewett, Smithsonian Institution, personal communication, February, 1990).

TABLE 2.-- Summary of meristic characters for specimens used in the multivariate analyses; X = mean, SD = standard deviation. Sample sizes are in parentheses.

Character		Bull trout (15)	Hybrid (6)	Brook trout (12)	Dolly Varden (6)
Precaudal vertebrae	X	38.3	37.0	33.2	36.5
	SD	0.8	0.9	0.9	0.6
Caudal vertebrae	X	25.8	26.0	24.3	26.5
	SD	0.6	0.6	0.8	0.6
Total vertebrae	X	64.2	63.0	57.6	63.0
	SD	0.7	0.9	0.7	0.6
Anal fin rays	X	12.1	12.2	12.7	12.8
	SD	0.5	0.9	0.7	0.8
Dorsal fin rays	X	13.9	14.0	14.1	14.3
	SD	0.4	0.4	0.6	0.4
Upper procurrents	X	13.1	12.7	13.7	13.7
	SD	1.5	1.0	1.2	1.0
Lower procurrents	X	12.2	11.7	13.0	12.8
	SD	1.3	1.2	1.3	1.0
Right branchiostegals	X	12.0	11.2	10.1	10.0
	SD	0.4	0.8	0.9	0.0
Total mandibular pores	X	14.6	13.7	14.7	12.2
	SD	0.8	0.8	1.5	0.4
Pectoral fin rays	X	14.0	13.7	13.3	13.2
	SD	0.6	0.5	0.8	0.8
Pelvic fin rays	X	9.0	8.7	8.4	8.8
	SD	0.0	0.5	0.7	0.4
Pyloric caecae	X	24.5	27.3	33.2	21.7
	SD	3.2	5.9	3.6	2.0

Bull Trout x Brook Trout Hybrids

The putative hybrids can be recognized as a distinct group using both meristic and morphometric characters (Figures 4 and 7). The analysis, therefore, corroborates the *a priori* identification of Oregon *Salvelinus* with spotted dorsal fins as belonging to a group other than bull trout or brook trout. Three biological explanations can be suggested: 1) the specimens are Dolly Varden, 2) the specimens represent natural variation of bull trout, or 3) the specimens are hybrids.

The only reason to suspect that putative hybrids might be Dolly Varden would be based on the discriminant function analysis of meristic data. The scores of putative hybrids and Dolly Varden on the first axis were almost identical (Figure 7). However, good separation occurred on the second axis, and the morphometric analyses (Figure 4) gave little reason to believe these specimens were Dolly Varden.

In most analyses, the putative hybrids were either close to, overlapping with, or within the multivariate space of bull trout. The putative hybrids were from presumably small populations: Sun Creek and Long Creek on the Klamath River and the Meadow Fork of Big Creek on the Malheur River. Specimens with spotted dorsal fins have been seen but not collected in other areas where population numbers appear low and

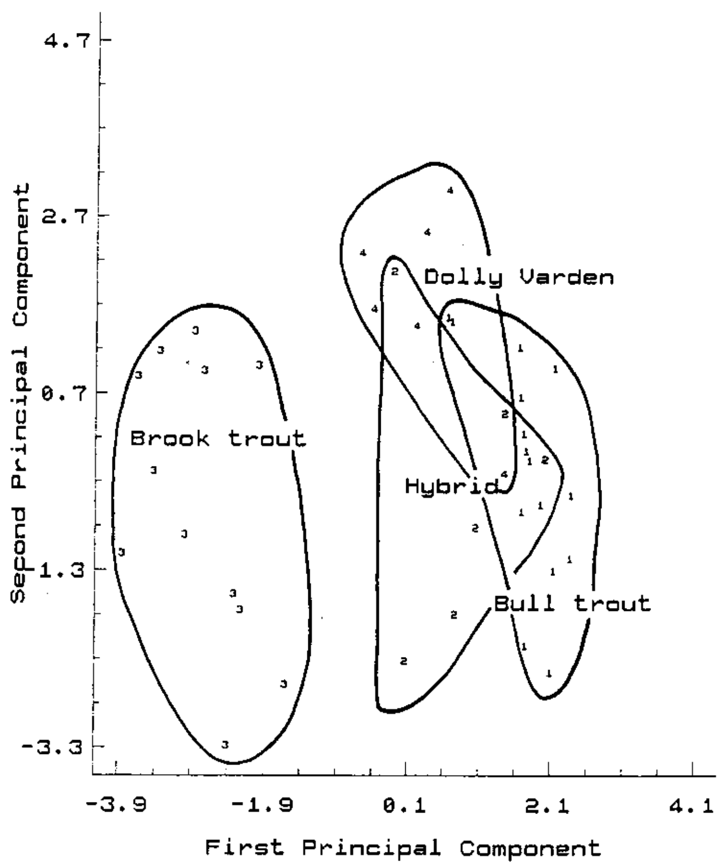


FIGURE 5. -- Scatter plot using first and second principal component axes from meristic data. Symbol abbreviations as in Fig. 3.

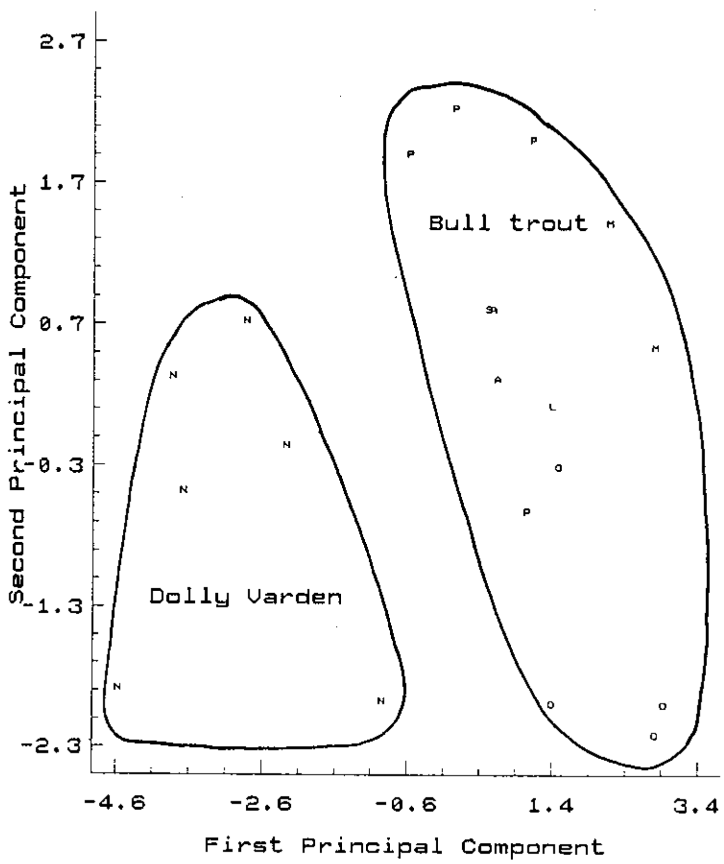


FIGURE 6. -- Scatter plot using first and second principal component axes from meristic data, bull trout and Dolly Varden data only. Symbol abbreviations: N = Nooksack R., P = Pine Creek, Lewis R., M = Metolius R., S = Sun Creek, Klamath R., L = Long Creek, Klamath R., A = Anderson Creek, Willamette R., and O = Trapper Creek, Odell Lake.

TABLE 3. -- Loadings of meristic variables on principal components axes from the correlation matrix. Variance percentage is in parentheses.

Variable	PCI (35.0)	PCII (20.4)	PCIII (11.1)	PCIV (8.6)
Precaudal vertebrae	0.467315	-0.028891	0.059362	-0.035664
Caudal vertebrae	0.298855	0.380737	-0.216654	-0.211849
Total vertebrae	0.468068	0.109103	-0.015214	-0.109124
Dorsal fin rays	-0.040985	0.204447	-0.172950	0.420981
Anal fin rays	-0.259896	0.348686	0.062709	-0.252923
Upper procurrent caudal fin rays	-0.149423	0.502572	0.357912	0.028482
Lower procurrent caudal fin rays	-0.225837	0.458234	0.231686	0.056765
Right branchiostegals	0.340509	-0.087279	0.455048	-0.069715
Total mandibular pores	-0.082951	-0.261055	0.659012	-0.265163
Pectoral fin rays	0.179739	0.103210	0.301051	0.710109
Pelvic fin rays	0.257093	-0.013302	0.038104	0.227413
Pyloric caecae	-0.330800	-0.360232	0.015259	0.256063

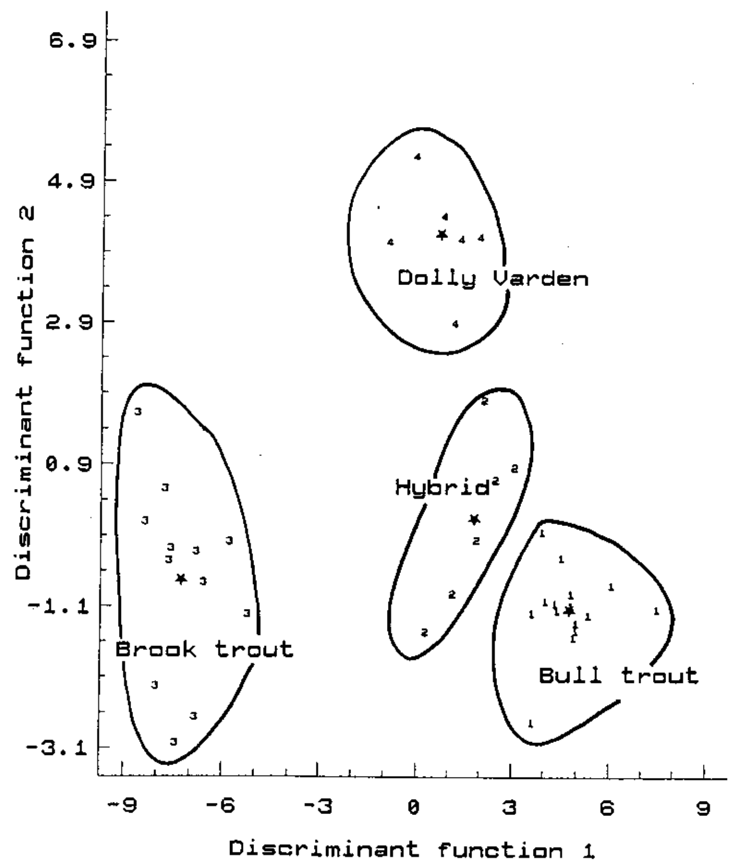


FIGURE 7. -- Scatter plot using first two discriminant function axes from meristic data. Stars indicate group centroids. Symbol abbreviations as in Fig. 3.

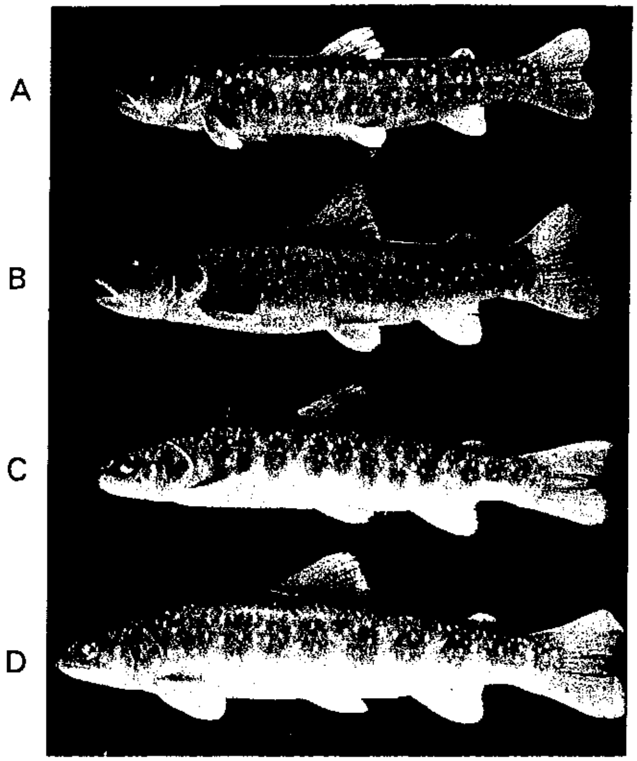


FIGURE 8. -- Bull trout: A. OS 124 mm SL, Odell Lake; B. OS 12459, 129 mm SL, Metolius River. Dolly Varden: C. OS 12462, 128 mm SL, Nooksack River; D. OS 12462, 144 mm SL, Nooksack River.

where brook trout have been introduced (McKenzie River and Odell Lake) (F. Goetz, U.S. Forest Service, personal communication). These specimens might represent the results of genetic drift in small populations, but it seems unlikely that a complex of characters involving color, shape and meristic features would drift in the same direction in three separate populations.

Morphological variation within bull trout, however, was present and very obvious. Overall body form varied from an elongate, cigar shape to a deeper, more fusiform shape, and body spotting varied in size and shape (Figure 8). In general, it appears that elongate forms also have irregularly shaped spots. Whether these elongate forms represent a phenotypic response to poor food supply, a genetically distinct form, or evidence of backcrossing with hybrids is not known.

The simplest explanation of the putative hybrids (Figure 9) is that they are bull trout x brook trout hybrids. Cavender (1978) reached the same conclusion for two specimens he examined from Long Creek. Cavender's hybrids appear to fit the hybrid group described herein (62 total vertebrae and "mottled" dorsal fins).

The literature on salmonid hybrids suggest four univariate patterns that might be expected in bull trout x brook trout hybrids: 1) high values for meristic characters in hybrids, 2) all-male hybrids and hybrid sterility, 3) high levels of fluctuating asymmetry in hybrids, and 4) reduced developmental stability. According to Leary et al. (1983), bull trout x brook trout hybrids from Montana have meristic characters that are not significantly different from the parental species with the higher count. The same pattern was found in the three vertebral and branchiostegal ray counts in the present study but not in other characters. Leary et al. (1983) also reported that all bull trout x brook trout hybrids were males, presumably sterile. Five hybrids in this study were also males, but the largest, a 213 mm SL specimen from Sun Creek, was a female with a shrunken (spent?) ovary. In a second report, Leary et al. (1985) demonstrated that hybrids have a higher number of asymmetric characters than parental species. For three paired characters examined in the present study (pectoral fin rays, pelvic fin rays and mandibular pores), hybrids had a higher mean number of asymmetric characters (1.3 vs. 1.1 for bull trout and 1.2 for brook trout), but the differences were not significant ($P < 0.05$). Finally, Leary et al. (1985) suggest reduced developmental stability as the mechanism responsible for higher levels of fluctuating asymmetry in hybrids. Developmental breakdown may also be reflected in other morphological features. Two developmental abnormalities were detected on hybrids in this study: fused precaudal vertebrae in a Long Creek specimen (OS 12451) and a multi-branched lateral line on the left side of the specimen from the Malheur River (OS 12452). These observations certainly are not convincing proof of the identity of the hybrids, but they are generally consistent with an identification as hybrids.

Even acknowledging the tentative nature of the identity of specimens with spotted dorsal fins, field biologists would be well advised to keep records of their occurrence, especially in areas where brook trout have been introduced. At the least, they may represent a first approximation of the magnitude of hybridization. As the probability of hybridization is frequently dependent on local habitats (Campton 1987), the distribution patterns of these fish may provide insight into habitat conditions necessary for bull trout x brook trout hybridization.

Oregon bull trout populations with putative hybrids may require significant effort to save them. Because some of these populations appear to be quite small and probably represent isolated glacial relicts, it may be worth prioritizing populations based on their phylogenetic uniqueness. Criteria based on phylogeny are not the same as those based on genetic diversity. Phylogeny in this case considers the temporal sequence of isolation and the goal of such prioritization would be to conserve as many early branches of the bull trout tree as late branches. Early branch populations that have changed the least from the ancestor probably differ in

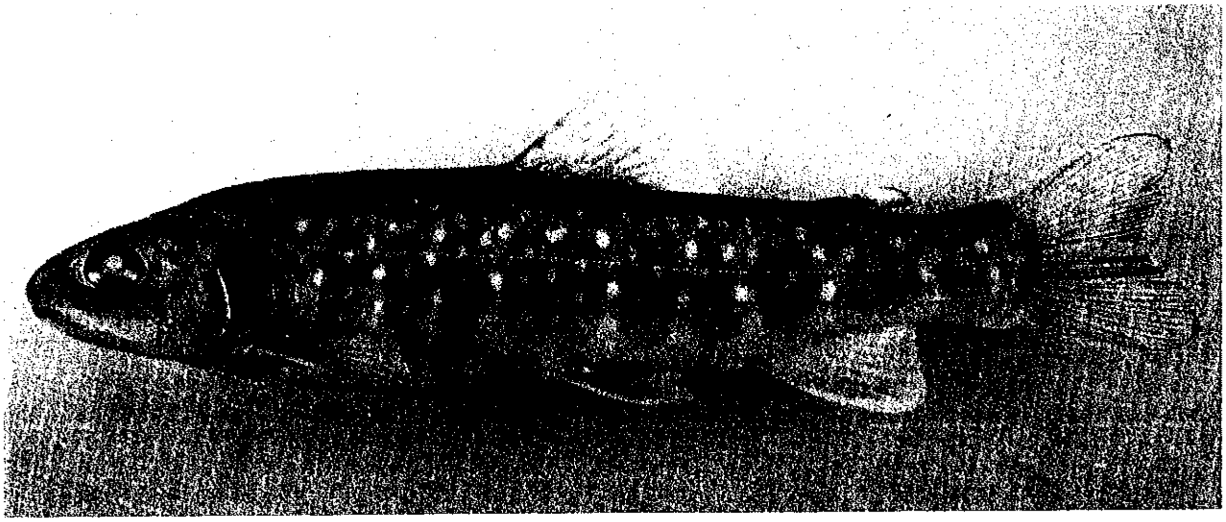


FIGURE 9. -- Bull trout x brook trout hybrid, OS 12451, 92.2 mm SL, Klamath R., Long Creek.

adaptability from those that have changed more. A summation of observed genetic diversity may or may not reflect that history and thus genetic diversity criteria may or may not achieve the same end.

A comprehensive research program on bull trout population genetics and differentiation should: 1) attempt to relate morphology to F1 hybrids; 2) include bull trout from its three major southern drainage systems (Puget Sound, Columbia River, and Klamath River); 3) include isolated bull trout populations; 4) include sympatric brook trout; 5) include southern Dolly Varden from Washington; and 6) attempt to reconstruct the phylogeny and zoogeographic history of bull trout.

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