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CONSISTENTLY HIGH MERISTIC COUNTS IN NATURAL HYBRIDS BETWEEN BROOK TROUT AND BULL TROUT

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STATE OF CALIFORNIA—THE RESOURCES AGENCY GEORGE DEUKMEJIAN, *Governor*

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July 8, 1988

Dear Interested Parties:

Attached is a June 20, 1988 draft of the Department of Fish and Game's bull trout status and recovery report. The text and recommendations of the draft will be revised based on public comment received in writing prior to August 31, 1988. Comments should be sent to the Department of Fish and Game's Redding office at 601 Locust Street, Redding, CA 96001.

If you have any questions on the draft, you can contact members of my staff: Don Weidlein at (916) 225-2372 (Redding) or Michael Rode at (916) 926-5683 (Mt. Shasta).

Sincerely,

Gary B. Stacey
for A. E. Naylor
Regional Manager
Region 1

Attachment

DRAFT - 6/20/88:MR/DW

BULL TROUT, SALVELINUS CONFLUENTUS SUCKLEY, IN THE MCCLOUD RIVER, STATUS AND RECOVERY RECOMMENDATIONS

by
Michael Rode
Region 1

Inland Fisheries
Administrative Report No.
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ABSTRACT

Varied and intensive efforts to capture bull trout from the McCloud River have been unsuccessful since two angler-caught fish were confirmed in 1975. The disappearance of the bull trout is documented and attempts to assess its status in the McCloud River are described. Bull trout life history and habitat data from other waters are reviewed to aid in evaluating the reasons for its disappearance and to assess chances for its successful reintroduction. Extirpation of the bull trout from the McCloud River (and California) is attributed primarily to the construction of McCloud Dam in 1965. The Dam inundated bull trout spawning and nursery areas and physically isolated upstream spawning and nursery areas from prime juvenile and adult holding habitat below the Dam. McCloud Dam has drastically altered downstream flows and water temperatures and has also significantly reduced flushing flows and gravel recruitment, all to the detriment of the bull trout. Other major factors that may have contributed to the demise of the bull trout are: (1) angler over-harvest, (2) the introduction of exotic salmonids and (3) the construction of Shasta Dam. Justification for bull trout reintroduction from out-of-state stocks is discussed and a preliminary reintroduction action plan is proposed.

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INTRODUCTION

The bull trout, Salvelinus confluentus (Suckley) is a species of char indigenous to western North America. Although it is common throughout much of its range, in California the bull trout was native only to the lower McCloud River of northern Shasta and southern Siskiyou counties (Figure 1). This population was the southernmost within the range of the species and represented California's only native char.[1/] Due to its unique zoogeography, interesting history, and limited numbers and distribution, the bull trout had constituted an important, though small, component of the California ichthyofauna.

By the mid 1970's, bull trout numbers in the McCloud River had declined drastically to the point where none had been reported since 1968. In 1975, however, two bull trout were captured by anglers, giving hope that sufficient numbers still remained to effect a recovery of the population. Nevertheless, extensive investigations conducted from 1976 through 1987 have been unsuccessful in capturing any additional specimens. Thus, it appears the bull trout is now extirpated from the McCloud River system.

Under a mandate from the California State Legislature (1970 California Species Preservation Act, 1970 Endangered Species Act, and other legislation), the Department of Fish and Game (Department) is charged with identifying those species threatened with extinction or endangerment and with providing recommended actions to insure their survival, protection and recovery. The Department, with guidance from its Threatened Trout Committee, is undertaking the preparation of management plans for various threatened native salmonid species throughout the state. The purposes of this report are to (1) summarize the known existing information regarding the bull trout, including its taxonomy, life history, distribution, status and habitat requirements and (2) recommend an appropriate plan for re-establishing the bull trout in the McCloud River. New material in this report includes documention of the decline of the McCloud River bull trout, an evaluation of causative factors leading to the decline, a review of Department activities aimed at assessing bull trout status, and recovery and management recommendations.

1/Until 1978, the California population of bull trout was believed to be Dolly Varden (Salvelinus malma). Although the two oldest museum specimens from the McCloud River were tentatively identified by Cavender (1978) as S. malma, he has identified all subsequent specimens as S. confluentus. For purposes of this report, the char native to the McCloud River is recognized as the bull trout, S. confluentus.

The McCloud River Wild Trout Area Management Plan (Rode, in press) also provides much information that relates to bull trout in the McCloud River. Particularly relevant are descriptions of the river's history, fish populations and current wild trout management program with emphasis on the first 16.9 km (10.5 mi) of the McCloud River below McCloud Dam. Within this wild trout area, special angling regulations apply that emphasize catch and release angling. That plan also makes numerous recommendations for the management of the area and its fishery habitat which are generally complimentary to those in this report for the bull trout.

There has been little information gathered on bull trout life history or taxonomy in California (Wales, 1939), a fact that is reflected by the paucity of museum specimens that have been collected from the McCloud River within the last century (Cavender, 1978). Most available background information comes from studies of northern waters, particularly in Montana, British Columbia and Alberta.

TAXONOMY

The bull trout is actually a char and is most closely related to the Dolly Varden (Salvelinus malma, Walbaum) and both, in turn, are closely related to the Arctic char (S. alpinus, Linnaeus) (McPhail, 1961, Cavender, 1978). More distant relatives include other congeners such as the eastern brook trout, (S. fontinalis, Mitchill), lake trout (S. mamaycush, Walbaum), and other Asian and European chars (Morton and Miller, 1954).

Electrophoretic data have shown that the amount of genetic divergence between the bull trout and Arctic char is about half of that shown between these fish and brook trout and lake trout (Leary, 1985).

An examination of five populations of bull trout from the upper Columbia River drainage showed relatively low intrapopulation genetic variation; whereas, a substantial percentage (26.4) of the total amount of genetic variation detected was due to genetic differences between populations (Leary, 1985). This underscores the importance of maintaining many diverse populations in order to preserve the genetic resource represented by the bull trout and also supports the liklihood that the McCloud population was gentically distinct.

The earliest published account of the bull trout[2/] in California was by Livingston Stone (1874), who reported it as Wye-dar-deekit, an Indian phrase meaning "trout of the north"; this Indian name enforces the fish's classification as a native California species rather than the result of an early fish cultural transplant as has been suggested by some skeptics. Stone also first published the name "Dolly Varden" which was used for the fish caught from the McCloud River and brought to Soda

Springs, a resort on the nearby upper Sacramento River. The common name evidently arose from an association between the bright coloration of this char and the popular "Dolly Varden" dress style then in vogue or after a character in Dickens' book "Barnaby Rudge." Accounts of the origin of the common name, Dolly Varden, appear in several sources (Jordan, 1894; Evermann and Bryant, 1919; Wales, 1939, 1946; Robbins, 1967; and Moyle, 1976).

The bull trout was originally described by Girard in 1856 as Salmo spectabilis, from a specimen collected from the lower Columbia River. The specific name was discarded, however, when it was found to be a secondary homonym in violation of the rules of zoological nomenclature. After four further descriptions by Suckley (Salmo confluentus, S. bairdii, S. parkeii and S. campbelli), the bull trout was placed in synonymy with Salvelinus malma by Jordan and Gilbert in 1882. For years, the bull trout and the "Dolly" had remained officially lumped together under one common and scientific name, the Dolly Varden, Salvelinus malma (Walbaum), even though in interior drainages of the United States and Canada where native Salvelinus attain quite large size, fishermen have long referred to these fish as "bull trout" (Cavender, 1978).

In redescribing the bull trout, Cavender (1978) proposed the binomen, Salvelinus confluentus (Suckley) and differentiated it from the Dolly Varden on the basis of osteological, morphometric and meristic characteristics that have proven to be consistent over the entire geographical range of both species, even where they occur sympatrically. Bull trout differ from Dolly Varden in having a longer and broader head, a higher branchiostegal ray count, a higher mandibular pore count, a marked difference in gill raker morphology and differences in a multitude of cranial characteristics (Cavender, 1978).

Two important features distinguished McCloud River bull trout from other S. confluentus populations to the north. They possessed the largest head size and had the greatest percentage of individuals (59%) lacking basibranchial teeth of all the populations analyzed by Cavender. This latter characteristic was used by Jordan to recognize the McCloud River bull trout population as a separate species (Cavender, 1978). This fact further tends to support the origin of the McCloud char as a native California population that may have been genetically distinct.

Of the 15 museum specimens that Cavender examined from the McCloud River, 13 were identified as bull trout. The other two, deposited by Livingston Stone in the U. S. National Museum of Natural History sometime prior to 1877, were badly decomposed and represent the only Dolly Varden ever confirmed from the McCloud River. Cavender feels that at one time, both species may have

2/ When citing historical accounts of native char in California, the name bull trout will be used since Cavender (1978) notes that earlier references were most likely to the bull trout and not the Dolly Varden.

existed sympatrically in the lower McCloud River but that the Dolly Varden became extirpated as early as the turn of the century. Because bull trout most likely outnumbered "Dollies" in the late 1800's, the name Dolly Varden may originally have been applied to S. confluentus. However, Cavender feels that because of its international usage, the common name Dolly Varden is best retained for S. malma (Cavender, 1978).

The bull trout reaches a larger size (to 18.2 kg, 40 lbs.) than does the Dolly Varden (Hart, 1973). Its trunk is more rounded and slender and less compressed than that of the Dolly (Cavender, 1978). Both fish are similar in coloration: olive green with small yellow or light spots on the back and inconspicuous small red spots on the sides. The fins are completely devoid of any spotting save for possibly a few yellow spots at the base of the tail. The anal and paired fins have cream or white-colored leading edges (Moyle, 1976). The bull trout can be easily differentiated from the more vividly colored eastern brook trout by the absence of vermiculations on the back or fins and is distinguished from the brown trout by a complete lack of dark spotting.

DISTRIBUTION

Bull trout are primarily non-anadromous, occurring in a north-south distributional pattern along the Rocky Mountain and Cascade ranges of North America. Dolly Varden, however, are predominately anadromous and are more widely distributed, occurring in Pacific drainages from Oregon northward to Alaska and along Siberian shores of the Arctic Ocean (McAfee, 1966). Both species are known to occur or have occurred sympatrically in three major northern drainages and possibly the McCloud River (Cavender, 1978).

Bull trout have been found in the McCloud River only below Lower Falls (Figure 1 and 2). This seems to have been the case as early as the 1880's when Campbell (1882) reported bull trout occurring from the mouth of the McCloud River upstream to Big Springs but not beyond. Unconfirmed reports suggest bull trout were also at one time present in the Pit and Sacramento rivers and had been unsuccessfully stocked in two Yosemite National Park waters (Wales, 1939; McAfee, 1966). In the mid-1960's anglers caught small numbers of bull trout in Shasta Lake and one bull trout was captured in a sample of 124 trap-net-caught trout taken from Shasta Lake in 1962 and 1963 (Smith, 1963).

LIFE HISTORY

Bull trout populations are characterized as being resident, fluvial, or adfluvial. In resident populations both adults and juveniles are found in the same general stream location throughout the year; adults do not undertake extensive spawning migrations. Resident populations are typically found in isolated headwater

tributaries. Isolation can result from natural geologic processes such as glaciation, geological faulting and water temperature gradients or from more recent events such as environmental stream degradation that separate headwater resident populations from downstream fluvial or adfluvial populations.

In fluvial and adfluvial populations, juveniles are found in upstream or tributary locations, while adults reside most of the year in the main river (fluvial) or lake (adfluvial) environments. Spawning migrations can be extensive, covering distances up to 161 km (100 mi) (Oliver, 1979).

The following life history and preferred habitat data for bull trout from other waters is presented for various life stages to facilitate an understanding of why the McCloud River bull trout disappeared and what factors need to be considered for its successful reintroduction. (Most research has been done on adfluvial populations. However, bull trout in the McCloud River appear to have been fluvial in nature).

Egg Deposition Through Emergence

On average, bull trout eggs eye up by October 17 and require 35 days and 200 temperature units (TU^S, °C) from the time of fertilization. Hatching is generally completed by the end of January after 100-145 days and averages 350 TU^S (°C) (Shepard, et.al., 1984). McPhail and Murray (1979) reported laboratory incubation periods of 126 days at 2°C (35.6°F) and 95 days at 4°C (39.2°F).

Survival rates of redd deposited bull trout eggs through hatching range from approximately 40 to 50% (Blackett, 1968; Allan, 1980). Egg survival and development is highly affected by temperature. McPhail and Murry (1979) found that at high temperatures (8-10 °C 46.4-50°F) only 0-20% of eggs survived. At 6°C (42.8°F) the survival rate was 60-90% and at 4°C (39.2°F) the survival rate had increased to 80-95%. At lower temperatures, alevins (sac fry) were also of larger size and the hatch duration shorter. Experiments at the Kootnay Hatchery, British Columbia, have shown that the optimum egg incubation temperature is 4°C (39.2°F) while the best temperature for rearing is 7°C (44.6°F) (P. Brown, unpublished report).

Sedimentation also has a strong negative affect on bull trout egg survival. Weaver and White (1984) have shown in laboratory experiments that as the percentage of fines ($\leq$6.35mm or 0.25 in diameter) in spawning gravel increases, the percentage of surviving embryos decreases; at 30% fines, only 15% of fertilized eggs survived to hatch.

Bull trout generally emerge in April with the average time from fertilization being 223 days (634 TU^S, °C). Bull trout alevins require approximately 65-90 days to absorb their yolk sacs

(Shepard, et.al., 1984). Unlike other salmonids, they then remain in the gravel for up to three more weeks before filling their air bladders, becoming neutrally bouyant and photo-positive. Feeding begins and parr marks develop while the fry are still in the gravel. Bull trout are approximately 25-28mm (1.0-1.1 in) long at emergence (Shepard, Pratt and Graham, 1984). A peak downstream movement of fry to areas of lower water velocity occurs in May (Allan, 1980).

Juvenile Stage

Small (≤ 110 mm, 4.3 in) juvenile bull trout strongly associate with instream cover in the form of gravel, rubble, cobble and fine debris. They are found within, on, or immediately above the streambed in micro-habitat areas of extremely low water velocity. Their use of the stream bottom for cover allows small bull trout to utilize a wide range of macro-habitat stream types such as runs, riffles and pocket water. In the Wigwam River of British Columbia, Oliver (1979) found the greatest concentrations of juveniles in reaches dominated by a rubble-boulder bottom and "rolling flow" (deep run) water. In tributaries of the Metolius River in Oregon, however, juveniles were found almost exclusively in debris-formed, slack water side channels (D. Ratliffe, Environmental Scientist, Portland General Electric, personal communication). Estimating juvenile density is difficult in most waters due to the bull trout's inconspicuous nature resulting from its strong orientation to the stream bottom.

Older juveniles (> 110 mm, 4.3 in) typically used faster (but still slow) water and were located higher in the water column in deeper water (Shepard, et. al., 1984). Two-year-old fish in the Flathead River drainage were found in greater densities in pools than in runs or riffles and large numbers were found among rocks along stream margins (Fraley, Read and Graham, 1981).

Water temperature is important in determining juvenile bull trout distribution and densities. In the Flathead River drainage, juvenile bull trout were not found in streams that exceeded 18°C (64.2°F) and highest densities were found in reaches where maximum temperatures were 12°C (53.6°F) or less (Shepard, et. al., 1984). Throughout its range, bull trout occurrence, especially in large numbers, appears to be frequently influenced by cold perennial springs (Oliver, 1979; Allan, 1980; Shepard, et.al., 1984). Based on the above temperature criteria, juvenile bull trout could have ranged throughout the length of the McCloud River before McCloud Dam.

In fluvial or adfluvial populations, juvenile bull trout generally emigrate downstream from their natal tributaries at age 1, 2 or 3, with the majority being age 2 (Bjorn, 1957; Oliver, 1979; McPhail and Murphy, 1979; Shepard, et. al., 1984). However, Allan (1980) found that bull trout of the Clearwater system of Alberta remained in their natal streams for up to six years and upon maturation

would join migratory adults in spawning and then move downstream for the first time to over-winter. In most waters, juvenile emigration takes place during the summer and fall (Shepard, et. al., 1984; Oliver, 1979).

Adult Stage

Adult bull trout are bottom dwelling fish that prefer deep pools and runs in cold-water rivers and their larger tributaries. In some areas they have also been successful in cold-water lakes and reservoirs, but this has not been the case in California (Moyle, 1976).

In the Flathead system, adult bull trout are found mainly in pools and runs. Higher densities of bull trout and larger individuals were associated with lower order streams. The most significant habitat characteristics associated with a high density of bull trout were over-hang and instream cover. However, other environmental parameters such as average depth, channel width, substrate size, wetted width and percent run were also important and all variables should be considered together when evaluating bull trout habitat (Fraley, et. al, 1981).

Reproduction

Bull trout generally mature by their fourth or fifth year (Moyle, 1976) although in northern waters, maturation of some fish may be delayed until year six (Allan, 1980). Spawning adults in the upper Flathead River basin ranged from five to nine years of age (Shepard, et. al., 1984).

In most populations, a high percentage of bull trout are annual repeat spawners (Scott and Crossman, 1973; Allan, 1980). However, in some populations such as those in the upper Flathead drainage, a substantial portion of adults may not spawn each year (Shepard, et. al., 1984).

Bull trout generally spawn during a relatively short time period from early September through late October in different areas (Scott and Crossman, 1973; Shepard, et. al., 1984). Campbell (1882) found that the McCloud River bull trout spawned from September through November.

It is suspected that spawning is initiated by a number of environmental cues, including water temperature, stream flow and photoperiod. Spawning does not begin until maximum daily water temperatures drop below 9°C (48.2°F) and occurs at water temperatures between 5°C (41°F) and 9°C (48.2°F) (Shepard, et.al., 1984).

Spawning bull trout appear to have a strong homing instinct, since they have been observed returning to the same specific spawning grounds each year (Fraley, et. al, 1981). This specificity of site selection also is indicative of the bull trout's precise spawning habitat requirements. Extensive surveys of upper Flathead River tributaries found redds in only 28% of the stream reaches examined (Shepard, et.al., 1984).

Spawning bull trout prefer low gradient (1.6-1.7%) low velocity (< 0.6 m, 2.0 ft/sec) reaches of larger, higher stream order tributaries (Allan, 1980; Oliver, 1979, Shepard, et.al., 1984). Spawning sites are strongly associated with areas influenced by groundwater recharge and springs (Allan, 1980; Shepard, et.al., 1984). It is thought that these springs stabilize flows and temperatures, thereby providing suitable overwinter conditions that maximize egg survival (Allan, 1980).

Spawning areas are also found in low gradient areas immediately below steeper gradient sections of a stream channel and where the stream splits into multiple channels (braided sections). These are aggrading stream channel areas that are formed by uncompacted, recently deposited gravels which make ideal spawning substrate (Shepard, et.al., 1984).

Spawning generally takes place in shallow runs or the tails of pools (Oliver, 1979; Shepard, et.al., 1984), predominately during the day (Scott and Crossman, 1973). Redds are typically constructed in shallow water at average depths of less than 0.5 m (1.6 ft) of egg deposition ranges from about .05 - .25 m (2.0-9.8 in) (Shepard, et.al., 1984). Redds are constructed in bed material predominated by small gravel 2-25 mm (0.1 - 1.0 in) in size, followed by large gravel 25-50 mm (1-2 in) in size (Shepard, et.al., 1984). Bull trout have been observed spawning in relatively exposed areas of streams (Allan, 1980), suggesting that they do not appear to pick spawning areas associated with abundant cover. However, spawning areas have escape cover located nearby with an average distance between redd and stream bank being approximately 3 m (9.8 ft) (Oliver, 1979; Fraley, et. al, 1981).

Egg number in females averages from 1337 - 8845 in Montana, with the mature eggs usually being 4.5-5.5 mm (0.18-0.22 in) in diameter, orange-red in color and demersal (Scott and Crossman, 1973). Eggs of McCloud River bull trout were reportedly small, about 17 - 19/cc (500 - 550/oz) and numbered about 1,000 to 9,000 eggs per female, depending on her size (Wales, 1939). Spawning behavior is much like that of the brook trout (Moyle, 1976).

Bull trout hybridize naturally with eastern brook trout (Cavender, 1978). This may be significant in view of the history of eastern brook plants in the drainage, particularly in McCloud Reservoir in the mid 1960's. They were artificially crossed with success at Sisson Hatchery, Mt. Shasta (McAfee, 1966, incorrectly gives the location of Sisson Hatchery as Lake Tahoe) in about 1892 (Evermann and Clark, 1931).

Age And Growth

Bull trout typically reach a maximum age of 10-12 yr (with occassional individuals to 20 yr) and can exceed 9.1 kg (20 lb) in weight. Maximum size varies with location and life history. Interior, high elevation and northern populations are often stunted and do not exceed 305 mm (12 inches) in length). Adfluvial populations generally attain largest size; resident headwater populations retain a diminutive form (Scott and Crossman, 1973).

Bull trout from the McCloud were commonly 203-254 mm (8-10 in) in length with reported specimens to 7.3 kg (16 lb) (Wales, 1939). More recently, the heaviest verified specimen from the McCloud system was a 4.1 kg (9.1 lb) dressed weight fish taken from McCloud Reservoir in 1968; this fish had a reported live weight of 5.1 kg (11.2 lb) (DFG files). A 19-year old individual, the oldest known, weighed between 5.9 and 6.4 kg (13-14 lbs) at death at Mt. Shasta Hatchery in 1918 (Anonymous, 1931). Another specimen weighed 6 kg (13.1 lb) when it died at Mt. Shasta Hatchery in 1964 (DFG files).

The angling size record, taken from Lake Pend Oreille, Idaho, in 1949 was reported by Field and Stream magazine as 1,029 mm (40.5 in) long, 755 mm (29.7 in) girth, and 14.5 kg (32 lb weight) (Scott and Crossman, 1973).

Food Habits

Bull trout appear to be highly opportunistic in their feeding habits. The most important food sources for young juveniles are adult and immature insects, snails and leeches taken in relation to their relative availability in streams (Armstrong and Morrow, 1980; Scott and Crossman, 1973). According to Shepard, et.al., (1982), bull trout less than 110 mm (4.3 in) TL in the upper Flathead drainage primarily utilized Diptera, with Ephemeroptera, Plecoptera and Trichoptera also well represented. In bull trout larger than 110 mm (4.3 in) TL, fish became an important part of the diet. Fish eggs can be an important part of the diet in the fall in those streams were fall spawning runs occur. However, most such eggs are consumed as wash-out drift when they are dislodged from redds by spawning fish during subsequent spawning (Armstrong and Morrow, 1980). Juvenile bull trout appear to eat little in winter as evidenced by weight loss and empty stomachs during this time of year (Armstrong and Morrow, 1980).

Adult bull trout, given the opportunity, generally are highly piscivorous, but will also take large quantities of other suitably sized vertebrates such as mice, frogs, snakes and even ducklings (Moyle, 1976). They have been known to cannibalize members of their own species (Cavender, 1978).

The opportunistic (and adaptive) feeding habits of bull trout were well demonstrated by Boag (1987) on the Muskeg River, Alberta. He found that above a beaver dam that blocked usual movement of fish, bull trout were strictly insectivorous whereas below the dam they fed on equal amounts of insects and fish. In a like fashion, there are numerous isolated headwater resident bull trout populations that are entirely insectivorous. Little life history information is available regarding these resident populations. There appears to be little feeding competition between bull trout and rainbow trout (Boag, 1987).

ANGLING

Bull trout are caught by conventional angling methods but, compared to other salmonids, are reportedly not spectacular fighters. However in areas where they attain large size, they are highly sought after by anglers for food and sport and provide a quality fishing experience that few other species can provide. Because of their piscivorous nature and voracious appetites, bull trout are highly vulnerable to angling with bait and large lures. In streams having mixed salmonid populations, angling is highly selective for bull trout (Allan, 1980) and in many waters they are over-harvested.

In many areas, the bull trout's slow rate of maturation subjects it to substantial angling mortality before it has a chance to spawn. In a fluvial population of the Muskeg River, Alberta, Boag (1987) found that the majority of bull trout harvested by anglers were immature individuals less than five years old.

Bull trout also are extremely susceptible to angling (and poaching) during the fall when large adults spawn in small tributaries. Many states and provinces having bull trout populations have closed spawning and nursery tributaries to fishing to protect these stocks.

Most bull trout taken from the McCloud River in the past were usually reported to have been caught on deeply fished salmon eggs in the larger pools and averaged 203-254 mm (8-10 in) in length, although larger individuals to sixteen pounds have been reported. An effective technique used to catch large bull trout in the 1930's was to use a live mouse for bait by floating it over a deep pool on a block of wood and then jerking it off.

They were a much sought-after fish in the late 1800's, particularly for food, as parties would travel by trail 6-8 km (15 mi) from the Sacramento River to fish expressly for them (Wales, 1939).

DESCRIPTION OF THE MCCLOUD RIVER

The McCloud River is a major tributary of the Sacramento River that flows through Siskiyou and Shasta counties. From its origins at approximately 1676 m (5,500 ft) MSL near Mushroom Rock, it travels 95 km (59 mi) in a general southwesterly direction, draining 16,122 ha. (622 sq mi) of terrain (U.S.G.S., 1984, U.S.G.S. unpublished data) before entering Shasta Lake (Figure 1).

About 56 km (35 mi) above Shasta Lake is Lower Falls which, prior to the construction of Shasta Dam, was a barrier to the upstream migration of anadromous fish. About 2.1 and 2.9 km (1.3 and 1.8 mi), respectively, below Lower Falls, Muir (Little) and Big Springs increase the summer flow of the McCloud River from roughly 1 m^3/sec (40 cfs) to about 23 m^3/sec (800 cfs). About 0.8 km (0.5 mi) above Wyntoon, a third spring source, equal in discharge to Muir Springs, further augments the flow of the river. This spring water inflow transforms the McCloud into a large, very clear, cold river with summer temperatures seldom exceeding 7.8°C (46°F) until the river reaches McCloud Reservoir.

McCloud Reservoir is part of Pacific Gas and Electric Company's (PG&E) McCloud-Pit project (Federal Energy Regulatory Commission Project License No. 2106). McCloud Dam diverts over 75% of the flow of the McCloud River to the Pit River for hydro-power production. Below McCloud Dam, the river is a moderate sized (9 - 23 m [30-75 ft] wide in summer), boulder-strewn canyon stream. River flows are highly regulated by McCloud Dam and, therefore, are relatively stable throughout the year. Summer flows at Ah-Di-Na, 6.3 km (3.9 mi) below the Dam, seldom exceed 6 m^3/sec (200 cfs) (U.S.G.S., 1984; U.S.G.S., unpublished data). For a more thorough description of the McCloud River, see the McCloud River Wild Trout Management Plan (Rode, in press).

HABITAT

In the McCloud River, bull trout were limited to the area below Lower Falls, a 6.1 m (20 ft) barrier located at the U.S. Forest Service Fowler's Campground near the town of McCloud. Although Stone (1874) reported the bull trout as being most common in the "headwaters" (presumably the area near Big Springs, below Lower Falls), it seems likely that major concentrations were located in the area below the present McCloud Reservoir downstream to Baird Hatchery (now inundated by Shasta Lake). The river from Lower Falls to McCloud Reservoir is typically very swift, almost continuous riffle and rapid, with very few pools. Below the reservoir, it contains numerous deep pools, the reported favorite stream habitat of adult bull trout.

Below Lower Falls, the bull trout historically shared the upper river habitat with native rainbow trout (Salmo gairdneri), steelhead rainbow trout (Salmo gairdneri gairdneri), chinook

salmon (Oncorhynchus tshawytscha) and riffle sculpin (Cottus gulosus). In the lower river, Sacramento sucker (Catostomus occidentalis) and Sacramento squawfish (Ptychocheilus grandis) were also native. The brown trout was introduced in the 1920's (Rode, in press).

Since the completion of McCloud Dam and the diversion of the major portion of the river's flow into the Pit River drainage in 1965, the primary habitat of the bull trout has been radically changed. In the reach below the dam, the average pre-project flow was about 28.3 m^3/sec (1000 cfs) (estimate based on a mean daily flow of 26.1 m^3/sec [921 cfs] for 40 yr of records at Gage 3675, located approximately 0.8 km [1/2-mi] above the head of McCloud Reservoir). The present minimum release is 1.13 m^3/sec (40 cfs). At the gage located just above Shasta Lake, the McCloud River flows are now less than half of what they were in pre-project days and summer temperatures average approximately 5.5°C (10°F) higher (DFG files). Peak summer temperatures in this lower portion of the river have increased to 23.9°C (75°F), far above that tolerated by bull trout.

The thermoregulatory effects and flow contributions of Big Springs evidently played a major part in providing the environmental conditions necessary for the existence of the bull trout in the McCloud River. Big Springs provides a constant flow of 7.5°C water (45°F) and, during summer low flow periods, increases the volume of the river twenty-fold (DFG Files). Its cooling effects were felt far downstream, as reported by Campbell (1882), who found water temperatures at the Baird Hatchery never exceeded 12.8°C (55°F) to 15.6°C (60°F) at midday during the hottest weather. Campbell also noted that water temperatures decreased 0.5°C (1°F) for every 16.1 to 19.3 km (10-12 mi) one traveled upstream from the hatchery (Cavender, 1978). The presence of McCloud Dam and its associated diversion have greatly diminished the beneficial effects of Big Springs.

Uncontrolled flows at McCloud Dam (dam surface spills) are very rare and only occur during major storm (flood) events or periods of rapid snow melt. PG&E hydro project licensing agreements have resulted in a complex arrangement of required seasonal minimum flows at both the McCloud Dam and Ah-Di-Na gages (Table 1). Flows at Ah-Di-Na are met by a combination of releases at the dam and downstream accretions, primarily from Hawkins Creek. When tributary accretion is high, flow releases at the dam are often at or near a minimum of 1.1 or 1.4 m^3/sec (40 or 50 cfs). Ironically, this has resulted in a situation where flows in the first one mi of river (below McCloud Dam and above Hawkins Creek) are generally lowest during early spring when, under unregulated conditions, they would normally be highest. This may have disrupted the bull trout's early life history cycle.

Summer flows in the Ah-Di-Na area seldom exceed minimum fish release levels and average about 5.7 m^3/sec (200 cfs) (Table 1). The highest flow recorded at Ah-Di-Na (Gage No. 11367800) since

the construction of McCloud Dam was an estimated 747.7 m^3/sec (26,400 cfs) on January 16, 1974; the lowest daily discharge of 1.2 m^3/sec (41 cfs) occurred on December 18-20, 1971, due to a valve malfunction at the dam (U.S.G.S., 1984).

During summer months water temperatures 8.5 km (5.3 mi) below the dam near the mouth of Ladybug Creek range from the high 9's to high 14's °C (40's to high 50's°F) and fluctuate about 5°C (10°F) daily.

Water clarity ranges from excellent to highly turbid. Much of the turbidity is generated by glacial mud and volcanic ash contributed by Mt. Shasta's Konwakiton Glacier via Mud Creek, a tributary to the McCloud River just above McCloud Reservoir. This gives the lower McCloud River its characteristic milky green color, a condition common to glacially fed rivers. Turbidity episodes occur regularly and predictably, most often during summer hot spells and are most severe when the previous winter has left little snow on the slopes of Mt. Shasta. During the 1920's and 1930's, large mud slides in upper Mud Creek Canyon (brought about by the partial break-up of Konwakiton Glacier) created such turbid conditions in the river that fishing for prolonged periods of times, was impossible (Wales, 1939; Hill and Engenhoff, 1976). The turbidity problem today is chronic but of a much less severe nature. However, at times, turbidity is severe enough to preclude successful fishing.

A second source of turbidity is associated with operation of McCloud Reservoir. After the reservoir is drawn-down at the end of the summer (this is general PG&E operating practice), the first substantial fall rains swell the upper McCloud River, causing it to down-cut into the now-exposed sediments deposited at the head of the reservoir. These sediments become resuspended, often causing prolonged bouts of turbidity in the lower river. Lastly, sluicing or testing of the McCloud Dam bypass valve discharges large amounts of bottom sediments from the reservoir. This causes high turbidities of relatively short duration in the lower river.

When the river is running clear, it is low in total dissolved solids (97 ppm), is soft (38 ppm CaCO3) and is slightly basic (pH 7.8) (Tippets and Moyle, 1978).

The lower McCloud River below McCloud Dam is noted for being a classic "pocket water" trout stream. It is characterized by long boulder-strewn runs ranging from 0.4 - 0.9 m (1 1/2 - 3 ft) in depth and 4.6 - 366 m (15 to 1,200 ft) in length, alternating with large bedrock pools 1.8 - 3.5 m (6 to 12 ft) deep and 18.3 - 91. m (60 to 300 ft) long (Tippets, 1976). Instream cover for fish is provided by boulders, cobble, turbulent water, deep pools and runs, some cut-banks and occasional downed trees and other debris.

STATUS

Bull trout appear to be declining throughout much of their range. In many areas, overharvesting by anglers has severely depleted populations. On waters where reduced bag and/or size limits have been placed on bull trout, anglers frequently have trouble identifying these fish from other species of trout (Anonymous, 1985). The demand for recreational fishing appears to be increasing in most areas and, with that increase, it can be expected that additional pressures will be placed on bull trout stocks. The sensitivity of bull trout to over-fishing is well demonstrated by experiences in Alberta, where most stocks are overharvested, even in some areas that have no road access. Heavy fishing pressure and easy access to much of the existing bull trout habitat have limited opportunities to rehabilitate this species (Anonymous, 1985). The introduction of exotic salmonids (such as brook trout and brown trout that may hybridize or compete with bull trout) has also impactd stocks in many areas (Allan, 1980).

The most serious threat to bull trout, however, appears to be loss and degradation of habitat due to a number of man-induced environmental alterations, including water impoundment and diversion, mining, road building and logging. Many such alterations or proposals have been the impetus behind much of the existing bull trout research.

In the McCloud River, Wales (1939) reported the bull trout was common as recently as 1938, prior to the completion of Shasta Dam. Since that time, however, there are few records of bull trout catches or populations in DFG files due primarily to the fact that nearly all of the primary McCloud River habitat was in private ownership; the public was excluded and the Department did not conduct extensive surveys. in more reent years there has been a drastic decline in abundance to the point where they are extirpated today (Table 2). An annual creel census from 1944 through 1952 (except 1948) conducted on the opening day of trout fishing season at the mouth of the McCloud River at Shasta Lake revealed occasional catches of bull trout. One exception was in 1949 when Department of Fish and Game biologist Eugene German (now retired) checked 12 bull trout caught in the lake and 2 more from the river along with a total of 74 rainbow and 5 brown trout. Of the trout checked on opening day of fishing in 1951 and 1952 there were no bull trout. In general, relatively few brown trout were seen in these checks (DFG files).

More recently, Department biologist Terry Healey captured four specimens from 14 gill net sets in the river about 6 1/2 km (4 mi) above Shasta Lake in 1964 and 1968. Intensive creel censusing of McCloud Reservoir in 1973 and population sampling in 1973 and 1974, including gill netting and electrofishing in the reservoir, the river and certain tributaries, failed to obtain a specimen of these fish.

Additionally, lake-wide creel checks of Shasta Lake anglers have sampled approximately 8,000 trout from 1968 through 1987 but no bull trout appeared in that sample (Weidlein, 1971; Healey and Van Woert, unpublished data). A few fishermen claim to catch bull trout in the McCloud River regularly but this has not been substantiated and most such reports are probably brown trout.

In 1973, the Nature Conservancy (TNC) acquired (through a gift) a portion of the McCloud River Club property lying upstream from the the Club's headquarters above the mouth of Squaw Valley Creek (Figure 1). This area (named the McCloud River Preserve) encompasses approximately six miles of river where human influence has been minimal, except for the flow effects of McCloud Dam. Extensive fish population sampling of this area in 1974 by a University of California, Davis study team, led by Dr. Peter B. Moyle, failed to produce any bull trout.

In July of 1975, however, a U.S.Forest Service employee, Steve Dion, caught a 413 mm (16 1/4 in) approximately .68 kg (1 1/2 lb) positively identified bull trout (CDFG collection #0513) from the lower reaches of the TNC's McCloud River property (Table 2). Shortly thereafter, Jamie Sturgess, a graduate student of Dr. Moyle, caught and released a second bull trout, roughly the same size, in the same area of the river (Table 2). These bull trout captures were the first confirmed native char reports from the McCloud River in 7 years and gave renewed hope that bull trout numbers were still large enough to enable recovery efforts to be exercised with the native strains.

In 1976 the California Fish and Game Commission, in response to this new information, declared it illegal to take or possess any bull trout in the McCloud drainage.

BULL TROUT SURVEYS

1976 Bull Trout Survey

In October of 1976, the Department undertook a modest effort at sampling the McCloud River to evaluate the status of the McCloud River bull trout. Fyke nets, continuously-monitored gill nets, set lines and hook and line sampling were utilized in an effort to capture fish in a 3.2 km (2 mi) upper section of the McCloud River Preserve and in the vicinity of Crocker Pool, near the Preserve's lower boundary. Thirty rainbow and fourteen brown trout were captured but no native char were sighted.

1977-1978 Bull Trout Survey

During 1977 and 1978, the Department conducted an intensive survey of the McCloud River from Lower Falls to Shasta Lake, a distance of approximately 56.3 km (35 mi). The intent of this study was to further define the status of the river's bull trout populations

and, if bull trout were captured, attempt to establish an artificial propagation program based on native strains. A secondary objective was to gather general environmental information and to collect data on the little understood, yet excellent, wild rainbow and brown trout fishery.

A two to four man study team utilizing visual (snorkel and face mask), gill net and hook and line sampling methods surveyed the entire McCloud River below Lower Falls. Some areas sampled in 1977 were re-examined in 1978, giving a total of 72.4 km (45 mi) sampled. Two hundred twenty individual sample sites of which 69% were pools, were examined during this two-year period. Although the study was hampered somewhat by turbid water conditions caused by melting glaciers on Mt. Shasta, and late summer algal blooms which clogged gill nets, a total of 3,305 trout, all but one being rainbow or brown, (1,843 visually, 224 via gill net and 1,238 via hook and line) were examined. Only one of these fish was suspected to be a bull trout, an individual observed during a face mask survey of the "Dolly Varden Hole", located between Big Springs and Muir (Little) Springs, above McCloud Reservoir. Follow-up sampling at this site could not confirm the initial sighting.

During 1978, nine gill net sets were also made at the inlet end of McCloud Reservoir during the month of August. This operation netted 26 rainbow trout, but no char.

1976-1978 Department Creel Surveys

During the period 1976 through 1978, the Department conducted creel surveys on the first 5 miles of the McCloud River immediately below McCloud Dam. A total of 1,770 anglers who had caught 7,900 trout were interviewed (over 75% of the fish caught above the McCloud River Preserve are released and fishing regulations on Preserve property require 100% release). Of the fish kept, none were identified as bull trout.

Based on the negative results generated by the aforementioned surveys, the California Fish and Game Commission declared the bull trout a state endangered species in 1980.

1976-1986 Preserve Creel Reports

Since the McCloud River Preserve was opened to fishing in 1976, anglers have been required to self-report their results upon leaving. For the period 1976 and 1978 to 1986, 8,702 anglers reported catching 39,963 rainbow, 5,491 brown and 72 bull trout (for more detail, see Rode, in press). None of the reported bull trout catches were confirmed and they are believed to have been mainly misidentified brown trout.

DRAFT

1981 and 1982 Upper Wild Trout Area Creel Survey

In 1981 and 1982, TNC clerks conducted a random walk-through survey in the 8 km (5 mi) stretch of river between McCloud Dam and the Preserve. The 1,050 anglers interviewed reported catching 1,206 trout of which 14 (1.2%) were said to be bull trout. These anglers had released about 85% of their catch and of those fish kept, none were identified as bull trout.

1983 TNC Fisheries Studies

During the summer of 1983, TNC interns snorkeled and hook and line sampled the McCloud River from the lower limit of public fishing area within the Preserve to one-half mi below the confluence of the river with Squaw Valley Creek and also the lower 10 mi of Squaw Valley Creek. No bull trout were seen or captured.

1984 Bull Trout "Bucket Survey"

In 1984, under special permit, TNC attempted to substantiate angler reported bull trout catches. Cages were placed at one-half mi intervals along the river within the Preserve and buckets with instructions were located at every pool and access site. Anglers catching fish suspected to be bull trout were directed to carry their fish via bucket to the nearest cage. A $50 reward was offered to the angler catching the first positively identified bull trout. Only one fish was placed in a cage during 1984, a misidentified rainbow trout. Based on this experience and discussions with anglers, it is believed all recent bull trout reports are most likely erroneous.

1984-1987 Weir Studies

In an attempt to capture possible migrating bull trout, a fish weir and trap was established seasonally in the upper reach of the Preserve. Operation of this trap started as early as 7 April in 1987 and continued as late as 16 February in 1986-87. A second weir was operated from 17 June to 14 November 1986 and from 4 April to 7 May 1987 on the lower McCloud River about 1.6 km (1 mi) above Shasta Lake. These weirs sampled a total of 3,399 rainbow and brown trout and substantiated a large spawning migration of brown trout from Shasta Lake to the lower reaches of the McCloud River. Interestingly, the brown trout peak migration from Shasta Lake occurs in April or earlier with a smaller secondary migration taking place in October. The peak of the brown trout movement at the Preserve Weir occurs in October and early November. Spawning takes place predominately in late October and early November

(Rode, In press). The presence of this large brown trout population in the lower McCloud River may have had significant implications in the disappearance of the bull trout.

A third weir was operated from mid-July to mid-November, 1985 on the McCloud River above McCloud Reservoir, approximately 0.8 km (0.5 mi) above Big Springs and just downstream from the "Dolly Varden "Hole", a deep plunge pool known to historically concentrate large numbers of bull trout. This weir, which because of its design selected for fish greater than 305 mm (12 in) in length, did not capture any fish until 20 September 1985. Only 32 brown trout and one rainbow trout were captured. No bull trout were seen. Many of the brown trout were in poor condition. This fact and the overall low numbers of brown trout in the upper river suggest that conditions for brown trout in this section of the McCloud are marginal. This also suggests that much of the McCloud River was probably marginal for brown trout before the completion of McCloud Dam.

1985 Diving Surveys

During the summer and fall of 1985, skin diving with face plate and snorkel was employed to make both quantitative and qualitative observations of the fish population from Lower Falls to McCloud Reservoir (Galovich and Ingram, 1986). The extremely clear water in this area of the river allowed almost unlimited ability to identify the species of fish seen. During the quantitative phase of the study, many thousands of trout were identified, yet not one bull trout was noted.

1985-1986 Electroshocking Surveys

During 1985 and 1986 extensive efforts were made to locate bull trout in both the upper and lower McCloud River and a number of its tributaries via electrofishing.

A major pool and run complex located 0.8 km (0.5 mi) above McCloud Reservoir was electrofished on four nights during the summer and early fall of 1985. Results yielded 235 rainbow and seven brown trout, but no bull trout.

Backpack electrofishing gear was employed to search for juvenile or spawning bull trout in Star City (tributary to McCloud Reservoir) and Huckleberry, Angel and Mud creeks (tributary to the McCloud River above McCloud Reservoir). Bull trout were not detected in any of these waters. Population sampling was also conducted on several nights in 1985 at the mouth of the McCloud River at Shasta Lake and on 1 October 1985 in a large pool just upstream from the mouth of Squaw Valley Creek. These efforts also failed to capture any bull trout. In 1986, trout population

estimates were made on two reaches of Hawkins Creek and several sections of Squaw Valley Creek (Deinstadt, et.al., in manuscript). These surveys, too, did not encounter any bull trout.

Survey Summary

To summarize, a number of intensive and varied surveys have been conducted over the past twelve years that have examined thousands of trout in the McCloud River for the purpose of assessing existing bull trout numbers. A number of unsubstantiated angler reports of bull trout have been received. Only one possible sighting (in 1978) has been made by persons trained to identify bull trout. Thus, it appears that the bull trout has become extirpated from the McCloud River and California.

POSSIBLE FACTORS AFFECTING BULL TROUT EXTIRPATION

Why the California bull trout has declined is not precisely known and is open to conjecture. Wales (1939) prophetically stated:

> "The fact that this fish which is so abundant northward, is not found elsewhere in the State, presents a baffling problem in ecology and one which adds greatly to its romance. Of course, a vanishing species is one which for some reason or reasons finds life impossible in an area, and as it slowly loses its foothold in stream after stream, it must eventually become relegated to one body of water from which it will probably some day disappear altogether."

A number of reasons have been suggested as the cause for the bull trout's extirpation from the McCloud River. These factors may have worked individually or in concert; some may be more important than others. An attempt will be made to evaluate each one and its interactions with the others, where applicable:

Zoogeography

The bull trout of the McCloud River is considered a glacial relict. It persisted as long as it did because of the unique environmental conditions afforded by the clear, cold water provided by Mt. Shasta, Big Springs and Little Springs. The retreat of the bull trout from the southern extreme of its range is occuring today as it probably has in the past. A gradual change in the climate since the Pleistocene is resulting in loss of water once supplied by glaciers and snow fields and is a major factor in eliminating bull trout habitat (Cavender, 1978).

As a general rule, populations living at the extremes of a specie's range are existing in conditions that are less than

optimal and are most vulnerable for extinction by environmental changes or some competitive pressure (Behnke, 1979). The California bull trout population was restricted to only the McCloud River drainage which emphasizes its vulnerability to environmental change in that one system. However, there is no indication in the recent historical record that would indicate that natural environmental changes have occurred to the degree necessary to extirpate a species as quickly as happened to the McCloud bull trout.

Mud Creek Flows

Mud Creek has been a major and chronic contributor of sediment and turbidity to the McCloud River. Major mud flows occurred in the 1920's and 1930's with the worst year being 1924 when it was estimated that between one and three million cubic yards of debris entered the McCloud River (Hill and Egenloff, 1976). Effects on aquatic life are not documented, but must have been severe. The bull trout population must have been affected but only temporarily, since Wales (1939) reported good numbers of bull trout in 1938.

Harvest

Harvest of the bull trout by the Indians and early settlers does not appear to be a significant cause for its decline, since as late as 1938, good populations of this fish were noted in the McCloud River (Wales, 1939). The rugggedness of the McCloud Canyon, poor access and private land ownership severely restricted harvest opportunities.

The formation of Shasta Lake (Figure 2) certainly increased the potential for bull trout harvest. However, the bull trout persisted for over 25 years after the impoundment of Shasta Lake. With the opening of fishing in McCloud Reservoir in 1965, the harvest of bull trout more than likely was intense for several years Table 2: 10 bull trout checked on McCloud Reservoir on 30 August 1968. As has been shown on other waters, bull trout are highly susceptible to angling.

Introduction of Exotic Fish Species

The two exotic salmonids that have been introduced to the McCloud River and may have contributed in some degree to the demise of the bull trout are the brook trout and the brown trout. The brook trout had become well distributed throughout California by 1890 (Moyle, 1976). It is found in a number of McCloud River tributaries above McCloud Dam. Brook trout are well adapted to

cold, small, headwater, spring-fed streams. Their preference for cold water may result in an overlap with bull trout in habitat and food preference through the juvenile stage. Brook trout are fall spawners and are also known to hybridize with bull trout in the wild (Cavender, 1978). However, there are no indications that brook trout severely impacted bull trout through the first half of this century.

The stocking of about 17,700 brook trout in McCloud Reservoir in 1966, however, may have resulted in competition and hybridization with bull trout. Bull-brook trout interactions may have resulted in: (1) competition for spawning and nursery area which could have reduced bull trout recruitment and (2) hybridization that may have resulted in sterile offspring. However, brook trout did not survive or grow as well as stocked rainbow, so brook trout stocking was discontinued after 1966. Brook trout are no longer seen in the reservoir or adjacent river reaches. This poor survival, growth and reproduction of stocked brook trout suggests that few may have survived to spawn and that impacts of the 1966 brook trout stocking were probably limited to competition in the reservoir.

Brown trout have been in the McCloud River since the 1920's. Prior to the construction of McCloud Dam, flow and temperature conditions in the lower river probably favored the bull trout and brown trout were fewer in number and perhaps in poor condition such as those that were trapped at the Dolly Varden Hole weir in 1985 (see section: "1984-1987 Weir Studies"). Under present conditions, the brown trout below McCloud Dam are more abundant (DFG files) and probably in better condition than before the Dam. Today, the brown trout in the lower river occupies a degraded bull trout habitat niche. Brown trout are present throughout the lower river, but are greater in number in downstream areas, reflecting warmer water temperatures and a greater percentage of large pools there. It therefore appears that brown trout impacts on bull trout could be substantial since and because of the habitat changes caused by McCloud Dam.

Shasta Dam

Shasta Dam, blocked all anadromous fish runs in November, 1942 (Needham, Hanson and Parker, 1943) and ultimately inundated the lower 25.8 km (16 mi) of the McCloud River (Figure 2). It also provided a haven (reservoir) for the proliferation of nongame fish, introduced exotic warmwater gamefish and stocked salmonids. Furthermore, Shasta Lake along with the reduced flows caused by McCloud Dam provided the conditions needed for the establishment of a large adfluvial brown trout population. Shasta Reservoir also became a recreational and fishing center for northern California and, no doubt, greatly increased the harvest of bull trout that migrated to the lake.

Shasta Dam prevented major spawning runs of chinook salmon from reaching the McCloud River. In other areas, salmon eggs, carcasses and salmon fry are known to provide an important seasonal source of protein for bull trout (Moyle, 1976) and it can be assumed McCloud River bull trout fed heavily on these too. The lack of this yearly influx of protein may have seriously affected the bull trout (Moyle, 1976).

The effect of the inundation of the lower 25.8 km (16 mi) of McCloud River by Shasta Lake did not cause the bull trout to disappear. It appears that most of the bull trout population was centered further upstream (Stone, 1874, Wales, 1939) and may not have been severely impacted. In other areas, fluvial populations whose rivers have been dammed have readily adjusted to an adfluvial existence and prospered. This did not occur to any great degree in Shasta Reservoir, based on relatively recent records of angler catches from 1945 to 1965 (Table 2). The small number of reports may be an artifact of small samples, poor reporting or perhaps bull trout simply didn't inhabit Shasta Lake to any great extent.

Other factors that may have affected significant use of Shasta Lake by bull trout are:

1. Stocking of salmonids and other game fish may have increased direct competition with bull trout in the reservoir and the first few kilometers of the river.

2. Establishment of highly popular and intense fisheries in Shasta Reservoir may have resulted in a significant but unreported harvest of bull trout. This harvest may have also been highly seasonal when creel surveys were not conducted.

McCloud Dam

The completion of McCloud Dam in 1965 resulted in a number of serious impacts on the bull trout. The Dam inundated approximately 8 km (5 mi) of prime habitat and isolated important upstream spawning and nursery areas from downstream adult and juvenile rearing and holding areas (deep pools) (Figure 2). In effect, the life cycle of the bull trout had been broken. Adults below the Dam could no longer reach upstream spawning grounds and young fish in the upper river could not readily descend downstream. The downstream habitat was greatly changed.

McCloud Dam has also greatly reduced periodic flushing flows. Dam operation often creates highly turbid water conditions in the fall, at a time in the year when water quality was generally good before Dam construction. This is the time of year when bull trout would spawn and their eggs would be impacted by this sediment.

Testing of the Dam valves (sluicing) during the winter releases tremendous amounts of silt that would smother bull trout eggs and pre-emergent fry. Present conditions indicate much sedimentation of the gravels in the first few kilometers of river below the dam and partial filling-in of pools. If any potential bull trout spawning habitat remained below the Dam, it has been rendered useless in most years by Dam operation. The turbidities generated by the Dam and reduced flushing flows may have also seriously affected invertebrate production.

Most dramatic of the Dam's effects has been its impact on downstream flows and water temperatures. It is hard to determine the exact change in flows that has occurred at McCloud Dam, since PG&E is required to measure flows at the Dam only up to the maximum Ah-Di-Na fish release level of 17.47 m^3/sec (210 cfs). However, flow measurements taken near the Dam site (Panther Creek) from 1955 to 1959 showed an average flow of 36.50m^3/sec (1,289 cfs). At minimum release levels of 1.13 - 1.42 m^3/sec (40-50 cfs), which occur during winter and spring, the flow at the Dam is only roughly 3-4% of average historic values. This severely reduced flow continues downstream until it is augmented by tributary accretion to levels required (Table 1) at the Ah-Di-Na gage 5.3 km (3.3 mi) downstream.

At Ah-Di-Na, the 8.44 m^3/sec (298 cfs) mean monthly flow for the 19-year period 1966-1984 is only 23% of the 36.22 m^3/sec (1,279 cfs) pre-project level and the range of the mean monthly minimum and maximum has decreased from 20.70 - 54.60 m^3/sec (731 to 1,928 cfs) to 4.87 - 18.35 m^3/sec (172 to 648 cfs) (Figure 3, USGS, 1967 to 1985). The average flows of the McCloud River just above Shasta Lake have decreased from about 48.14 m^3/sec (1,700 cfs) to approximately 22.66 m^3/sec (800 cfs), a reduction of more than 50%.

The reduced flows below McCloud Dam have raised water temperatures slightly in the upper reaches of the lower river but have substantially increased the diurnal temperature fluctuation from the stable, cold temperature levels that existed before the Dam. In the lower reaches of the river just above Shasta Lake, average water temperatures have been raised 5.5°C (10°F) and maxima increased 11.1°C (20°F) (DFG, unpublished data files). Post-McCloud Dam changes in flow certainly have resulted in concommitant alterations in stream habitat. Reduced flows have resulted in lowered water depth, reduced wetted perimeter, reduced cover and changes in a number of other parameters. These, and increased temperatures have adversely impacted bull trout while favoring brown trout. The higher temperatures in the lower river are also more favorable for nongame fish. The lower flows may have also increased the potential for fish passage at Tuna Creek Falls which is located about 8 km (5 mi) above Shasta Lake thus increasing the potential for impacts from migrating nongame fish and brown trout.

CONCLUSION

In conclusion, even though a number of factors may have been cummulatively affecting the bull trout population and reduced it's numbers somewhat during the first half of this century, catches of young fish, 203-229 mm (8-9 in) long (indicating reproductive success) were reported as recently as 1965 (Table 2). It was not until after the construction of McCloud Dam that the bull trout very suddenly disappeared.

The most critical impacts of McCloud Dam in causing the extirpation of bull trout were probably (1) preventing the movement of bull trout from the large pools of the lower river to the unaffected spawning area above the reservoir and (2) the drastic changes in the river below the Dam. Had the original strain of bull trout in the area above the Dam been more resident in nature, the extirpation may not have occurred. Below the Dam, critical habitat factors for the bull trout appear to be lacking so it may not be able to reproduce and successfully compete under the current temperature, flow and siltation regimes.

DISCUSSION AND RECOMMENDATIONS

Reintroduction

The disappearance of the bull trout from the McCloud River represents the loss of California's only population of native char. A variety of man-induced biological and physical changes may have contributed to the bull trout's demise, but the most severe and final impact on its ability to persist appears to have been the construction of McCloud Dam.

Although the gene pool of the original McCloud River bull trout has been lost forever, there is strong justification for re-establishing a population of bull trout in the river using introduced stock.

The McCloud River has long been associated with the bull trout. It was from this population that the common name "Dolly Varden" originated. It is anticipated that there would be strong support from California's many anglers as well as the non-fishing public to see the reestablishment of this species as a part of California's native fish fauna. Once reestablished, the bull trout would contribute to the diversity of the angling experience in California as well as throughout the west. It would complement the already established and highly successful catch-and-release emphasis fishery in the Commission designated McCloud River Wild Trout Area below McCloud Dam (Rode, in press).

The environmental conditions of the McCloud River above McCloud Reservoir have remained relatively unchanged in spite of the construction of McCloud Dam. This stretch of river is

representative of a highly unique aquatic ecosystem comprised of a number of critical physical, chemical and biological elements. The bull trout represented one of those elements. The fact that there are not many brown trout in this stretch of river and that they are in poor physical condition, suggests that a vacant bull trout niche may exist in the upper river. Re-establishing the bull trout in the upper river would help return this stretch of water toward its natural, historical ecological balance.

Reestablishment of the bull trout in the McCloud River would help secure a species that is declining throughout much of its range. The McCloud River could act as a refugium for a bull trout stock, possibly one that is declining or threatened elsewhere. The experience gained from the bull trout reintroduction effort could provide valuable information that could be used in restoration efforts in other areas.

Reintroduction Objectives

The major objectives of a bull trout reintroduction would be:

1. To establish a self-sustaining, naturally reproducing population of bull trout in the McCloud River and its suitable tributaries.

   A stock should be chosen that appears best adapted for present river conditions, i.e., (a) a resident form that has little tendency to move downstream to McCloud or Shasta reservoirs and (b) a stock that tends to be insectivorous rather than piscivorous.

   If a significant percentage of introduced bull trout migrate downstream, high rates of angler harvest may severely impede the chances of population recovery. In support of (a) above, a number of observations indicate that the original native McCloud River stocks were migratory and this tendency may have contributed to extirpation of that stock. It has been reported that the original stocks migrated from the deep pools of the lower river to the upper river near the springs where they spawned. Migratory tendencies are also suggested by past catches of bull trout in the lower river and in Shasta Lake. In support of (b) in the previous paragraph, it should be noted that the fish forage base is limited in the upper reaches of the river below McCloud Dam and in the river above McCloud Reservoir.

   If possible, a bull trout stock should be selected that has a close geographical proximity to the former McCloud River population, thereby maximizing potential genetic similarities between the introduced and original stocks.

2. Emphasize establishment of a bull trout population to a level capable of supporting fishing.

The opportunity to fish a unique population of trout has great appeal to many anglers. If this can be accommodated without detriment to the population, much good publicity and support can be generated from the angling community.

If natural reproduction is inadequate, maintenance stocking of wild strain hatchery bull trout could be considered. This action would only be a last resort remedy, if it were shown that natural reproduction was not sufficient to maintain population numbers, but all other life history requirements were adequate. "Booster stocking" of hatchery reared wild stocks may also be required initially to ensure sufficient numbers of bull trout are introduced to the river.

3. Below McCloud Dam, emphasize establishment of bull trout as a part of the wild trout catch-and-release program stressing its uniqueness in California.

   Introduction of the bull trout below the Dam will be helped by the restrictive angling regulations already in place there and the prevailing attitudes of the anglers, who release 85% of their catch above the Preserve and 100% in the Preserve (Rode, in press). Initially anglers will have to release all bull trout which would still be protected by the current zero fish limit for that species.

Preliminary Proposals For Action

At the time of writing, we have located only one facility that regularly takes disease-free eggs from a wild bull trout stock. These eggs are taken from an adfluvial population in upper Arrow Lakes, British Columbia. Due to the unavailability of resident hatchery stock, it is proposed that the McCloud River introduction be based on eggs taken from resident wild stocks. These eggs would have to be tested and certified disease-free.

One possible source for such eggs is the headwaters of the Upper Klamath Lake drainage in southern Oregon. There are six known (and probably more) populations of bull trout in the Sprague and Sycan rivers, tributaries to Klamath Lake. These populations may be the most closely related to the original McCloud populations, since it is thought that during the Miocene-Pliocene or Pleistocene periods, connections occurred between the ancestral Klamath, Pit and Sacramento River drainages. This is thought to have been a probable distribution route of bull trout from the north to the upper Sacramento River drainage, including the McCloud River (Moyle, 1976). The populations under consideration in the upper Klamath drainage are a resident type, the kind considered most likely to be successfully established in the McCloud River under present conditions

Bull trout reintroduction is proposed as a two-phased project with reintroduction to be conducted first in the river above McCloud Reservoir. Concurrently, instream flow studies, habitat

evaluations and evaluation of dam operations would be conducted downstream from McCloud Dam to determine what changes are necessary to restore bull trout habitat and to increase the chances of bull trout reestablishment there.

Introduction of bull trout above McCloud Dam is proposed first because chances for success are greater there. This phase of the project is less complex and knowledge gained there can help facilitate the more involved downstream recovery effort.

The greater chance for success above McCloud Dam is based on the fact that flows, temperatures, water quality, instream habitat and riparian habitat have remained relatively unchanged in the river above the reservoir. The river and most of its tributaries above the reservoir run entirely through land under a single private ownership. The general public is not allowed to fish there, resulting in little fishing pressure or harvest that might interfere with recovery efforts.

The following is a proposed sequence of events for reintroducing bull trout to the upper river:

1. Chemically treat Huckleberry Creek which is tributary to the McCloud River immediately above McCloud Reservoir to remove brook trout (Huckleberry Creek appears to be an ideal bull trout spawning and rearing stream and a culvert near its mouth is a barrier to upstream migration of other trout species). Close Huckleberry Creek to all fishing and stock with bull trout from out-of-state sources. Periodically, transfer Huckleberry Creek bull trout to the main river and other suitable tributaries.

2. Stock bull trout from out-of-state sources and young-of-the-year reproduction from Huckleberry Creek in a rearing facility at an existing spring-fed pond at Wyntoon on the banks of the river. Raise fish to yearling size and release into the river and suitable tributaries.

3. Monitor the success of bull trout reintroduction via snorkeling, electrofishing and, possibly, the operation of weirs during fall months.

4. Consider more restrictive angling regulations in the river and/or reservoir if angler harvest of bull trout appears detrimental.

5. As a last resort, consider augmenting natural reproduction with a hatchery program based on trapped wild bull trout spawners.

Reintroduction of bull trout below McCloud Dam should incorporate the following considerations:

1. Attempt reintroduction of bull trout above McCloud Dam first; success there will determine, in part, feasibility of downstream introductions.

2. Initiate instream flow, temperature modeling, sediment transport and other studies to determine potential changes that can be made in dam operation and instream habitat that would contribute to successful reestablishment of bull trout.

3. Reintroduce bull trout from areas above McCloud Dam planting most bull trout in the upper half of the lower river where conditions are more favorable.

4. Monitor bull trout success via snorkel surveys, creel checks, electrofishing and possibly fall weir deployment.

5. Consider a zero limit for all trout in the wild trout area below the dam if anglers tend to keep bull trout under the current zero limit for bull trout and 2 trout limit for other species.

6. If reproduction of bull trout is unsuccessful or inadequate, consider maintenance stocking of hatchery fish.

7. Emphasize the uniqueness of catch and release opportunities for bull trout in the McCloud River Wild Trout Area.

ACKNOWLEDGEMENTS

I especially wish to thank T. Hesseldenz and W. D. Weidlein for their input and participation in most aspects of bull trout investigation on the McCloud River. Special thanks also go to the many DFG seasonal aids and TNC interns who, over the years, participated in one way or another in the often frustrating search for the McCloud River bull trout. D. Hoopaugh initiated some of the earlier field investigations, including the bull trout survey in 1977 and T. Healey helped with the weir data summarization. The Hearst Corporation, McCloud River Club and Bollibokka Club were very helpful in allowing access and providing support for these studies. S. Ellis, E. Gerstung, J. Hayes, T. Hesseldenz, D. Hoopaugh, C. VonGeldern and W. D. Weidlein reviewed the manuscript.

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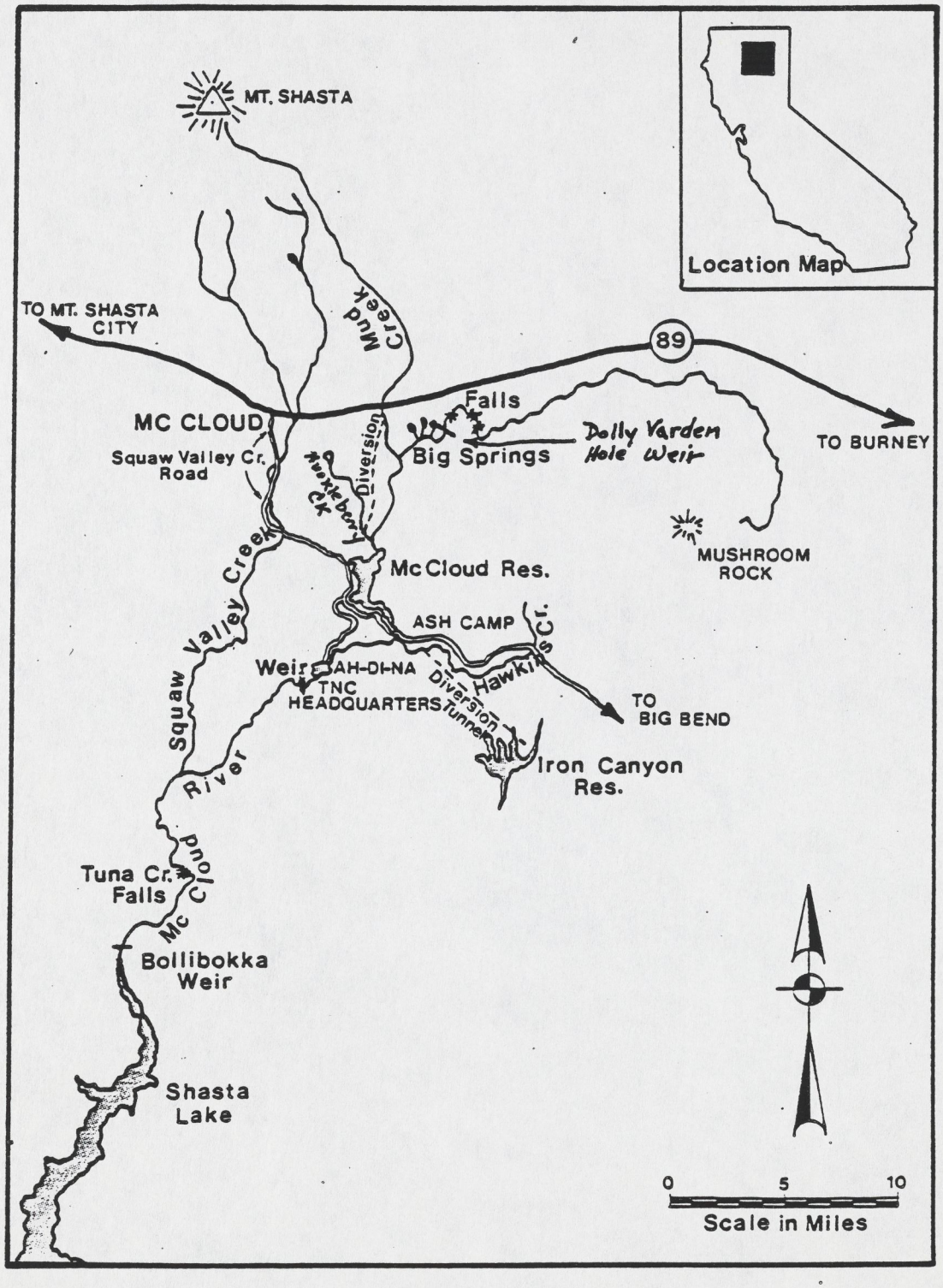

FIGURE 1. McCloud River Drainage, CA

From Rode, M. in press. McCloud River Wild Trout Area Management Plan, Calif. Dept. of Fish and Game, Inland Fish. Rpt.

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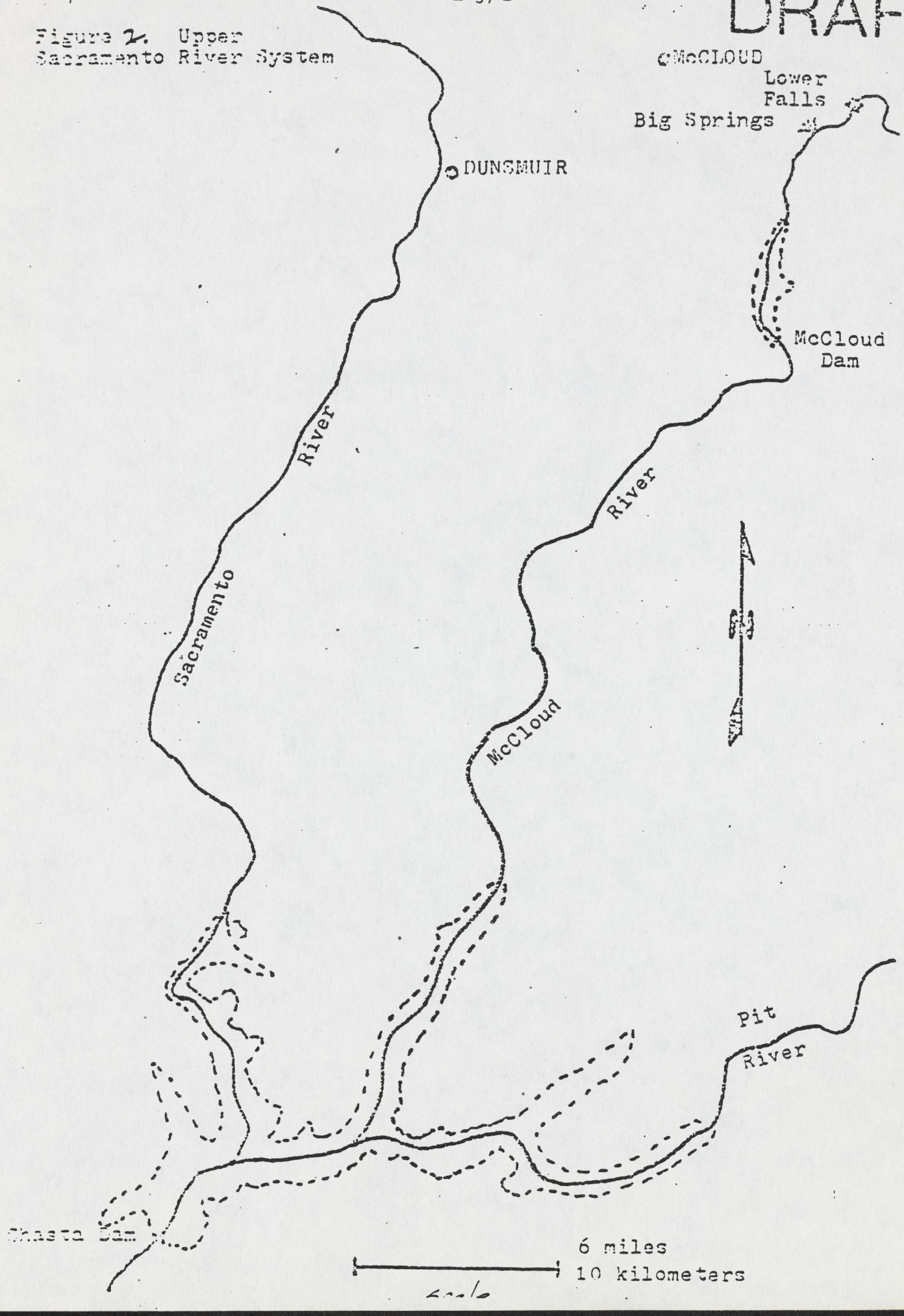
Figure 2. Upper Sacramento River System



Scale will be changed to metric in next draft

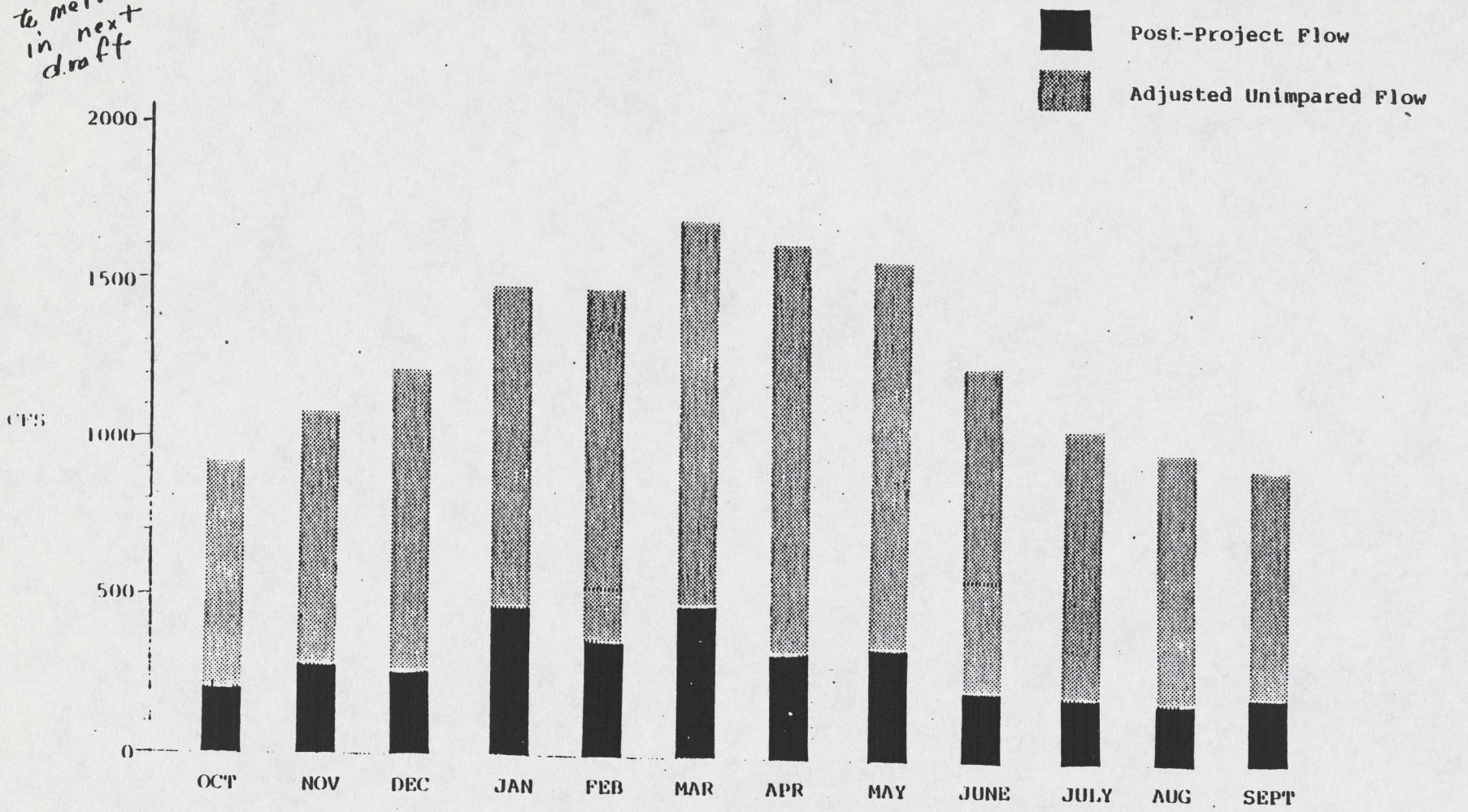


FIGURE 3. Mean Monthly Flows and Adjusted Unimpared Flows at Gate No. 11367800, McCloud River at Ah-Di-Na, 1966 - 1984 (From USGS Records 1967 to 1985).

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MR/DW

TABLE 1. Required Fishery Flow Releases for McCloud Dam

Measurement Location	Time Period	Minimum Required Release (CFS) Normal Year	Dry a/ Year
Gage No. 11367760	May 1 - Nov. 30	50	50
Below McCloud Dam	Dec. 1 - Apr. 30	40	40
Gage No. 11367800	Jan. and Feb.	160	160
at Ah-Di-Na	Mar. and April	170	170
	May 1 - 15	170	160
	May 16 - - Aug. 31	200	160
	Sept. 1 - Dec. 15	210	180
	Dec. 16 - Dec. 31	170	170

a/ A dry year is defined as one in which the California Department of Water Resources April projected inflow from the McCloud River into Shasta Lake for the period April to July will be 300,000 acre-feet or less, except that not more than two years in succession will be considered dry, regardless of forecast.

TABLE 2 Confirmed Reports of Bull Trout Captures in California

Date	Name	Type	Location	Number
8-22-44	Wales & Dill	Creel census	McCloud Arm, Shasta L.	1
? 44	Wales & Dill	Reports	Pit R. Arm, Shasta L.	"some"
5-1-45	?	Creel survey	McCloud Arm, Shasta L.	2
5-6-46	Wales	Creel survey	McCloud Arm, Shasta L.	?
5-1-47	Wales	Creel survey	McCloud Arm, Shasta L.	2
5-1-49	German	Creel survey	Mouth McCloud R., Shasta L.	14
4-29-50	German	Creel survey	Mouth McCloud R., Shasta L.	2
4-28-51	German	Creel survey	Mouth McCloud R., Shasta L.	?
5-3-52	German	Creel survey	Mouth McCloud R., Shasta L.	?
1950	Coots	Report	Ah-Di-Na	1 (4.5+ kg)
1956	Shott	Fish captured and brought to Mt. Shasta Hatchery	Wyntoom	1 (3.4 kg)
9-29-64	Healey	Gill net	McCloud R. 6 1/2 km above mouth	1 (20 cm)
12-18-64	Healey	Gill net	McCloud R.	1 (20 cm)
2-5-65	Healey	Gill net	McCloud R.	1 (20 cm)
2-26-65	Healey	Gill net	McCloud R.	1 (23 cm)
8-30-68	Shott	Creel survey	McCloud Res.	10
7-75	Dion	Photography	McCloud R. Preserve	1 (_50 cm)
8-75	Sturgess	Report	McCloud R. Preserve	1 (_50 cm)

The Nature Conservancy

McCLOUD RIVER PRESERVE
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McCloud, California 96057

McCloud
Bell Trust

Robert J. Behnke
Colorado State University
Fort Collins, Colorado

McCLOUD RIVER PRESERVE
Post Office Box 409
McCloud, California 96057

July 20, 1982

Robert J. Behnke
Colorado State University
Fort Collins, Colorado

Dear Dr. Behnke:

I am writing to you with reference to the bull trout Salvelinus confluentus, recently taxonomically differentiated from Salvelinus malma by Ted Cavendar (1978). In his paper, Taxonomy and distribution of the bull trout, Salvelinus confluentus (Suckley) from the american northwest, he ascertains that other characteristics than conventially used in Salmonidae taxonomy (ie: number of gill rakers and pyloric caeca) are necessary to distinguish between the two species : shape of head, number of mandibular pores and branchiostegal rays as well as gill raker morphology, etc. Cavendar further maintains that the main difference between the species is that one is anadromous (S.malma), while the other is a interior variety, non anadromous. Of the 15 specimens Cavendar examined from the McCloud River, he identified two as being S.malma. These individuals were from Livinston Stone's collection from 1872. The other 13 specimens were identified as S.confluentus.

This question is of particular interest to me because I am presently working on the bull trout in the McCloud River for The Nature Conservancy. The results of this investigation will aid The Nature Conservancy in determining the future management needs of this area.

In trying to assess the factors that may have led to the demise of the bull trout populations in the McCloud River, I am frustrated by the lack of historical evidence as well as to the uncertainty as to whether bull trout in this river were originally anadromous or non anadromous. I have been unable to find any papers commenting on Cavendars work, and in view of the fact that "ecological and behavioral differences between the two have not been studied in detail" (Cavendar, 1978), I am wondering if there may be room for doubt as to some of Cavendars taxonomic conclusions. The fundamental difference, of whether they may have been anadromous or not in this area, is important in determining more precisely the impact of man made alterations to the McCloud River - such as the construction of Shasta Dam.

Your opinion and comment on this matter would be greatly appreciated.

Sincerely,

Cindy L. Halbert

Cindy L. Halbert

L. Malaria Trutta

1981(4)

— Copeia fontinalis

G. S. .89 N. ⇨ S.

Cindy L. Halbert

McCLOUD RIVER PRESERVE
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The Nature Conservancy

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Dr. Robert J. Behnke
Department of Fishery and Wildlife Biology
Colorado State University
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McCLOUD RIVER PRESERVE
Post Office Box 409
McCloud, California 96057

August 28, 1982

Dr. Behnke
Department of Fishery and Wildlife Biology
Colorado State University
Fort Collins, Colorado 80523

Dear Dr. Behnke:

Thank you very much for your early and informative reply to my last letter and for taking an interest in my work. I have just recently completed a 12 day trip through Oregon, Washington, Idaho, Montana and British Columbia where I had the opportunity to visit several rivers and lakes where bull trout occur, as well as to talk to several knowledgeable people who have done studies on bull trout. The purpose of this trip was to do a comparative study of the areas where bull trout currently exist versus existing conditions found on the McCloud River.

Your letter pointed out relevant points regarding bull trout distribution and in view of the fact that bull trout (or Dolly Varden) have not been recorded from the Pit and Sacramento Rivers it does seem most plausible that the bull trout in the McCloud River were nonanadromous. They probably preferred the McCloud R. due to it low water temperature regime maintained by "Big Springs" (about 800 cfs at 44° F). If the bull trout in the McCloud were indeed nonanadromous, I wonder what their earlier distribution was with respect to other bull trout populations. Were they at one time associated with the Klamath drainage populations? I am curious as to which populations in N.America you feel may at one time have been from the same genetic stock and how recently they were separated.

The Fish and Game Department in California is considering introducing bull trout from elsewhere into the McCloud River. Although it is unfortunate that the only population of bull trout in California is disappearing, I have several reservations on this matter. If the McCloud River population is merely the southernmost distribution of an overall larger population, than it may be best to let it go extinct in its southernmost range, where as you said, it is most susceptible to environmental changes, etc. If it was a unique genetic population, than I don't feel that it can be remedied by the introduction of a different genetic population that did not evolve in the McCloud River. What are your feelings on this matter?

The last official confirmed reporting of bull trout in the McCloud River was in 1975. Steve Dion, a USFS employee caught a 16¼ bull trout on The Nature Conservancy McCloud River Property. Shortly thereafter, J.Sturgess, a graduate student

of Dr. Moyle, caught and released a second bull trout, roughly the same size, in the same area of the river. (Rode & Hoopaugh-unpublished California Fish and Game report). The last report before 1975 was in 1968.

An intensive study by Dr.Moyle and his graduate students in the summer of 1974 failed to reveal any bull trout. The Fish and Game Department also conducted an intensive survey of the lower McCloud River, from lower Falls to Shasta Lake, during the summers of 1977 and 1978 and failed to confirm any presence of bull trout. My own limited attempts this summer (through SCUBA and angling) have also failed to reveal any bull trout. Although the water visibility (due to glacial silt), swift current, etc. greatly hamper a true assessment of any existing bull trout, it does not seem that they exist in any great numbers. The Nature Conservancy will make an attempt this fall to look at the tributaries to determine whether they can locate any spawning bull trout and/or redds.

A few fishermen (all fishermen who fish on the McCloud River Preserve are requested to fill out their fishing results) have recorded catching bull trout. Some of these reports are most likely a confusion with brown trout (especially lake browns that come up from Shasta Lake), but others caught by experienced fishermen who have caught bull trout before, may be quite possible. These citings are of course difficult to verify since the McCloud River Preserve maintains a catch and release only fishing area. Here is a summary of the unconfirmed reports of bull trout caught on the Preserve since 1978.

1978 - 1
1979 - 1
1980 - 3
1981 - 14
1982 - 4

I understand that you have published a more recent paper than the 1972 paper on "The Systematics of Salmonid Fishes of Recently Glaciated Lakes". I would appreciate a copy of your recent report.

Sincerely,

Cindy L. Halbert

Cindy L. Halbert

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