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

by

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Inland Fisheries

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ABSTRACT

Bull trout in California were native only to the lower McCloud River of northern Shasta and southern Siskiyou counties. 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. Life history and habitat data from other waters are reviewed to aid in evaluating reasons for the bull trout's disappearance and to assess chances for its successful reintroduction.

Extirpation of the bull trout from the McCloud River is attributed primarily to the impacts of McCloud Dam which was constructed in 1965. The dam inundated bull trout spawning and nursery areas and physically isolated upstream spawning and nursery habitat from prime downstream juvenile and adult holding habitat. McCloud Dam has also drastically altered downstream flows and water temperatures and has 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: (i) angler overharvest, (ii) introduction of exotic salmonids and (iii) 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 in northern Shasta and southern Siskiyou counties (Figure 1). This population was the southernmost extension of the species within its range and represented California's only native char.[3/] Due to its unique zoogeography, interesting history, and limited numbers and distribution, bull trout constituted a small but important component of the California ichthyofauna.

Bull trout in the McCloud River had declined drastically by the early 1970's. In 1975, however, two bull trout were captured by anglers, giving hope that sufficient numbers still remained to recover 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 in 1970 (California Species Preservation Act, Endangered Species Act, and other legislation), the Department of Fish and Game (Department) must identify species threatened with extinction or endangerment and recommend actions to insure their survival, protection and recovery. With guidance from its Threatened Trout Committee, the Department is preparing management plans for various threatened native salmonid species throughout the state. The purposes of this report are to (i) summarize existing information regarding the bull trout, including its taxonomy, life history, distribution, status and habitat requirements and (ii) recommend an appropriate plan for re-establishing the bull trout in the McCloud River. This report documents the decline of the McCloud River bull trout, evaluates causative factors leading to the decline, reviews Department activities aimed at assessing bull trout status, and provides recovery and management recommendations.

The McCloud River Wild Trout Area Management Plan (Rode in press) also provides information on trout in the McCloud River. Particularly relevant are descriptions of the river's history, fish populations and current wild trout management program with

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[3/] 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.

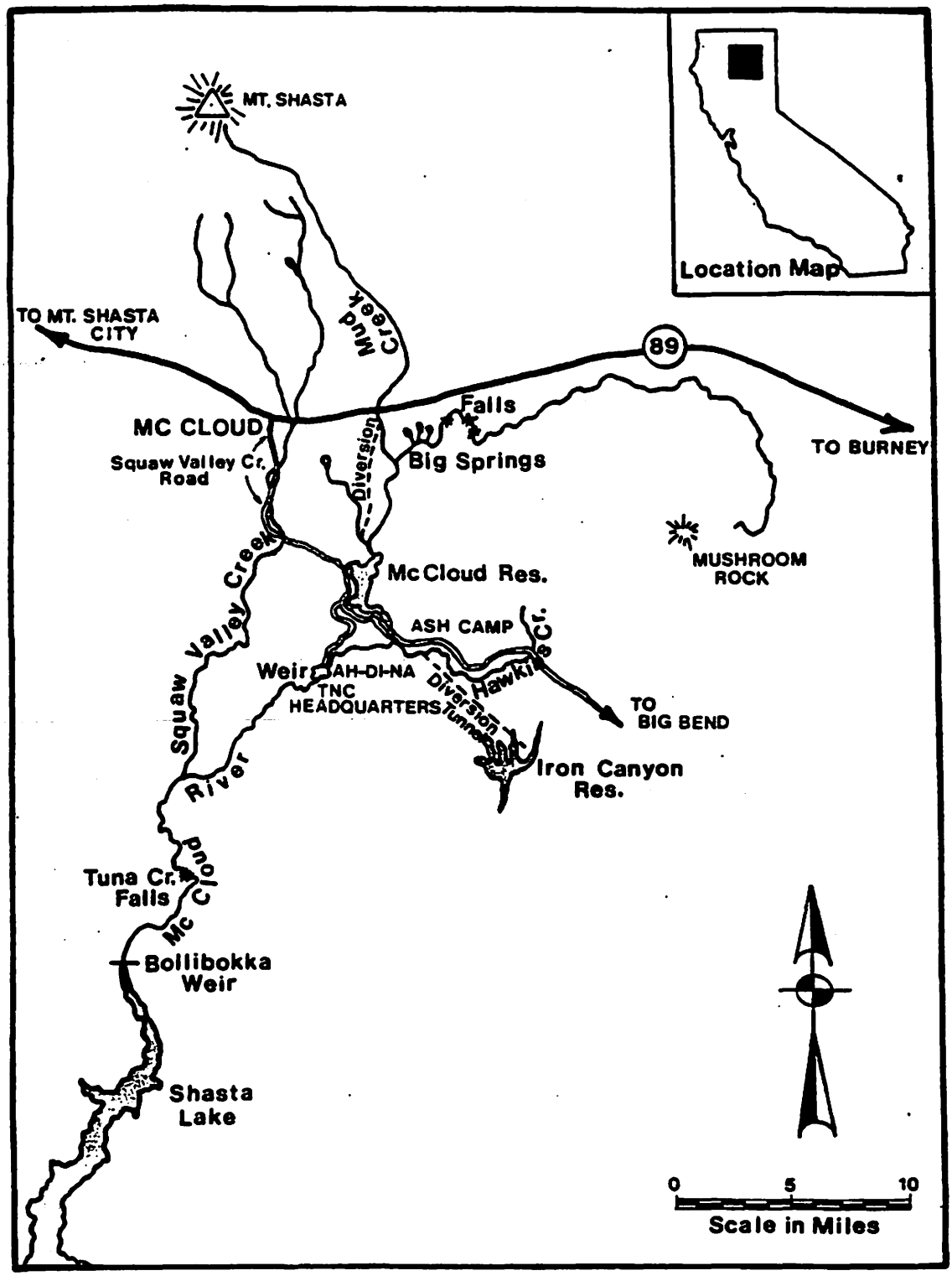

FIGURE 1. McCloud River Drainage, California.

emphasis on the first 16.9 km (10.5 mi) of the McCloud River below McCloud Dam. Special angling regulations apply within this wild trout area emphasizing catch and release angling. That plan also makes numerous recommendations, generally complementary to those in this report, for the management of the area and its fish habitat.

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

TAXONOMY

The bull trout is a char 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 brook trout (S. fontinalis Mitchill), lake trout (S. namaycush Walbaum), and other Asian and European chars (Morton and Miller 1954).

Electrophoretic data have shown that 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).

Five bull trout populations 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 to preserve the genetic resource represented by the bull trout and also supports the likelihood that the McCloud population was genetically distinct.

The earliest published account of the bull trout[4/] 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 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

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[4/] 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.

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. McCloud River bull trout 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 supports the origin of the McCloud char as a native California population that may have been genetically distinct.

Cavender examined 15 museum specimens from the McCloud River and 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 both species may have existed sympatrically in the lower McCloud River but 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 lb) 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 have similar coloration: olive green with small yellow or light spots on the back and inconspicuous small red spots on the sides. Fins are completely devoid of any spotting save for possibly a few yellow spots at the base of the tail. 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 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). 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 present in the Pit and Sacramento rivers and were unsuccessfully stocked in two Yosemite National Park waters (Wales 1939, McAfee 1966). Bull trout fry raised at the Mt. Shasta Hatchery were planted in the Sacramento River near Soda Springs and in Squaw Creek near its confluence with the Truckee River in 1895 (Mt. Shasta Hatchery records). The source of these eggs is not documented, but it is highly probable that they originated from Baird Hatchery on the lower McCloud River, since Baird Hatchery supplied Mt. Shasta Hatchery with salmon eggs at that time. The 1895 plant of 2,000 fry in the Sacramento River may have accounted for some subsequent bull trout catch reports.

Anglers caught small numbers of bull trout in Shasta Lake in the mid-1960's 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, water temperature gradients or from more recent events such as 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 are presented to help explain why the McCloud River bull trout disappeared and what factors should 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 prior to the construction of Shasta and McCloud reservoirs.

Reproduction

Bull trout generally mature by their fourth or fifth year (Moyle 1976) but some fish may mature in their sixth year in northern waters (Allan 1980). Spawning adults in the upper Flathead River basin ranged from five to nine years of age (Shepard, Pratt and Graham 1984).

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

Bull trout generally spawn during a relatively short time period from early September through late October (Scott and Crossman 1973, Shepard et al. 1984). Campbell (1882) found McCloud River bull trout spawning 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 begins when 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, frequently returning to specific spawning grounds each year (Fraley, Read and Graham 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/s, 2.0 ft/s) reaches of larger, higher stream order tributaries (Allan 1980, Oliver 1979, Shepard et al. 1984). Spawning sites are strongly associated with areas influenced by springs (Allan 1980, Shepard et al. 1984). Springs may 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 and where streams split into multiple channels (braided sections). These aggrading stream channel areas 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). Eggs are deposited from about 0.05 - 0.25 m (2.0-9.8 in.) in the gravel (Shepard et al. 1984). Redds are constructed in bed material dominated by small (2-25 mm [0.1 - 1.0 in.]) gravel and large (25-50 mm [1-2 in.]) gravel (Shepard et al. 1984). Bull trout have been observed spawning in relatively exposed areas of streams (Allan 1980) suggesting that they do not pick spawning areas associated with abundant cover. However, spawning areas have escape cover located nearby with the average distance between redd and stream bank being approximately 3 m (9.8 ft) (Oliver 1979, Fraley et al. 1981).

Females lay from 1337 - 8845 eggs 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 brook trout (Cavender 1978). This may be significant in view of the history of brook trout plants in the McCloud River drainage. They were artificially crossed with success at Sisson Hatchery, Mt. Shasta in about 1892 (Evermann and Clark 1931).

Egg Deposition Through Emergence

Bull trout eggs are spawned from September through October and require an average of 35 d and 200 temperature units (TU^s, °C) from the time of fertilization to the eyed stage (Shepard et al. 1984). Hatching is generally completed by the end of January after 100-145 days and 350 TU^s (°C) (Shepard et al. 1984). McPhail and Murray (1979) reported laboratory incubation periods of 126 d at 2°C (35.6°F) and 95 d at 4°C (39.2°F).

Survival rates of naturally spawned eggs to hatching range from approximately 40 to 50% (Blackett 1968, Allan 1980). Egg survival and development is highly affected by temperature. McPhail and Murray (1979) found that survival was 80-95% at 4°C (39.2°F), 60-90% at 6°C (42.8°F) and only 0-20% at 8-10°C (46.4-50°F); at lower temperatures, alevins (sac fry) were larger and the hatch duration shorter. Experiments at the Kootenay Hatchery, British Columbia, have shown that the optimum egg incubation temperature is 4°C (39.2°F) (Brown 1985).

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

Bull trout alevins require approximately 65-90 d to absorb their yolk sacs (Shepard et al. 1984). Unlike other salmonids, bull trout fry remain in the gravel for up to three wk following hatch before filling their air bladders and becoming neutrally bouyant and photo-positive. Bull trout generally emerge in April with the average time from fertilization being 223 d (634 TU^s, °C). 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 et al. 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 microhabitat of extremely low water velocity. Their

use of the stream bottom where water velocities are greatly reduced from velocities in the upper water column, allows small bull trout to utilize a wide range of macrohabitats 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 use faster (but still slow) water and are 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 et al. 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 (64.4°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 and abundance 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. The optimum temperature for hatchery rearing is 7°C (44.6°F) (Brown 1985).

In fluvial or adfluvial populations, juvenile bull trout generally emigrate downstream from their natal tributaries in summer and fall at age one, two or three, with the majority being age two (Bjornn 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.

Adult Stage

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

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

Age And Growth

Bull trout typically reach a maximum age of 10-12 yr (with occasional 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 in.) 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). 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 two fish at the Mt. Shasta Hatchery were originally taken by angling from the McCloud River and maintained as exhibits at the hatchery; they were not a hatchery broodstock.

More recently, the heaviest verified specimen from the McCloud system, recognized as the California State angling record, 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).

The angling size record, taken from Lake Pend Oreille, Idaho, in 1949 was reported by Field and Stream magazine to be 1,029 mm (40.5 in.) long, 755 mm (29.7 in.) in girth, and 14.5 kg (32 lb) in 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). 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 (Shepard et al. 1982). Fish became an important part of the diet in bull trout larger than 110 mm (4.3 in.) TL. Fish eggs can be an important part of the diet seasonally where fall spawning runs of other species occur. However, most such eggs are consumed as wash-out drift when they are dislodged from redds by spawning fish (Armstrong and Morrow 1980). Juvenile bull trout appear to eat little in winter as evidenced by weight loss and empty stomachs (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 fish movement 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. However, 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 they are reportedly not spectacular fighters. In areas where they attain large size, however, bull trout are highly sought after by anglers for food and sport and provide a quality fishing experience that few other species provide. Because of their piscivorous nature and voracious appetites, bull trout are highly vulnerable to angling with bait and lures. In streams having mixed salmonid populations, angling is highly selective for bull trout (Allan 1980), and in many waters they are overharvested (Anonymous 1985, Boag 1987).

In many areas, the bull trout's slow rate of maturation subjects them to substantial angling mortality before they have 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 with bull trout populations have closed spawning and nursery tributaries to fishing to protect these stocks.

Most bull trout taken from the McCloud River were reported to have been caught on deeply fished salmon eggs in the larger pools. However, 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 (Wales 1939).

McCloud River bull trout were much sought-after in the late 1800's, as parties would travel by trail 24 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) near Mushroom Rock, the McCloud travels 95 km (59 mi) in a southwesterly direction, draining 161,222 ha (622 sq mi) (USGS 1984, USGS 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/s (40 cfs) to about 23 m^3/s (800 cfs). About 0.8 km (0.5 mi) above Wyntoon, a third spring source further augments river flows. 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), 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/s (200 cfs) (USGS 1984, USGS unpublished data). The McCloud River Wild Trout Management Plan (Rode in press) contains a more thorough description of the McCloud River.

MCCLOUD RIVER 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 (hatchery now inundated by Shasta Lake). The river from Lower Falls to McCloud Reservoir is typically very swift riffles and rapids, with very few pools. Below the reservoir, the McCloud 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 resident rainbow trout (Oncorhynchus mykiss [formerly Salmo gairdneri]), steelhead rainbow trout (Oncorhynchus mykiss [formerly 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 (Wales 1939). The brown trout (Salmo trutta) 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 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/s (1000 cfs) (estimate based on a mean daily flow of 26.1 m^3/s [921 cfs] for 40 yr of records at USGS Gage 3675, located approximately 0.8 km [0.5-mi] above the head of McCloud Reservoir). The present minimum release is 1.13 m^3/s (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 reached levels as high as 23.9°C (75°F) (DFG files), 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 (45°F) water and, during summer low flow periods, increases river volume twenty-fold (DFG Files). Its cooling effects were felt far downstream, as reported by Campbell (1882), who found that the upper range of 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

'ABLE 1. Required Fishery Flow Releases for McCloud Dam.

		Minimum Required Releases			
		CFS		CMS	
Measurement Location	Time Period	Normal Year	Dry [a] Year	Normal Year	Dry [a] Year
Gage No. 11367760 Below McCloud Dam	May 1 - Nov. 30	50	50	1.416	1.416
	Dec. 1 - Apr. 30	40	40	1.133	1.133
Gage No. 11367800 at Ah-Di-Na	Jan. and Feb.	160	160	4.531	4.531
	Mar. and April	170	170	4.814	4.814
	May 1 - 15	170	160	4.814	4.531
	May 16 - Aug. 31	200	160	5.664	4.531
	Sept. 1 - Dec. 15	210	180	5.947	5.098
	Dec. 16 - Dec. 31	170	170	4.814	4.814

[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 370.05 hectometers (300,000 acre-feet) or less, except that not more than two years in succession will be considered dry, regardless of forecast.

resulted in an 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/s (40 or 50 cfs). Ironically, this has resulted in a situation where flows in the first 1.6 km (1 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 spawning and 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/s (200 cfs) (Table 1). The highest flow recorded at Ah-Di-Na (USGS Gage No. 11367800) since the construction of McCloud Dam was an estimated 747.6 m^3/s (26,400 cfs) on 16 January 1974; the lowest daily discharge of 1.2 m^3/s (41 cfs) occurred on 18-20 December 1971, due to a valve malfunction at the dam (USGS 1984).

Water temperatures 8.5 km (5.3 mi) below the dam near the mouth of Ladybug Creek range from 9.4°C (49°F) to 15°C (59°F) and fluctuate about 5°C (10°F) daily during summer months (The Nature Conservancy and PG&E unpublished data).

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 was impossible for prolonged periods (Wales 1939, Hill and Egenhoff 1976). The turbidity problem today is chronic but much less severe. At times, however, turbidity is severe enough to reduce fishing success.

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 river erodes the sediments deposited at the head of the reservoir; this erosion may be particularly severe following the first substantial fall rains. These sediments become resuspended and may cause prolonged bouts of turbidity in the lower river. Lastly, sluicing or testing of the McCloud Dam bypass valve discharges bottom sediments from the reservoir. This causes high turbidities of relatively short duration in the lower river.

When the river is running clear, the water is low in total dissolved solids (97 ppm), soft (38 ppm $CaCO_3$) and slightly basic (pH 7.

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 0.5 - 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 - 3.7 m (6 to 12 ft) deep and 18.3 - 91.4 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 sensitivity of bull trout to overfishing is well demonstrated by experiences in Alberta, where most stocks are overharvested, even in some areas without 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 demand for recreational fishing appears to be increasing in most areas, and it can be expected that additional pressures will be placed on bull trout stocks.

The most serious threat to bull trout, however, appears to be habitat loss due to a number of man-induced environmental alterations, including water impoundment and diversion, mining, road building and logging. The introduction of exotic salmonids (such as brook trout and brown trout that may hybridize or compete with bull trout) has also impacted stocks in many areas (Allan 1980).

Very little information is available on the historical status of bull trout in the McCloud River. Wales (1939), in documenting the species in the McCloud River, seemed to rely on angler reports rather than more formal sampling:

> "S. malma was supposedly less abundant toward the mouth of the McCloud, though I was told by one fisherman that he had caught them in the Pit River near the mouth of Squaw Creek. They range nearly up to the lower falls at present and seem to be common throughout most of this range. The size of those caught is usually between 8 and 10 inches, although reports are heard of them reaching a weight of 16 pounds, even at the present time." (Emphasis added)

The scarcity of data on the McCloud fish population in 1938 (as well as today) appears to have been due to the lack of public access to nearly all the river from Lower Falls to the area now inundated by Shasta Lake. The Department did not conduct extensive surveys on this reach of the river since the public was excluded and there was relatively little fishing pressure.

Wales (1939) seems to suggest that the bull trout was common in the McCloud River in 1938 even though its range was severely restricted. However, the bull trout does not appear to have been the dominant trout species; its numbers were limited in comparison to the more abundant rainbow trout. It is likely that historically the bull trout has never constituted more than a small fraction of the total trout population in the McCloud River. Regarding the bull trout's status, Wales (1939) further states:

> "There is no bag limit on this trout but the writer does not feel that it is in any danger of extinction despite its limited range." (Extinction would probably not have been mentioned if the bull trout was the dominant species of trout in the McCloud River or found commonly elsewhere in California).

An annual creel census from 1944 through 1952 (except 1948) conducted on the opening day of trout fishing season near the mouth of the McCloud River at Shasta Lake revealed occasional catches of bull trout. One exception was in 1949 when Department fishery biologist Eugene German (now retired) checked 12 bull trout caught in the lake and two more from the river along with a total of 74 rainbow and five brown trout. No bull trout were checked on opening day of fishing in 1951 and 1952. In general, relatively few brown trout were seen in these checks (DFG files).

More recently in 1964 and 1965, Department fishery biologist Terry Healey captured four bull trout from 14 gill net sets in the lower 6.4 km (4 mi) of the river above Shasta Lake; the bull trout represented 9.5% of the total trout caught (Table 2). No bull trout were captured in 10 subsequent gill net sets in the same area from 1968 to 1974 (Table 2, DFG files).

When the McCloud River was first diverted to Iron Canyon Reservoir on 20 August 1964, about 0.8 km (0.5 mi) of river was dewatered. Department biologist Millard Coots rescued or counted as dead a total of 118 rainbow trout and five bull trout primarily from a side channel area (DFG Files; Millard Coots, former DFG fishery biologist, Redding, CA).

Creel checks of anglers at McCloud Reservoir from 1967 to 1973 showed bull trout were caught occasionally during the first five years after dam completion, but none were seen thereafter (Table 3, DFG files). Population sampling in 1973 and 1974, including gill netting and electrofishing in McCloud Reservoir, McCloud River, and a number of tributaries, failed to capture any bull trout.

TABLE 2. Results of Gill Net Sets in the Lower McCloud River Between Chatterdown Creek and Shasta Lake, Shasta County.

Date	Number of Fish Caught				
	Bull Trout	Rainbow Trout	Brown Trout	Kokanee Salmon	Nongame Fish
PRE-McCLOUD DAM					
8-13-64	0	4	1	3	0
9-28-64	1	3	0	2	1
10-15-64	0	0	1	1	1
11-12-64	0	3	1	0	1
12-07-64	1	1	2	0	0
1-19-65	0	3	0	0	0
2-04-65	1	1	0	0	0
2-25-65	1	4	0	3	0
3-11-65 (2 sets)	0	5	0	7	0
3-30-65	0	1	1	2	0
5-13-65 (2 sets)	0	3	2	8	0
8-09-65	0	2	0	6	0
Total	4	30	8	32	3
POST-McCLOUD DAM					
9-03-68	0	4	0	3	7
9-03-68	0	0	0	4	1
2-01-70	0	6	0	0	0
5-21-74	0	4	2	2	0
6-18-74	0	2	0	1	0
7-17-74	0	4	0	0	0
8-14-74	0	1	0	0	1
10-10-74 (3 sets)	0	5	1	0	4
Total	0	26	3	10	13

TABLE 3. Trout Species Composition of Angler Catch, McCloud Reservoir, Shasta County, Based on Creel Surveys, 1967-1973.

Year	Number of Trout Kept				Percent
	Rainbow Trout	Brook Trout	Brown Trout	Bull Trout	Bull Trout
1967	354	15	19	2	0.5
1968	493	0	9	11	2.1
1969	57	0	10	2	2.9
1970	1,336	0	109	6	0.4
1971	374	0	10	2	0.5
1972	536	0	4	0	0.0
1973	322	0	6	0	0.0

Additionally, lake-wide creel checks of Shasta Lake anglers have sampled approximately 8,000 trout from 1968 through 1987 without recording a bull trout (Weidlein 1971, Healey and Van Woert unpublished data). Fishermen claim to catch bull trout in the McCloud River regularly but such catches have not been substantiated and such reports are probably brown trout.

In 1973, The Nature Conservancy (TNC) acquired (through a gift) a portion of the McCloud River Club property located upstream from mouth of Squaw Valley Creek (Figure 1). This area, named the McCloud River Preserve (Preserve), encompasses approximately 9.7 km (6 mi) 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 1975, however, a U.S. Forest Service (USFS) employee, Steve Dion, caught a 413 mm (16 1/4 in.) approximately 0.68 kg (1 1/2 lb) fish positively identified as a bull trout (CDFG collection #0513) from the lower reaches of the Preserve. Scale analysis indicated this bull trout was 4+ years of age. This suggests that this fish could have resulted from natural spawning below McCloud Dam in 1970 or that (less likely) the fish washed down from above McCloud Dam. 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. These bull trout captures were the first confirmed native char reports from the McCloud System in four years and gave renewed hope that bull trout numbers were still large enough to enable the use of native strains in recovery efforts.

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. The Commission declared the bull trout a State endangered species in 1980 after annual surveys failed to identify a single bull trout. Detailed surveys conducted from 1976 through 1986 are described below.

MCCLOUD RIVER BULL TROUT SURVEYS

1976 Bull Trout Survey

The Department undertook a modest effort at sampling the McCloud River in October 1976 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, 14 brown trout, but no native char were captured.

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). Primary objectives were 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. 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" (a deep plunge pool which historically held large numbers of bull trout), located between Big Springs and Muir (Little) Springs above McCloud Reservoir. Follow-up sampling at this site could not confirm the initial sighting.

Nine gill net sets at the mouth of the river in McCloud Reservoir during August 1978 netted 26 rainbow trout but no char.

1976-1978 Department Creel Surveys

The Department conducted creel surveys on the first 8.0 km (5 mi) of the McCloud River immediately below McCloud Dam from 1976 through 1978. Although anglers reported catching 10 bull trout among the 1,473 trout reportedly released, no bull trout were among the 322 trout kept (angling regulations since 1976 required the release of all bull trout).

1976-1986 Preserve Creel Reports

Anglers have been required to self-report their results upon leaving the McCloud River Preserve since it was opened to fishing in 1976. For 1976 and from 1978 to 1986, 8,702 anglers reported catching 39,963 rainbow, 5,491 brown and 72 bull trout (Rode in press). Reported bull trout catches were not confirmed.

TNC attempted to confirm angler reported bull trout catches in 1984, under a special Department permit. Cages were placed at 0.8 km (0.5 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, a misidentified rainbow trout was placed in a cage. During 1984, the volunteer angler (sign-out) reports for the Preserve indicated only one bull trout was caught for the year (the misidentified rainbow), as compared to an average of 7.9/yr for the balance of the 1976 to 1986 period (Rode in press). The preceding suggests that the other reported bull trout catches were misidentified rainbow or brown trout.

1981 and 1982 Upper Wild Trout Area Creel Survey

TNC clerks conducted a random walk-through survey in the 8 km (5 mi) stretch of river between McCloud Dam and the Preserve in 1981 and 1982. The 1,050 anglers interviewed reported releasing 1,030 trout of which 14 (1.2%) were said to be bull trout. No bull trout were among the 176 trout kept.

1983 TNC Fisheries Studies

TNC interns snorkeled and hook and line sampled the McCloud River from the lower limit of public fishing within the Preserve to 0.8 km (0.5 mi) below the confluence of the river with Squaw Valley Creek and also the lower 16 km (10 mi) of Squaw Valley Creek in summer, 1983. No bull trout were seen or captured among the 249 trout that were sampled.

1984-1987 Weir Studies

A fish weir and trap was established seasonally from 1984 through 1987 in the upper reach of the Preserve in an attempt to capture migrating bull trout. The trap was operated as early as 7 April and continued as late as 16 February. 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. No bull trout were captured while 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. Brown trout peak migrations from Shasta Lake occurred in April or earlier with a smaller secondary migration in October. Peak brown trout movements at the Preserve Weir occur in October and early November. In 1986, when 333 brown trout were tagged at the Bollibokka Weir, only 30 of these fish were recaptured at the Preserve Weir. Spawning takes place predominately in late October and early November (Rode in press).

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." This weir, which selected for fish greater than 305 mm (12 in.) in length because of its design, did not capture any fish until September 20, 1985. Only 32 brown trout and one rainbow trout were captured. No bull trout were seen. Many 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 the upper 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

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 during summer and fall, 1985 (Galovich and Ingram 1986). The extremely clear water in this reach allowed accurate species identification. Many thousands of trout were identified during the quantitative phase of the study, yet not one bull trout was noted.

1985-1986 Electroshocking Surveys

Extensive efforts were made to locate bull trout in both the upper and lower McCloud River and a number of its tributaries via electrofishing in 1985 and 1986. A major pool and run complex located 0.8 km (0.5 mi) above McCloud Reservoir was electrofished on four nights during summer and early fall 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 Creek (tributary to McCloud Reservoir) and Huckleberry, Angel and Mud creeks (tributaries to the McCloud River above McCloud Reservoir). Bull trout were not found in any of these waters. Population sampling also was 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 (John Deinstadt, Assoc. Fishery Biologist, DFG, unpublished data). These surveys, too, did not locate any bull trout.

Survey Summary

Several intensive and varied surveys conducted over the past 12 yr have examined thousands of trout in the McCloud River to assess the status of bull trout. 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 FROM THE MCCLOUD RIVER

Many 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. The following sections evaluate each factor and some possible interactions as causes of the bull trout's extirpation in California.

Zoogeography

The bull trout of the McCloud River is considered a glacial relict. It has persisted only because of the unique environmental conditions afforded by clear, cold water provided by Mt. Shasta, Big Springs and Muir (Little) Springs. The retreat of the bull trout from the southern extreme of its range is occurring today as it probably has in the past. Gradual climatic changes since the Pleistocene are reducing water quantities once supplied by glaciers and snow fields and are major factors eliminating bull trout habitat (Cavender 1978).

As a general rule, populations living at the extremes of a species' range are existing in conditions that are less than optimal and are most vulnerable to extinction by environmental changes or competitive pressure (Behnke 1979). The bull trout in California was undeniably living in the extreme end of its range, but habitat conditions in the McCloud River are unique for California. Even so, bull trout were probably not the dominant fish in the McCloud River historically (just before McCloud Dam was completed, gill net samples in the lower McCloud River indicated that about 10% of the trout were bull trout, and when the dam was completed, about 4% of the trout sampled were bull trout [see Conclusion Section]). Any species limited to one river system, however, is vulnerable to environmental change in that system. The recent historical record does not indicate that natural environmental changes have occurred at rates 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 1924 the worst year when between 764,600 and 2,293,800 m^3 (1,000,000 and 3,000,000 yd^3) of debris entered the McCloud River (Hill and Egenloff 1976). Effects on aquatic life are not documented but must have been severe. Adverse impacts on bull trout were probably temporary since Wales (1939) reported that bull trout "seemed to be common" in 1938.

Harvest

Bull trout initially were harvested by Indians and early settlers (Wales 1939). The ruggedness, poor access and private land ownership of the McCloud Canyon severely restricted harvest opportunities (Wales 1939). Wales (1939) stated that "There is no bag limit on this trout but the writer does not feel that it is in any danger of extinction despite its limited range."

The formation of Shasta Lake increased the potential for bull trout harvest in the lake, but bull trout persisted for over 25 yr after the lake was impounded. With the opening of fishing in McCloud Reservoir in 1966, the harvest of bull trout increased and may have been intense for several years. This is suggested by data from infrequent creel checks made on McCloud Reservoir from 1967 through 1971 (Table 3).

Bull trout harvest most likely also increased significantly in the river below McCloud Dam after the dam's construction. New roads in the area, land exchanges that provided public access to the first 8 km (5 mi) of river below the dam, and establishment of Ah-Di-Na Campground greatly increased angler access. Severely reduced flows and reduced summer turbidity may have made fishing for bull trout easier. These factors may have led to a substantial increase in bull trout harvest. Bull trout have been shown to be highly susceptible to angling on other waters (Boag 1987, Anonymous 1985).

Introduction of Exotic Fish Species

Two exotic salmonids, brook and brown trout, were introduced to the McCloud River and may have contributed to the demise of the bull trout. Brook trout were well distributed throughout California by 1890 (Moyle 1976) and were established in the McCloud River drainage by the 1910's (DFG files). They are presently found in a number of McCloud River tributaries above McCloud Dam and in the main river above Lower Falls. Brook trout are well adapted to cold, small, headwater, spring-fed streams.

They do not appear to have been successful in the main river below Lower Falls. Their preference for cold water may have resulted in sympatric populations with bull trout. Competition for habitat and food may have occurred through the juvenile stage in some tributary populations. 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 may have resulted in competition and hybridization with bull trout. Bull-brook trout interactions may have resulted in: (i) competition for spawning and nursery areas which could have reduced bull trout recruitment and (ii) hybridization that may have resulted in sterile offspring. However, brook trout did not survive or grow as well as stocked rainbow or brown trout so brook trout stocking was discontinued after 1966. Small numbers of brook trout appeared in the McCloud Reservoir catch in 1967, the year the reservoir was first opened to public fishing and thereafter were not seen in the catch (Table 3). Brook trout were not recorded in any of the creel surveys or population samples in adjacent river reaches. This poor survival, growth and reproduction of stocked brook trout suggests that few, if any, 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 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 and probably in better condition than before the Dam (Wales 1939, DFG files). Today, the brown trout in the lower river occupies a severely degraded bull trout habitat niche. Brown trout are present throughout the lower river but are more numerous in downstream areas, probably as a result of warmer water temperatures and a greater percentage of large pools. It therefore appears that brown trout impacts on bull trout could have been substantial below McCloud Dam because of the habitat changes caused by the 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. 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 conditions needed to establish a large adfluvial brown trout population. However, only about 10% of the brown trout tagged just above Shasta Lake in 1986 were recaptured at the Preserve Weir (Rode in press). Therefore, the impact of Shasta Lake browns on the area immediately below McCloud Dam may be less than in the lower reaches of the river. 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. Salmon eggs, carcasses and fry are known to provide an important seasonal source of protein for bull trout and the loss of this important food supply may have seriously affected the bull trout (Moyle 1976).

Inundation of the lower 25.8 km (16 mi) of McCloud River and other impacts of 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 have readily adjusted to an adfluvial existence and prospered after rivers were dammed (Moyle 1976). This did not occur to any great degree in Shasta Lake based on relatively recent records of angler catches from 1945 to 1965 (DFG files). 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 use of Shasta Lake by bull trout are:

i. The surface water temperatures of Shasta Lake are higher than those preferred by bull trout (over 24°C [75°F] and 13°C [55°F] water is at least 30m [100 ft.] deep during the summer period [DFG files]).

iii. Stocking of salmonids and other game fish may have increased direct competition with bull trout in the reservoir and portions of the river where these fish migrated.

iii. Establishment of highly popular and intense fisheries in Shasta Reservoir may have resulted in a significant but unrecorded (in present day DFG files) harvest of bull trout. This harvest may also have been highly seasonal, at times when creel surveys were not conducted.

McCloud Dam

McCloud Dam was completed in 1965 and resulted in a number of serious impacts on the bull trout. The dam and reservoir inundated approximately 8 km (5 mi) of habitat and isolated upstream spawning and nursery areas from downstream adult and juvenile rearing and holding areas (deep pools). 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 easily migrate downstream. Also, the downstream habitat was greatly changed.

Because of dramatic flow and water temperature changes, the reach below the dam may not have supported bull trout even if suitable spawning and nursery areas were available. The change in flows below McCloud Dam must be estimated since PG&E measures flows at the dam only up to the minimum Ah-Di-Na fish release level of 5.95 m^3/s (210 cfs). An average flow of 36.50m^3/s (1,289 cfs) occurred near the Dam site (Panther Creek) from 1955 to 1959. At minimum release levels of 1.13 - 1.42 m^3/s (40-50 cfs) which can occur during winter and spring, the flow at the dam is now only about 3-4% of average historic values. This severely reduced flow continues downstream until it is augmented by tributary accretion (primarily Hawkins Creek, located about 1.6 km (1.0 mi) below the dam), to levels required at the Ah-Di-Na gage 5.3 km (3.3 mi) downstream (Table 1).

At Ah-Di-Na, the 8.44 m^3/s (298 cfs) mean monthly flow for the 19-year period 1966-1984 is only 23% of the 36.22 m^3/s (1,279 cfs) pre-project level, and the range of the mean monthly minimum and maximum flows has decreased from 20.70 - 54.60 m^3/s (731 to 1,928 cfs) to 4.87 - 18.35 m^3/s (172 to 648 cfs) (Figure 2; USGS 1967 to 1985). Average McCloud River flows just above Shasta Lake have decreased from about 48.14 m^3/s (1,700 cfs) to approximately 22.66 m^3/s (800 cfs), a reduction of more than 50% (USGS 1967 to 1985).

Reduced flows below McCloud Dam have raised water temperatures slightly in the reach of the river below the dam but have substantially increased the diurnal temperature fluctuation from the stable, cold temperature levels that existed before the dam. In the reach of river just above Shasta Lake, average summer water temperatures have been raised 5.5°C (10°F) and maxima increased 11.1°C (20°F) (DFG unpublished file data).

Post-McCloud Dam changes in flow have resulted in concomitant alterations in stream habitat. Reduced flows have resulted in reduced water depth, wetted perimeter and cover, and changes in several other parameters. These changes have adversely impacted bull trout while favoring brown trout. Higher temperatures in the lower river also favor nongame fish. Lower flows may have increased the potential for fish passage at Tuna Creek Falls which is located about 8 km (5 mi) above Shasta Lake, thus increasing potential impacts from migrating nongame fish and brown trout.

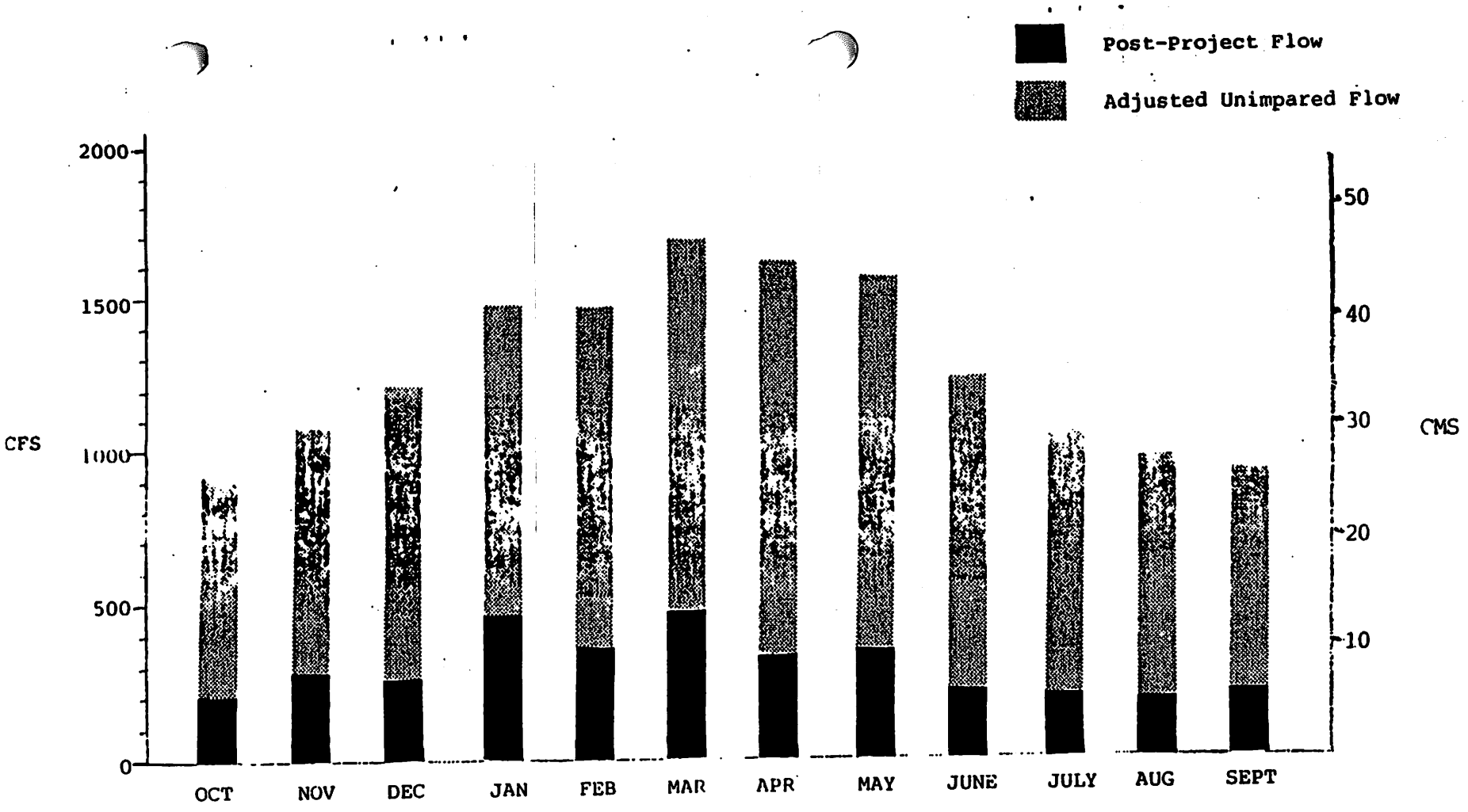

FIGURE 2. Mean Monthly Flows and Adjusted Unimpared Flows at Gage No. 11367800, McCloud River at Ah-Di-Na, 1966-1984 (From USGS Records 1967 to 1985).

McCloud Dam has also greatly reduced periodic flushing flows. Dam operation can create highly turbid water conditions and sedimentation in the fall when water quality was generally good before dam construction. Bull trout eggs spawned in the fall would be impacted by this sediment. Testing of the dam valves (sluicing) during the winter releases silt that could 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. Department observations of the river when the dam was first closed indicated deep silt deposits at the dam due to construction activities. The turbidities generated by the dam and reduced flushing flows may also seriously affect invertebrate production. Conversely, during much of the summer, the dam has reduced turbidity.

CONCLUSION

Very little fish population or creel data are available to document the historical status of bull trout in the McCloud River and none is available to document the pre-Shasta Lake status of the species. Most available information (DFG files) is from the lower river and Shasta Lake where public access was available, but this area was probably below the prime bull trout habitat located below Muir and Big Springs and in the mid-reaches of the river where large pools and cold water temperatures provided rearing and holding habitat. The creel surveys at the mouth of the McCloud River indicated only occasional catches of bull trout with the exception of 1949 when bull trout comprised 15% of an opening day creel survey (DFG files). About 10% of the trout sampled during pre-McCloud Dam sampling in the lower river were bull trout (Table 2). In the one fish sample collected when a 0.8 km (0.5 m) section of the river was dewatered at the McCloud Dam construction site in 1964, 4% of the 123 trout captured were bull trout (DFG files). Basically, all other information available including that of Wales (1939) was from occasional angler reports.

The limited creel surveys on McCloud Reservoir showed that bull trout contributed 0.4% to 2.9% of the catch sampled from 1967 through 1971 (Table 3). This contribution to the reservoir catch occurred in spite of the stocking of over 1,311,000 trout in the reservoir from 1966 through 1971 (DFG files). Bull trout may have comprised a much higher percentage of the fish population in the unstocked portions of river above the reservoir during this same period.

The last two large bull trout were recorded in 1975 from the river below the dam. The paucity of bull trout below the dam and especially the absence of small bull trout in creel samples indicate that reproduction was severely limited or totally lacking below the dam.

Bull trout persisted in the McCloud River despite their limited distribution, Mud Creek flows, angler harvest, the introduction of exotic species and Shasta Dam. However, the bull trout's disappearance soon after the completion of McCloud Dam strongly implicates this project. Further, the project's impact on critical aspects of the bull trout's life history again suggests that the project was a primary factor in this extirpation.

The most critical impacts of McCloud Dam Project contributing to the extirpation of bull trout were probably (i) isolation of spawning and nursery habitat in the upper river from juvenile and adult holding habitat in the lower river, (ii) increased harvest of bull trout in the reservoir, and (iii) drastic habitat changes in the river below the Dam. The extirpation may not have occurred if enough juvenile and adult habitat was present above McCloud Reservoir, or if an adult fluvial population could have been maintained. If angler overharvest in McCloud Reservoir played an important role in the bull trout's disappearance, a more resident (non-migrating) strain may have avoided extirpation. Critical bull trout habitat below the dam appears to be lacking. Successful reproduction, growth and survival may not be possible there under the current temperature, flow and siltation reqimes.

Critical life history requirements of the bull trout were not considered when project operational criteria were developed for both federal and State licensing of the McCloud-Pit Hydropower Project in the early 1960s (DFG files). Furthermore, the State Water Resources Control Board (Board) determined that because public fishing access to the Lower McCloud River was limited, there was no justification for requiring fish release flows from McCloud Dam that would sustain fish populations at close to pre-dam levels (DFG files). With respect to minimum fish release flows, the Board used as its strongest criterion the amount of flow needed to support salmonid spawning runs from Shasta Lake (at that time, mainly kokanee salmon and rainbow trout). No consideration was given to bull trout needs (DFG files).

Following the opening of McCloud Reservoir and the downstream river reach to public fishing in 1967, overharvest may have also contributed to the bull trout's decline since it was not until 1976 that a prohibition on the take of bull trout was enacted by the Fish and Game Commission. However, earlier enactment of this restriction may not have had a significant impact since few anglers can identify bull trout from other trout.

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 biological and physical changes may have reduced the bull trout population to a relatively low level, but the species was able to persist until soon after the construction and operation of McCloud Dam. The gene pool of the original McCloud River bull trout has been lost forever, but there is strong justification for re-establishing a bull trout population in the river using introduced stock.

The McCloud River has long been associated with the bull trout. The common name "Dolly Varden" originated from the McCloud population. There probably would be support from California's many anglers as well as the non-fishing public to see the re-establishment of this species as a part of California's native fish fauna. If re-established, the bull trout would diversify the angling experience in California as well as throughout the west. It would complement the already established and highly successful catch-and-release fishery in the Wild Trout Area below McCloud Dam (Rode in press).

The river conditions 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 Department's Natural Diversity Data Base recognizes the McCloud River as an "only known occurrence" (found nowhere else) of a "Valley Char/Trout Stream" natural community in California. It has given maintenance of this community its highest priority ranking (A1.1).

The presence of only a few poorly conditioned brown trout in the reach of river above McCloud Reservoir suggests that competition between the two species may not be a problem for bull trout in the upper river. Re-establishing the bull trout in the upper river would help return this stretch of water to its natural, historical ecological balance.

Re-establishment of the bull trout in the McCloud River would enhance distribution of a species 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 for use in restoration efforts in other areas.

Reintroduction Objectives

The major objectives of a bull trout reintroduction would be:

i. Establish a self-sustaining, naturally reproducing wild population of bull trout in the McCloud River and its suitable tributaries.

"Booster stocking" of hatchery reared wild stocks may be required initially to ensure sufficient numbers of bull trout are introduced to the river. Later, if natural reproduction is inadequate, maintenance stocking of wild strain hatchery bull trout could be considered. This action would 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.

ii. Introduce a stock that appears best adapted for present conditions.

The introduced stock should be a resident form that has little tendency to move downstream to McCloud or Shasta reservoirs and that tends to be insectivorous. If a significant percentage of introduced bull trout migrate downstream to McCloud Reservoir, high rates of angler harvest may severely impede the chances of establishment. 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 is probable 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. A stock that is insectivorous rather than piscivorous would appear to have a greater chance of becoming established since 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.

iii. Establish a bull trout population to a level capable of supporting fishing.

The opportunity to fish for a unique trout species has great appeal to many anglers. For the short term, fishing would have to be on a catch and release basis (zero fish limit) only. Later there may be an opportunity for very limited harvest.

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

The potential success of an introduction of bull trout below the dam will be helped by 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 need to release all bull trout which would still be protected by the current zero fish limit for that species. However since anglers have difficulty identifying bull trout from other trout species (see discussion in Section: 1976-1986 Preserve Creel Reports), it may be necessary to require the release of all species of trout (zero fish limit).

Preliminary Proposals For Action

Only one facility that regularly takes disease-free eggs from a wild bull trout stock has been identified to date; a spawning station above upper Arrow Lakes, British Columbia, takes eggs from an adfluvial population. Therefore, to obtain a resident strain, eggs will have to be taken from captured wild stock. These eggs would need to be tested and certified disease-free before they can be imported into California.

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 connections occurred among the ancestral Klamath, Pit and Sacramento River drainages during the Miocene-Pliocene or Pleistocene periods. 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 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. Subsequently, instream flow studies, habitat evaluations and evaluation of dam operations should 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 re-establishment.

Introduction of bull trout above McCloud Dam is proposed first because few changes would be required prior to the reintroduction. This phase of the project is also less complex and knowledge gained can help facilitate the more involved downstream recovery effort.

An initial introduction attempt above the reservoir looks promising since the river and most of its tributaries above the reservoir and below Muir Springs flow 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. Flows, temperatures, water quality, instream habitat and riparian habitat have remained relatively unchanged in the river above the reservoir and this suggests good chances for success. However, the low velocities for juvenile rearing and large deep pools preferred by both juveniles and adults are rare in the main river. Two tributaries, Huckleberry and lower Mud creeks, might be more suitable for establishing a small resident headwater type population.

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

i. Chemically treat Huckleberry and lower Mud creeks which are tributary to the McCloud River above McCloud Reservoir to remove existing populations of rainbow, brown and brook trout. These creeks appear to have adequate coldwater for bull trout spawning and rearing. Modify a culvert near the mouth of Huckleberry Creek to provide a barrier to upstream migration of all trout species. Construct a barrier near the mouth of Mud Creek for the same purpose. Stock with bull trout from out-of-state sources (barriers were constructed in 1989 and a total of 270 bull trout fry from Oregon's upper Klamath drainage were stocked in the two streams on April 4, 1990. Additional stocking is planned). Periodically, transfer bull trout from Huckleberry and lower Mud creeks to the main river and other suitable tributaries.

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

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

iv. Consider more restrictive angling regulations such as a zero fish limit in the river, tributaries, and/or reservoir once bull trout reach a size vulnerable to angling.

v. If necessary to maintain a viable population, 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:

i. 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 re-establishment of bull trout.

ii. Reintroduce bull trout to areas of the lower river where conditions are most favorable; this will probably be in the upper half of the lower river.

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

iv. Consider a zero limit for all trout in the wild trout area below the dam to minimize harvest mortality that might occur even with the current zero limit for bull trout.

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

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

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