Title: Bull Trout Restoration and Brook Trout Eradication at Crater Lake National Park, Oregon.

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Abstract: A survey of fish populations and instream habitat in Sun Creek, Klamath River Basin, Oregon, during the summer of 1989 revealed a remnant population of resident bull trout (*Salvelinus confluentus*) sympatric with introduced brook trout (*S. fontinalis*) in a 1.9 km reach near an upper edge of useable habitat. Hybridization and competition with the brook trout appeared to threaten the bull trout population with a high risk of extinction. A bull trout restoration plan was drafted and peer reviewed in October, 1991. The objectives of the plan were to restore the remnant population of bull trout to historic numbers and distribution in Sun Creek (within the park), remove the brook trout, and prevent re-invasion of non-native species in the future. During the summer of 1992, a restoration program was initiated. Brook trout were removed from Sun Creek with electroshockers within and upstream of the bull trout zone, and with a piscicide, antimycin, downstream of the bull trout. Two log and rock barriers were constructed near the park boundary to prevent re-invasion of non-native fishes. Genetic analysis on a small sample of trout suggested that identification of bull trout-brook trout hybrids from field marks was not reliable. Brook trout removal will continue and a monitoring program is in place to evaluate bull trout and macroinvertebrate recovery.

Introduction:

Bull trout (*Salvelinus confluentus*) are widely distributed throughout the Northwestern United States and Western Canada although many populations are declining in abundance and distribution and local extinctions have likely occurred (Bond 1992, Goetz 1989, Ratliff and Howell 1992, Roberts 1982). Bull trout are found in the Columbia River Basin and the Klamath River Basin in Oregon. The Klamath Basin populations are evolutionarily distinct from Columbia River Basin populations and represent an important component of ecological and genetic diversity for the species at a southern edge of its range (Leary et al., 1991).

Klamath basin bull trout populations display a resident life history pattern and are restricted to cold headwater streams. There is no recent evidence of a significant fluvial or adfluvial life history component. There are twelve known historic, or recently identified, bull trout populations in the basin. Of the 12 populations, 3 are probably now extinct, 5 are at high risk of extinction, and 4 populations are at moderate risk (personal communication with area biologists). These status categories closely follow those in Ratliff and Howell (1992) and were determined subjectively, based on relative abundance, habitat characteristics, sympatric species, population trends, and recovery potential. The Sun Creek population, Crater Lake National Park, is believed to be declining in number and at a high risk of extinction. A petition to list the Klamath Basin bull trout as endangered is currently being considered by the U.S. Fish and Wildlife Service.

Bull trout may be the only fish species native to Sun Creek, within Crater Lake National Park. Approximately 45,000 brook trout fry (*Salvelinus fontinalis*) and 7,000 rainbow trout fry (*Oncorhynchus mykiss*) were introduced into the headwaters of Sun Creek, within the National Park, between 1931 and 1940 (Wallis 1948). An additional 230,000 brook trout fry and 50,000 rainbow trout fry were stocked into Sun Creek 0.5 km downstream of the park boundary between 1926 and 1971 (Oregon Department of Fish and Wildlife, unpublished data). A comprehensive survey of stream fishes and habitat in 1947 found that brook trout occurred in Sun Creek from a subalpine meadow near the origin of the stream to a natural waterfall 3 km downstream of the headwaters, and that brook trout, bull trout, and rainbow trout (in order of abundance) were well distributed between the waterfall and the park boundary (Wallis 1948). A 1989 survey of fishes and instream habitat in tributaries of the Klamath River in Crater Lake National Park, revealed a remnant population of 133 adult bull trout in Sun Creek, sympatric with brook trout, in a 1.9 km reach near an upper edge of useable habitat (Dambacher et. al. 1992, Dambacher et. al. 1993). Bull trout and brook trout utilized habitat similarly at the habitat unit and microhabitat unit scale. Interspecific competition and hybridization appeared to restrict bull trout distribution and abundance within Sun Creek.

A bull trout restoration plan was drafted and peer reviewed by a panel of biologists in October, 1991. The peer panel included personnel from the National Park Service, US Fish and Wildlife Service, US Forest Service, Desert Fishes Council, Oregon Department of Fish and Wildlife, and Oregon State University, with expertise in fish population restoration, fish toxins, electrofishing, fish barriers, genetics and fish and macroinvertebrate ecology. The longterm goals of the recovery program were to 1) restore the remnant population of bull trout to historic numbers and distribution in Sun Creek; 2) remove all of the brook trout; and 3) prevent re-invasion of non-native fish species in the future.

A restoration program was initiated during the summer of 1992. Brook trout were removed from Sun Creek with electroshockers within and upstream of the bull trout zone. Brook trout removal effort within the bull trout zone was limited to minimize shocking and handling stress to bull trout. Bull trout-brook trout hybrids were not removed due to the uncertainty of identification from field marks. Non-lethal adipose fin clips were taken for genetic analysis, on a subsample of bull trout, brook trout and hybrids, to evaluate field identification criteria. Due to increased structural complexity and stream flow downstream of the bull trout zone, brook trout were removed with the piscicide antimycin. Two log and rock barriers were constructed near the park boundary to prevent the re-invasion of non-native fishes. In 1993 brook trout removal continued with electroshockers and a monitoring program was initiated. This report summarizes the restoration and monitoring results through 1993.

Study Site:

Sun Creek occupies a glacial valley that was inundated with hot ash and pumice, hundreds of feet deep, during Mount Mazama's climactic eruption roughly 7,000 years ago (Bacon, 1983). The creek originates from headwater springs, several hundred meters from the rim of the Mt. Mazama caldera, within Crater Lake National Park, at approximately 2,200 m in elevation (Figure 1). In the upper reaches, Sun Creek meanders through subalpine meadows and forest, where the creek varies in width from 0.1 m to 1.5 m. Stream discharge increases at the confluence of Vidae Creek, and Sun Creek cascades down a series of natural waterfalls, some of which preclude upstream fish passage. Downstream from the waterfalls the creek is incised into deep pumice deposits and meanders across a narrow valley floor. Fourteen kilometers downstream from its headwaters Sun Creek leaves the park at 1,400 m in elevation where the stream is 3 to 6 m in width and flows between 6 and 38 cfs. Sun Creek flows into Annie Creek, which is a tributary of the Wood River in the Klamath Lake drainage.

The lands within the original boundaries of the park have received federal protection since 1886. Other than the Crater Lake rim road which crosses the top of the Sun Creek basin, and the introduction of non-native salmonids, the upper reaches are not impacted from human activity. Old-growth mountain hemlock (*Tsuga mertensiana*) and shasta red fir (*Abies magnifica*) are the dominant vegetation types in the basin and in much of the riparian zone. Canopy closure, stream elevation, and the spring-fed nature of the stream maintain low daily water temperatures, in the bull trout section in August, between 3.5 °C and 9.5 °C. Stream conductivity ranged between 16.2 ug/cm in the upper reaches to 65.6 ug/cm near the park boundary in 1991. The creek is commonly covered by snow from December through May because Crater Lake National Park receives an average annual snow fall of 13.5 m at 1,950 m in elevation.

Sun Creek actively erodes the base of adjacent hill slopes, that stand near their angle of repose, this supplies large amounts of pumice sediment to the stream. Sand-sized and smaller sediment are actively transported during seasonal periods of low flow. Most substrate crevices are filled with pumice fines. Instream structure is dominated by large wood, undercut banks, and pumice, with very little bedrock and boulder substrates (Dambacher et. al., 1992).

Outside Crater Lake National Park, Sun Creek crosses Oregon State Forestry land where lodgepole pine (*Pinus contorta*) and ponderosa pine (*Pinus ponderosa*) are harvested. The lowermost reaches of Sun Creek cross private land in the Wood River Valley and are impacted by channelization and cattle grazing.

Methods:

Reach descriptions: Sun Creek was divided into four reaches for purposes of data analysis and stream restoration treatment (Figure 1). The boundaries of the reaches were adjusted slightly from those of the 1989 survey (Dambacher et. al. 1992) based on 1991 fish distribution, treatment strategy, and natural barriers. Starting at the headwaters, the stream was marked off in 50 m sections. The Sun Meadow reach extended from the headwaters to a natural waterfall 3 km downstream (stream sections 0 through 60). The Upper reach started at the waterfall and continued 2.2 km downstream to section 104. The 2.6 km Middle reach included stream sections 105 through 156 and encompassed the 1989 bull trout distribution limits. The Lower reach extended roughly 5 km downstream from stream section 157 to the downstream artificial barrier.

Electroshocking: Four different electroshocking units, and several levels of sampling effort were used in the four stream reaches to minimize the impact on bull trout and to maximize brook trout removal efficiency in water with relatively low conductance (Table 1). Each sampling effort included one electroshocking unit and up to 3 field personnel with dip nets, depending on the width of the stream. Abundance values obtained by electroshocking are presented as direct counts except in 1992 for the Upper and Middle reaches where abundance values calculated for a subsample of each reach were expanded in proportion to the total habitat in the reach. In 1992 45 % of the Upper reach was sampled, and 51 % of the Middle reach was sampled.

Antimycin treatment: The use of antimycin (trade name FINTROL) was favored over rotenone, to remove brook trout in the lower reach, because antimycin is effective in parts per billion dosages (ug/l), and is more easily neutralized below the target area than rotenone in cold water situations. Antimycin is an antibiotic that is toxic to fish and is licensed by the U.S. Environmental Protection Agency (EPA). The antimycin was neutralized with potassium permanginate directly below the downstream artificial barrier, approximately 1 km upstream of the park boundary. The toxin treatment was planned and supervised by Bruce Rosenlund, Project Leader, U.S. Fish and Wildlife Service, Colorado Fish and Wildlife Assistance Office, Golden Colorado.

In preparation for the toxin treatment, several studies were conducted to evaluate stream retention time, water chemistry, and flow. Bioassays were conducted on brook trout to determine effective dosages of antimycin and potassium permanginate at cold temperatures, in Sun Creek water (Pister and Buktenica 1992). Aquatic macroinvertebrates and amphibians were surveyed on Sun Creek to determine the likely impact of antimycin on these organisms (Wisseman 1992).

Antimycin was delivered to the stream at drip stations that operated for 5.4 to 8.2 hrs (Table 2). In addition to the drip stations field personnel carried backpack sprayers to deliver antimycin to spring seeps and isolated side channels and backwaters. Potassium permanginate was delivered to the stream at 4.0 ppm until sufficient time elapsed for the antimycin to pass the detoxification station. Block nets and fish held in live cars were placed at 0.5 hr flow time intervals to evaluate toxin and detoxification effectiveness and to collect fish for analysis of length, weight, abundance, and biomass.

Population index: Snorkel surveys were conducted in the bull trout section of Sun Creek in 1989, and 1991 through 1993 to provide an estimate or index of bull trout, brook trout and hybrid abundance. Stream sections 105 through 150 were snorkeled, these sections extended slightly upstream and downstream of the 1989 bull trout distribution. In 1989, 10 % of the riffles and glides, and 20 % of the pools were snorkeled, direct counts of trout were expanded in proportion to the number of each habitat unit found in the index reach. From 1991 through 1993 all habitat in the index reach was snorkeled. More effort, time per habitat unit, was dedicated to pool units since both species were found in greater abundance in pools then riffles and glides (Dambacher et. al. 1992).

Barrier Construction: Two log and rock fish immigration barriers were constructed upstream of the park boundary near stream sections 197 and 257 to prevent re-invasion of non-native fishes (Figure 1). The structures enhanced existing 0.75 to 1.0 m waterfalls and elevated the stream channel in stream sections naturally constricted by rock outcrops. If the downstream barrier were to fail, the upstream barrier would prevent brook trout from immigrating further upstream into the park before the lower barrier could be repaired. Barrier location, design, and construction were determined in consultation with Tom Felando, Stream Hydrologist, U.S. Forest Service, Deschutes National Forest, Bend, Oregon.

The downstream barrier was constructed with a Schaeff HS40 walking excavator and field crews. The backhoe-excavator pulled itself through the woods with two claw-like arms trailing two large rubber wheels. With this mode of propulsion the backhoe could crawl into the stream canyon where conventional equipment could not. Access to the stream-side was via an abandoned road. The tracks of the backhoe were raked out by field crews. The backhoe was used to excavate keyways in the stream banks, place logs in the keyways, and cover trevira filter cloth lining the backside of the barrier with boulders and gravel (Figure 2). The logs were pinned together with 1.3 cm and 1.9 cm re-bar 1.25 m in length.

The upstream barrier was constructed by U.S. Forest Service and National Park Service field crews. Keyways were dug by hand and logs were winched into place with block and tackle. Filter cloth was staked to the stream bed and banks and covered with rocks and gravel that back-filled the barrier. A wire basket filled with rock formed a spillway to eliminate a downstream plunge-pool.

<u>Genetic sampling:</u> Non-lethal adipose fin clips were taken on a subsample of bull trout, brook trout, and hybrids for genetic analysis. Brook trout, bull

trout, and hybrids were identified primarily based on dorsal fin coloration, banded in brook trout, solid in bull trout, and spotted in hybrids (Markle 1992), in addition notes were taken on pectoral fin coloration, and on the pattern of spots or vermiculations on the dorsal surface. The samples were shipped on dry ice and analyzed at Robb Leary's laboratory, Division of Biological Sciences, University of Montana, Missoula, Montana. Starch gel electrophoresis (Leary and Booke 1990) was used to determine each fish's genetic characteristics at a locus coding for a lactate dehydrogenase (LDH-B2) and a malate dehydrogenase (sMDH-A2) protein. At these loci, brook trout and bull trout do not share alleles in common. Thus, the information obtained from these loci could be used to determine whether the fin came from a brook trout, bull trout, or a hybrid between these fishes.

Results and Discussion:

Distribution, abundance, and length frequency of trout: Bull trout were found in the Upper and Middle study reaches of Sun Creek in 1992 and 1993 with electroshockers (Figure 3). Hybrid trout were only found in the Middle reach. Brook trout were captured and removed in all study reaches. In 1992, approximately three brook trout were captured for every bull trout in the Upper and Middle reaches combined. The 1992 brook trout removal appeared to reduce the brook trout to bull trout ratio in 1993 to approximately 2 to 1; however the number of bull trout and hybrid trout appeared to decline by approximately 50 %. Fish counts by snorkel diver from 1989 through 1993 also indicated declining trout populations in stream sections 105 - 150 (Figure 4). The increased counts between 1989 and 1991, for all species, may have been the result of increased diver effort. In 1991, two maturing brown trout (*Salmo* *trutta*) 200 to 250 mm in length were observed and removed by the diver. Estimates of bull trout abundance from single pass electroshocking without block nets (1.5/100 m) and from snorkeling (1.4/100 m) in the same reach were similar.

Estimates of the number of trout per 100 m of stream from electroshocking were highest in the Lower reach and the Sun Meadow reach, and lowest in the Upper reach (Figure 3). Estimates of brook trout biomass in 1992 also followed this trend even though the Sun Meadow reach had the lowest proportion of fish > 130 mm in length (Figure 5), as well as the least stream flow, area, and volume (Dambacher et. al. 1992). Length frequency histograms suggest that the size distribution of brook trout in the Upper, Middle, and Lower reaches was similar, however there appeared to be fewer small fish in the Upper and Middle reaches. The size distribution of bull trout and hybrid trout in the Middle reach (Figure 6) also appeared similar to brook trout size distribution, although the sample size of bull trout and hybrids measured for length was small. The size distribution of hybrid trout may suggest hybrid vigor however no conclusions can be made due to the small sample size. The brook trout length frequency histogram generated from the antimycin treatment in the Lower reach (Figure 7), indicated a much higher percentage of small fish in the population then did the histograms generated from the electroshocking treatment.

Sample efficiencies for antimycin and electroshocking were used to obtain a gross population estimate of bull trout. The number of fish per 100 m collected from the antimycin treatment averaged throughout the Lower reach was two to three times the number estimated by single pass electroshocking a sub-section of the Lower reach. Approximately 75 % of the fish captured in Sun Meadow with electroshockers in 1992 were captured with the first removal effort. If these gross sample efficiency estimates are applied to the Middle and Upper reaches appropriately in 1992 and 1993, it can be estimated that 185 to 235 bull trout remained in Sun Creek in 1992, and that 120 to 180 bull trout remained in Sun Creek in 1993.

Total trout abundance and size distribution of trout in the four study reaches support the hypothesis that bull trout distribution is currently restricted to less productive reaches downstream of the natural fish barriers in upper Sun Creek. The lower relative number of small fish in the Upper and Middle reaches may indicate poor recruitment in these sections. The most striking physical feature of the Middle study reach, where most of the bull trout were found, was the presence of iron springs that nearly doubled stream discharge, but appeared to adversely impact stream productivity. Within the iron spring area the substrate was covered by a yellow-orange flock and adjacent stream-side vegetation was stained yellow. It is possible that low water temperatures maintained by spring inflow (3.5 °C to 9.5 °C in August 1992) allowed bull trout to compete better with brook trout for available resources, although there is no data to support such a conclusion.

Removal techniques: The Sun Meadow brook trout removal data strongly suggest that intensive electroshocking in small, high elevation, streams is a viable method for fish eradication, when no desirable sympatric species occur. Studies in the Great Smokey Mountains have found electroshocking to be an effective tool to remove non-native rainbow trout from small streams to restore native brook trout populations (Moore et. al. 1983). The studies in the Smokey Mountains utilized less intensive shocking protocol extended over a period of 5 to 8 years and targeted the reproductive size classes each year. No impacts to sympatric brook trout populations were observed.

Electroshocking removal of brook trout within the bull trout zone was tried with caution in 1992 and abandoned after two bull trout mortalities and additional signs of stress were observed. Recent literature suggested that electroshocker incurred injury rates to rainbow trout, brown trout, and brook trout could be as high as 80 %, and may cause unacceptable mortality in the population sampled (Fredenberg 1992, Hollender 1992, Meyer and Miller 1990, Meyer and Miller 1992, Snyder 1992). Injuries documented included internal hemorrhaging spinal misalignment, and spinal fracture. The studies were conducted in streams encompassing a wide range of conductivity and temperature values, throughout the United States.

To better evaluate electroshocker injury to trout in low conductivity and low temperature waters within the park, non-native brown trout and brook trout were removed with electroshockers from Annie Creek and X-rayed to evaluate spinal injury. Three pass depletion with block nets was used to remove 100 fish with each of three electroshocker units. The electroshockers used were a Smith-Roote model 15-A DC unit, a Coffelt Mark-10 DC unit with CPS settings, and a shop-built AC unit with a Coffelt model BP-6 transformer. Preliminary analysis of the X-rays by a radiology technician at Oregon State University School of Veterinary Medicine found no spinal injuries. Although these results do not negate possible electroshocker injury to bull trout, single pass removal of brook trout within the bull trout zone was resumed in 1993 to reduce the brook trout to bull trout ratio.

Although it was difficult to evaluate, antimycin treatment in lower Sun Creek appeared to remove all the brook trout prior to fall spawning. Block nets and fish held in live cars at the park boundary and 0.8 km below the boundary showed little impact below the detoxification station. One of five fish in the live car at the park boundary died one week after the last treatment, but only a few young of the year brook trout were found in the block net at the park boundary. No fish died in the live car 0.8 km below the park boundary, up to one week after the last antimycin treatment.

Impact to aquatic macroinvertebrates from the antimycin treatment was lower then expected, with live mayflies (Ephemeroptera) observed on dead brook trout after three antimycin treatments at site 4. Invertebrate monitoring in 1993 indicated that aquatic insect recovery was proceeding rapidly (Robert Wisseman, personal communication). In 1993, more than 80% of the taxa found above the 1992 antimycin treatment area also were found within the antimycin treatment area. Late instars of many long-lived taxa were absent in the treatment zone and present above, however earlier instar larvae were often present. The recovery rate was probably enhanced by drift and colonization from the upper 7.9 km of stream that were not treated with toxin in 1992. No amphibian mortality was observed.

Genetic analysis: Samples collected for genetic analysis were taken from fish identified as brook trout, bull trout, or hybrids in the field. An estimate of accuracy in field identification can be made by comparing the field identification to electrophoretic identification (Table 3). Four out of 32 fish (12.5%) collected for this study were misidentified in the field. Two fish identified in the field as hybrids, were identified with electrophoresis as bull trout. One field identified bull trout, and one field identified brook trout, were identified as hybrid trout by electrophoreses. The results from this small sample indicated that all true, electrophoresis identified, brook trout had banded dorsal fins. True bull trout and hybrid trout had solid or spotted dorsal fins. All brook trout had tri-colored pectoral fins. One bull trout had weakly tri-colored pectoral fins. Hybrid trout had either bi-colored or tri-colored pectoral fins. All brook trout had strong vermiculations on the dorsal surface. Bull trout had spots or weak vermiculations on the dorsal surface. Hybrid trout varied from spots to strong vermiculations on the dorsal surface.

Leary et. al. (1983) have found bull trout x brook trout hybrids to be nearly always male and sterile. One hybrid trout collected in Sun Creek in 1992 was identified by electrophoresis as a bull trout x hybrid backcross. This data supports an earlier field identification of a female hybrid from Sun Creek with a shrunken, or spent, ovary (Dambacher et. al. 1992, Markle 1992).

The above genetic data indicate that only fish field identified as brook trout should be removed from Sun Creek. Removal of hybrids in the above subsample would have resulted in the inadvertent removal of 20 % of true bull trout.

Since hybrids appear to only rarely reproduce, successful elimination of brook trout would also eventually result in the elimination of hybridization (Robb Leary, personal communication).

Recovery outlook: It is alarming, and discouraging, to note the continued decline of bull trout in Sun Creek. It is unclear if this trend will continue or reverse. Brook trout removal first reduced the ratio of brook trout to bull trout spawners in the creek in the fall of 1992. Since the young of the year trout are not readily censused in Sun Creek with electroshocking and snorkeling techniques, the 1992 cohort will not be enumerable until summer of 1994. Therefore, 1994 will be the first year that an increase in the number of bull trout censused could occur. In addition, 5 km of stream above the artificial barriers were made available for bull trout through the antimycin treatment, however downstream migration rates for adult and juvenile bull trout and brook trout are unknown.

Fluctuating climatic conditions also make it difficult to assess the recovery outlook for bull trout. Sun Creek trout populations are likely experiencing increased environmental stress due to recent drought conditions. The total precipitation of the three water years ending in 1992 was the lowest three-year sum since records began at Park Headquarters in 1931. Drought conditions are continuing in 1994, at the writing of this report in March of 1994, Crater Lake National Park had received approximately 50 % of the annual average accumulated precipitation to date.

Bull trout recovery efforts on Sun Creek may not have been initiated soon enough to conserve the small population of trout. During the summer of 1994 brook trout removal will continue in Sun Meadow using electroshockers. In between the upstream natural barriers and the downstream artificial barriers, bull trout will be censused by snorkelers. When the snorkeler identifies a brook trout, an electroshocking crew will follow immediately and attempt to remove the brook trout. This technique will attempt to balance brook trout removal, bull trout census, and minimize inadvertent injury or mortality to bull trout from electroshocking. It is not known if the already small population can withstand even a small increase in mortality.

Future recovery strategy will depend on the 1994 bull trout census results. Habitat use data for bull trout and brook trout (Dambacher et. al. 1992) and data on distribution, abundance, biomass, and length frequency of bull trout and brook trout presented here suggest that the recent character of the brook trout population, in terms of these parameters, may serve as a fair template in the future to evaluate bull trout recovery in Sun Creek.

Acknowledgements:

Thanks to Gary Larson and Jeff Dambacher for their continued participation in the project. Special thanks to the Bull Trout Peer Panel - Recovery Team for their invaluable contributions in planning, implementation, and evaluation of the program: Phil Pister, panel chair; Bruce Rosenlund, antimycin treatment planning and supervision; Tom Felando, barrier design and construction; Steve Moore, electroshocking and restoration expertise; Doug Markle, genetics and taxonomy consultation; and Norm Anderson, aquatic macroinvertebrate impact and recovery consultation. Field crews and park staff provided tireless work in all aspects of the project, special thanks to Ken Stahlnecker, Scott Stonum, Larry Minich, Steve Elliot, Matt McDonald, Sam Brenkman, Kathy Derge, Scott Swartz, and Niels Luthold. Robb Leary and the University of Montana provided genetic analysis for the evaluation of field identification criteria of Sun Creek trout. Invertebrate sample analysis was conducted by Robert Wisseman, Aquatic Biology Associates, Corvallis, Oregon. U.S. Forest Service field personnel from the Deschutes National Forest provided expertise in the construction of the upper barrier. The project was funded by the U.S. National Park Service.

Referances:

Table 1. Electroshocking unit, stream sections sampled, and sampling technique in four stream reaches of Sun Creek, in 1992 and 1993. Multiple sample and removal efforts in each year are represented by E^n.

Year Stream Reach	Sampling effort (E^n)	Principle electroshocking unit	Stream sections (50 m sections) (0 = headwater)	Sampling technique
1992				
Sun Meadow	E^1	Shop built AC unit (Coffelt Model BP-6 transformer)	0 - 60	Multiple pass removal, with blocknets, until 2 out of 3 passes produced no fish.
	E^2	Shop built AC unit.	20 - 57	Multiple pass removal, with blocknets, until 2 out of 3 passes produced no fish.
	E^3	Shop built AC unit.	20 - 57	Two pass removal without blocknets.
Upper	E^1	Smith-Roote Model 15-A (DC).	61 - 80	Multiple pass sampling, with blocknets, until 2 out of 3 passes produced no fish.
Middle	E^1	Coffelt Mark 10 CPS (DC).	130 - 156	Single pass sampling without blocknets.
Lower	E^1	Shop built AC unit.	157 - 180	Single pass sampling without blocknets.
1993				
Sun Meadow	E^1	Smith-Roote Model 15-B (DC).	0 - 60	Multiple pass removal, with blocknets, until 3 consectutive passes produced no fish.
	E^2	Smith-Roote Model 15-B (DC).	19 - 57	Two pass removal without blocknets.
Upper	E^1	Smith-Roote Model 15-B (DC).	61 - 104	Single pass sampling without blocknets.
Middle	E^1	Smith-Roote Model 15-B (DC).	105 - 156	Single pass sampling without blocknets, with an additional pass in sections 132 - 156.
Lower	E^1	Smith-Roote Model 15-B (DC).	157 - 197 (to upper barrier)	Single pass sampling without blocknets, with an additional pass in sections 174 - 179.

Table 2. Antimycin treatment, Sun Creek, Crater Lake National Park, August 1992.

	Site 1	Site 2	Site 3	Site 4
Date	25 August	26 August	26 August	27 August
Location (river section)	section 157	section 215	section 245	section 182
Flow	6.9 cfs	6.9 cfs	6.9 cfs	6.9 cfs
Temperature °C (time)	3.5 (0800) 9.5 (1505)	4.0 (0900) 10.0 (1510)	9.0 (1330) 9.0 (1730)	5.0 (1100) 11.0 (1600)
Hours of treatment	8.0 0800-1600	8.16 0900-1610	8.0 1030-1830	5.4 1100-1624
Quantity of FINTROL	532 ml	445 ml spray 30 ml	224 ml	468 ml
Concentration of antimycin	9.48 ppb	7.8 ppb	4.0 ppb	12.3 ppb

Table 3. Comparison of field and electrophoretic identification of brook trout, bull trout, and their hybrids from Sun Creek. Numbers along the diagonal indicate number of fish correctly identified in the field and numbers off the diagonal indicate fish misidentified in the field.

Field Identification	Electrophoretic Identification: Brook trout	Hybrid trout	Bull trout
Brook trout	11	1	0
Hybrid trout	0	9	2
Bull trout	0	1	8

Numbers along the diagonal indicate number of fish correctly identified in the field, numbers off the diagonal indicate fish misidentified in the field.

Figure Cations:

Figure 1. Map of Sun Creek, Crater Lake National Park, indicating stream study reaches and barriers to fish immigration.

Figure 2. Fish immigration barrier cross-section illustrating design and construction.

Figure 3. Number of trout captured by electroshocking during 1992 and 1993, in four study reaches in Sun Creek. Sampling effort (En) in the tabular section of the figure corresponds to E^n in table 1. Fishless headwater springs and water falls were excluded from estimations of the number of fish per 100 m.

Figure 4. Snorkel dive counts of trout in Sun Creek stream sections 105-150, 1989 to 1993. In 1989 10% of the riffles and glides, and 20% of the pools, were snorkeled. Numbers of trout were expanded in proportion to the number of each habitat unit in the reach. From 1991 to 1993 each habitat unit was snorkeled in the reach.

Figure 5. Brook trout length frequency distribution in four study reaches in Sun Creek, 1992. Fish were collected with electroshockers.

Figure 6. Bull trout and hybrid trout length frequency distribution in the Middle study reach of Sun Creek, 1992. Fish were collected with electroshockers.

Figure 7. Brook trout length frequency distribution in the Lower study reach of Sun Creek, 1992. Fish were collected with antimycin.

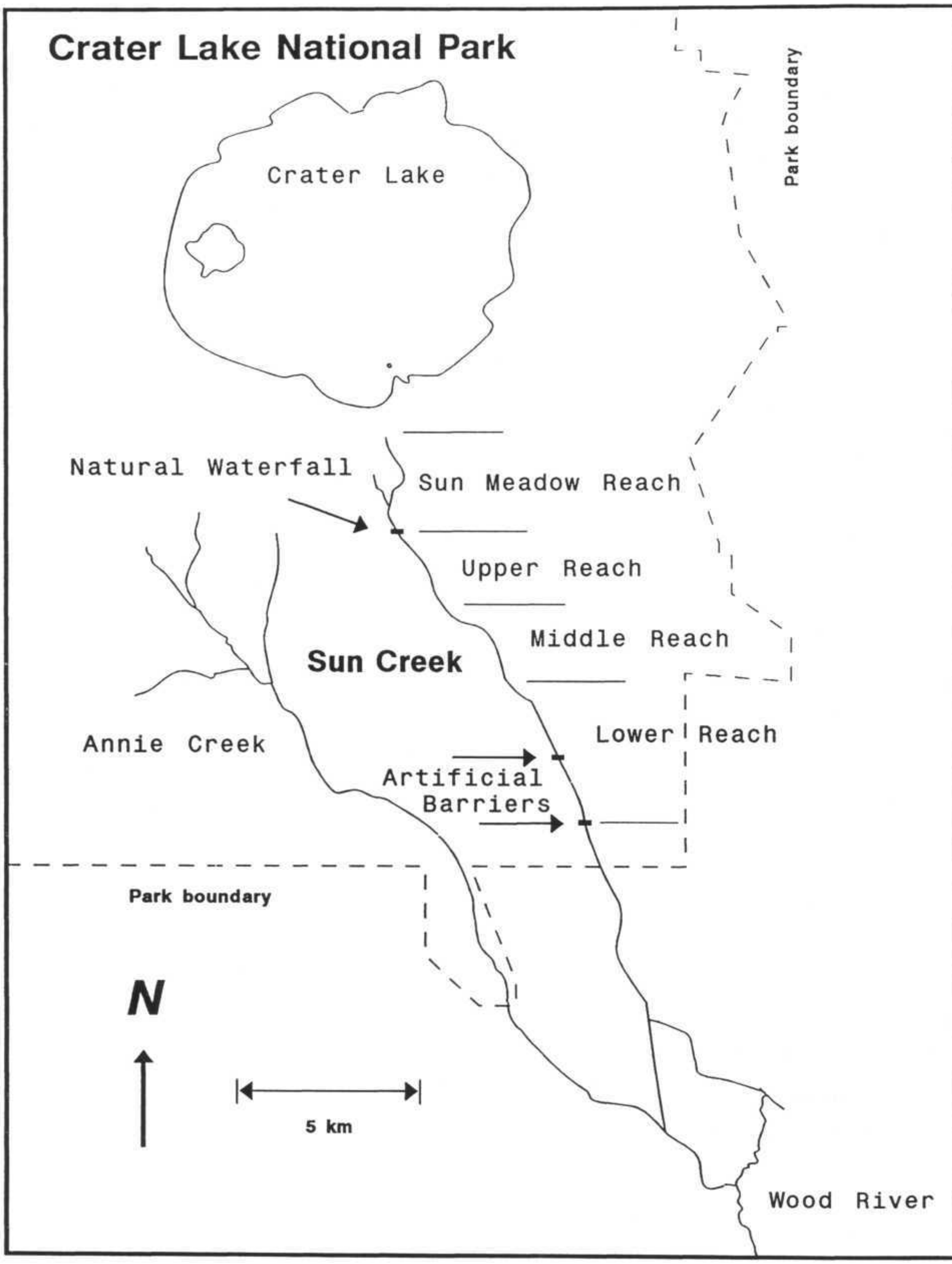


Figure 1. Map of Sun Creek, Crater Lake National Park, idicating stream study reaches and barriers to fish immigration.

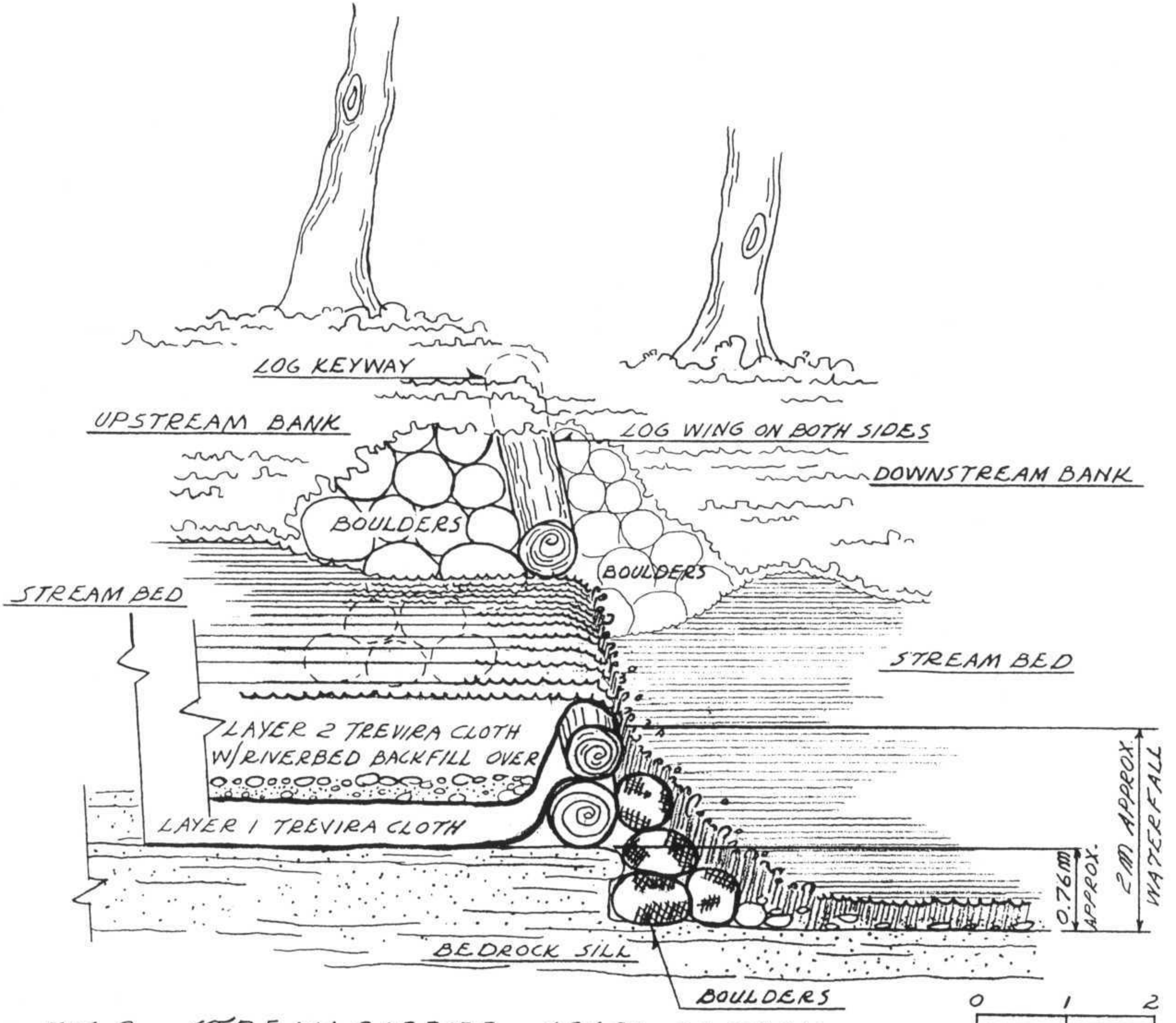
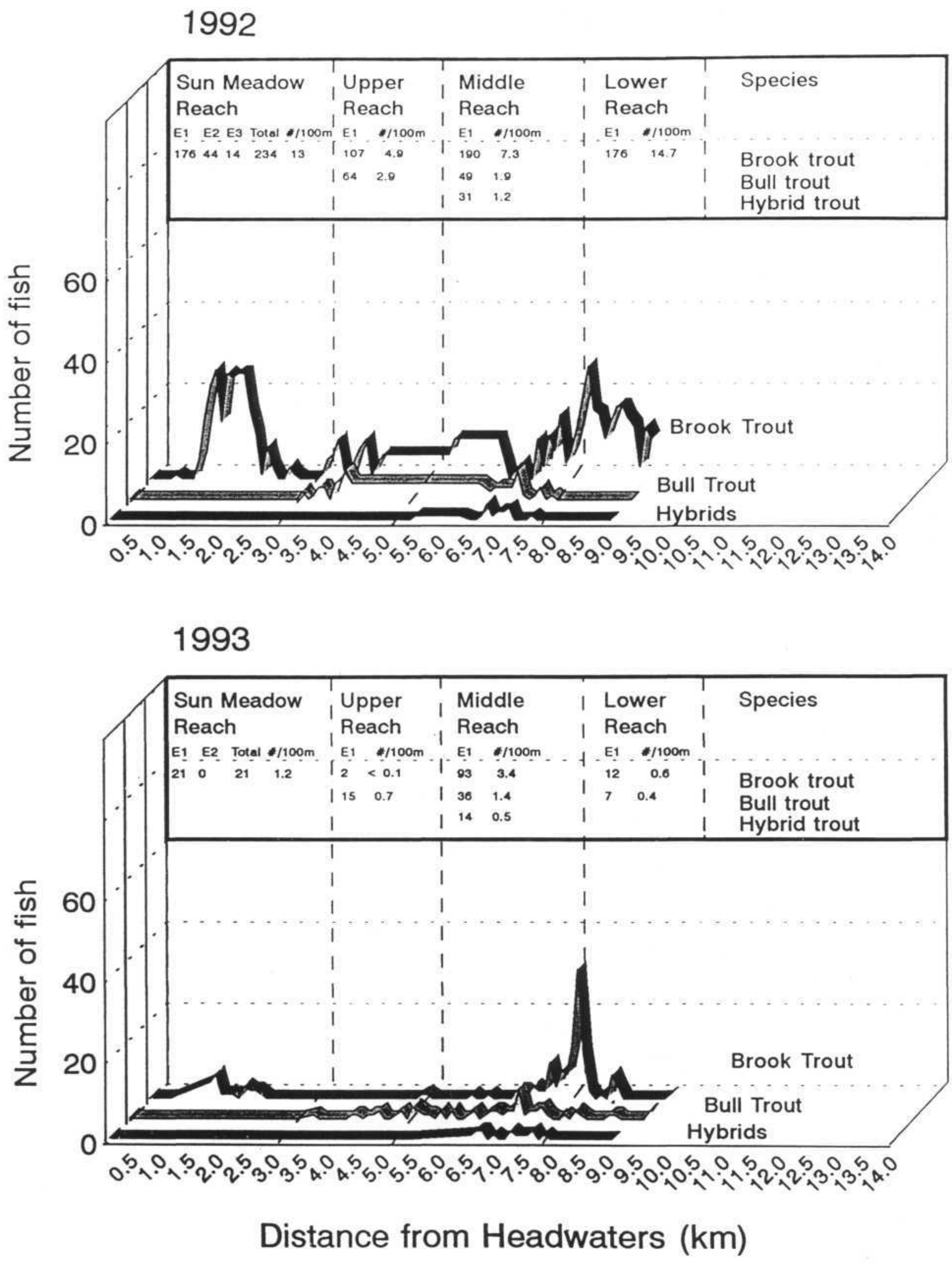


FIG. 2 - STREAM BARRIER CROSS SECTION ILLUSTRATING CONSTRUCTION



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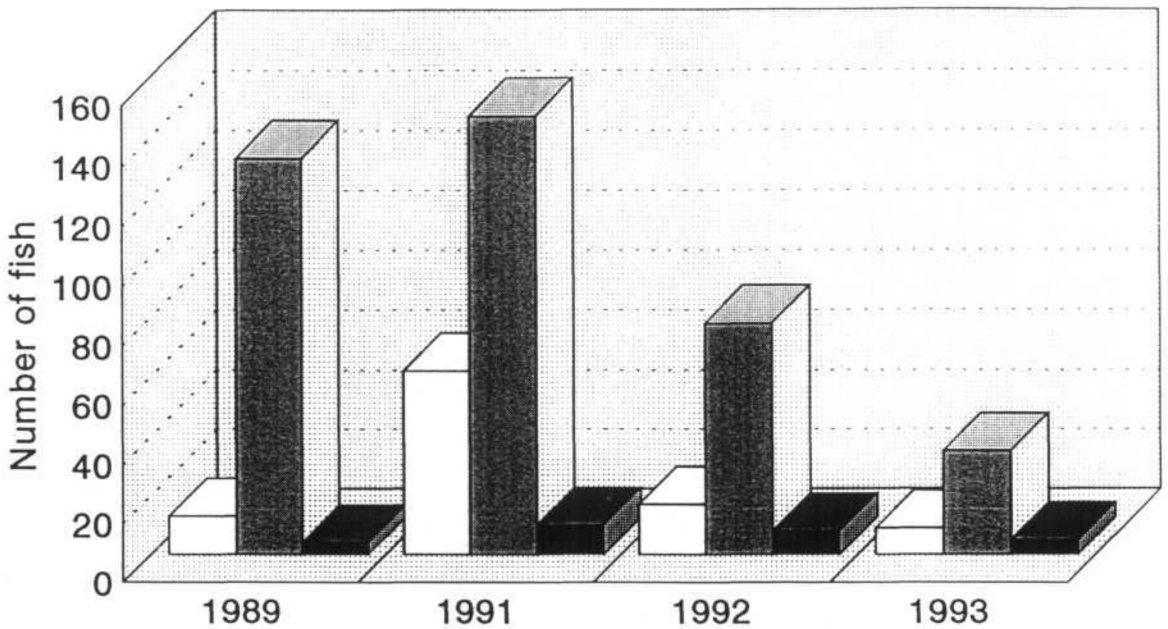

	1989	1991	1992	1993
Brook trout	13	62	17	9
Bull trout	133	147	78	35
Hybrid trout	4	10	8	5

Figure 4. Snorkel dive counts of trout in Sun Creek stream sections 105-150, 1989 to 1993. In 1989 10% of the riffles and glides, and 20% of the pools, were snorkeled. Numbers of trout were expanded in proportion to the number of each habitat unit in the reach. From 1991 to 1993 each habitat unit was snorkeled in the reach.

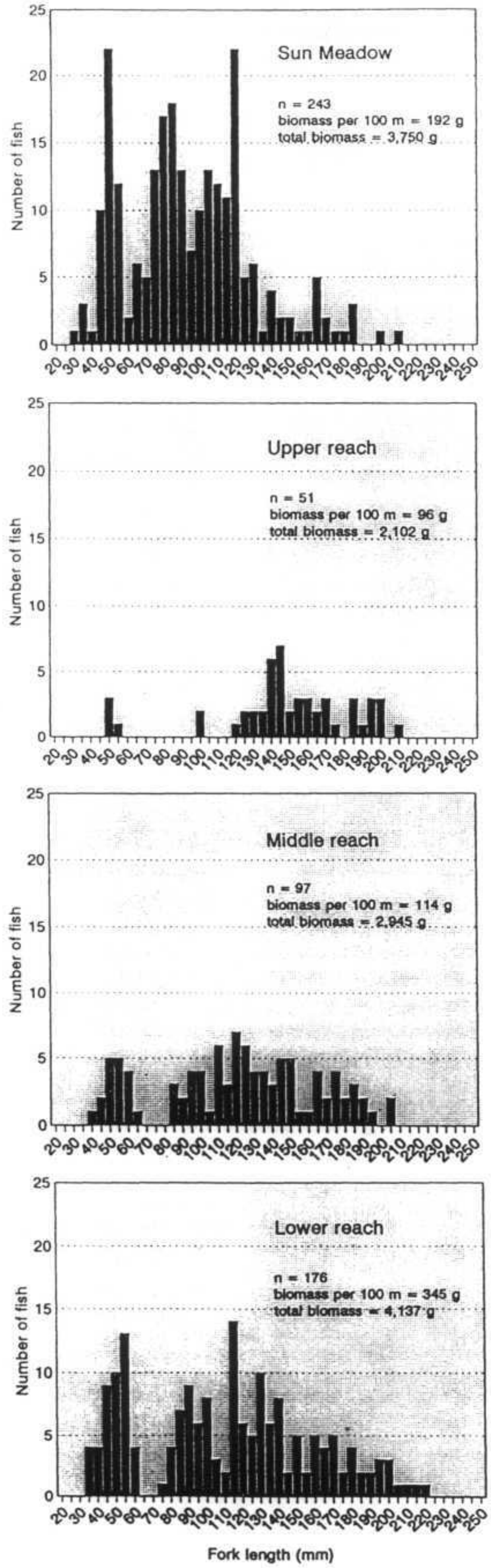

Figure 5. Brook trout length frequency distribution in four study reaches in Sun Creek, 1992. Fish were collected with electroshockers.

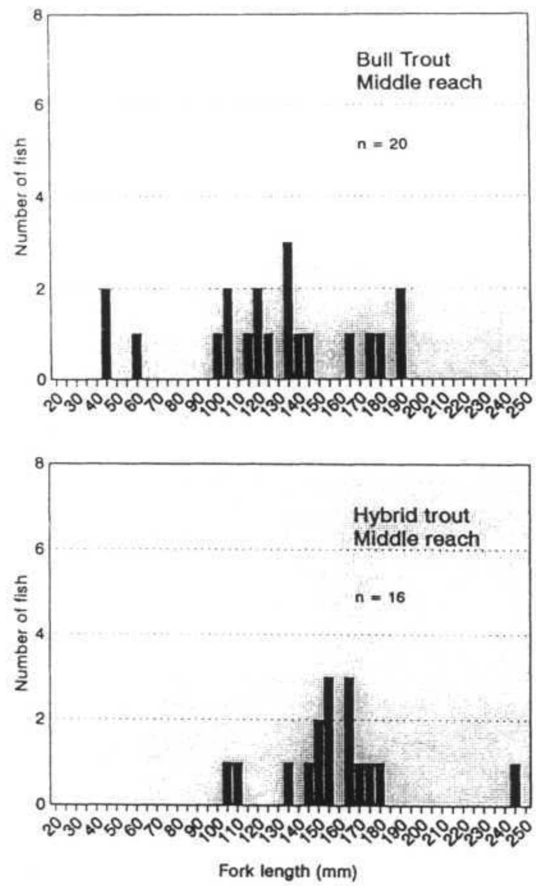

Figure 6. Bull trout and hybrid trout length frequency distribution in the Middle study reach of Sun Creek, 1992. Fish were collected with electroshockers.

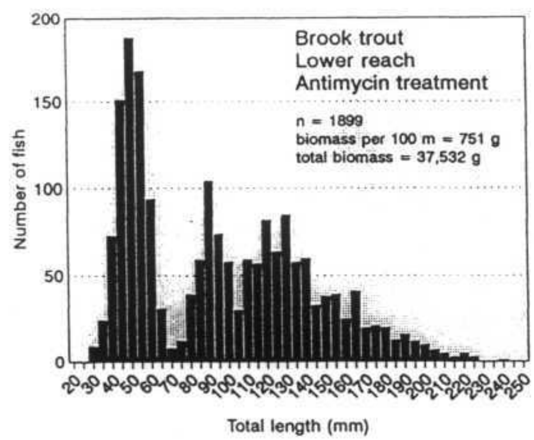

Figure 7. Brook trout length frequency distribution in the Lower study reach of Sun Creek, 1992. Fish were collected with antimycin.