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Hooking Mortality of Cutthroat Trout in a Catch-and-Release Segment of the Yellowstone River, Yellowstone National Park

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Abstract.- Hooking mortality was examined in a population of wild cutthroat trout (*Salmo clarki bouvieri*) in a portion of the Yellowstone River, Yellowstone National Park, which is managed under catch-and-release regulations. The number of trout dying from capture and release in the 4.5-km study area was assessed by searching for trout carcasses in established snorkeling routes. We divided our estimate of angler-induced mortalities by cutthroat trout abundance and creel survey data to estimate single capture hooking mortality and exploitation rates resulting from catch-and-release angling in the study area. The average number of times cutthroat trout were recaptured during the study period was estimated from the results of the creel survey and cutthroat trout abundance data. The hooking mortality rate per single capture was 0.3%. In 1981, 3% of the estimated cutthroat trout population died after capture and release by anglers. Cutthroat trout in the study area were captured an average of 9.7 times during the study period in 1981.

The increased demand for sport fishing in North America has required the development of innovative management techniques, one of which is the implementation of restrictive regulations such as minimum length requirements, slot limits, and catch-and-release programs. Thus, more fish are being released by anglers either voluntarily or because those fish do not meet harvest specifications. A major assumption underlying these regulations is that the majority of fish released survive to reproduce or be caught again. Special gear restrictions (typically, artificial lures and flies only) are often used in conjunction with this type of regulation. Numerous studies have been conducted to date concerning various aspects of hooking mortality, and these studies indicated that mortality rates of salmonids caught with artificial lures and flies averaged 6.1 and 4.1 %, respectively (Wydoski 1977).

Very little is known about hooking mortality in wild salmonid populations, despite the many studies concerning the topic, perhaps because of problems involved in holding test fish for observation. Past investigators working in lakes have confined test fish in floating live cars (Hunsaker et al. 1970; Warner and Johnson 1978). However, confining wild fish in this manner may induce additional stress (Wydoski et al. 1976) and result in overestimates of hooking mortality. Stress induced by holding could be especially important in fluvial situations if test fish were crowded and forced to maintain unfavorable holding positions.

The need to confine test fish for observation also has hindered the investigation of hooking mortality rates in fish caught more than once. If the effects of stress are cumulative, as suggested by Wydoski (1977), hooking mortality may be substantial in fish recaptured more than once in a relatively short period of time. Elevated mortality rates in fish captured repeatedly could reduce the effectiveness of special regulations in waters receiving intense levels of angler use.

Our study in 1980 and 1981 was designed to examine hooking mortality in a population of fluvial cutthroat trout (*Salmo clarki bouvieri*) that appeared to be subjected to repeated recapture. The study area, a segment of the Yellowstone River in Yellowstone National Park, was managed under catch-and-release regulations and was restricted to use of artificial flies and lures only. It is one of the most intensively fished wild trout streams in North America, sustaining over 1,300 angler hours per hectare during the 3.5-month 1981 angling season (Jones et al. 1982).

The immense popularity of this fishery, along with a probable increase in angler effort in the future, has prompted concerns about the potential impacts of catch-and-release angling on the cutthroat trout population. The park management goals state that native fish populations in the park should closely represent a pristine state, unexploited by man. If cutthroat trout in the Yellowstone River experience hooking mortality rates similar to those of salmonids in previous studies, the potential for impact does exist, particularly if the effects of repeated recapture are cumulative. The specific objectives of the study were to (1) estimate hooking mortality rate per single capture for cutthroat trout in the study area, (2) estimate the frequency of recapture for cutthroat trout within the study area, and (3) determine the fraction of the cutthroat trout population in the study area that die as a result of hooking mortality.

Study Area

The Yellowstone River originates in the Bridger-Teton Wilderness of western Wyoming and flows northward into Yellowstone Lake within Yellowstone National Park. The river drains the lake from the northern shore at an elevation of 2,600 m. The 4.5-km portion of the river examined in this study began 3 km downstream from the Yellowstone Lake outlet (Figure 1). Three study sites totaling 2.4 km in length were selected (Table 1). The uppermost site (Cable Car) started at the beginning of the study area and ended 250 m upstream from LeHardy Rapids. The middle study site, Big Eddy, is 110 m downstream from LeHardy Rapids and contained numerous lodgepole pine (*Pinus contorta*) deadfalls that extended up to 25 m out into the river from both banks. The lower site, Buffalo Ford, contained four long gravel bars and two side channels about 20 m wide.

River discharge during the study period (1 July-25 August) decreased from 105 to 45 m^3/s in 1980 and from 104 to 41 m^3/s in 1981 (U.S. Geological Survey 1981, 1982). Underwater visibility, measured as the maximum distance an object the size of an adult cutthroat trout 300 mm long could be clearly recognized by an underwater observer, was reduced briefly to a low of 2 m in mid-August of

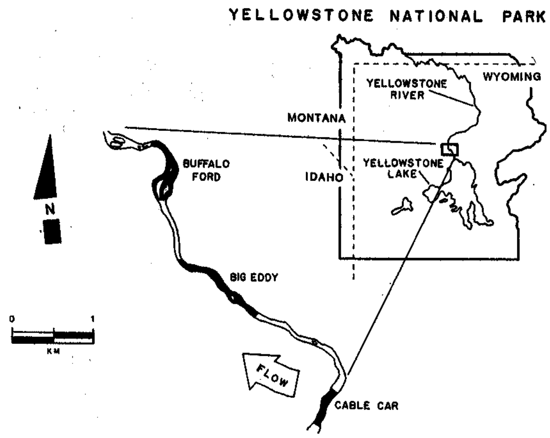

FIGURE 1.-Location of study areas (stippled) on the Yellowstone River in Yellowstone National Park.

both years while large amounts of *Anabaena flos-aquae* drifted from Yellowstone Lake. This period lasted from 7-17 August in 1980 and 12-18 August in 1981. Water temperatures ranged from 11.0 to 16.8°C and 11.1 to 15.6°C during 1980 and 1981, respectively, and peaked during the last week of July in both years.

The cutthroat trout was the most abundant fish present in the study area. The average length landed by anglers in the study area was 391 mm, and 83% were longer than 356 mm. Most fish were of age groups V and VI (Jones et al. 1982). Except for young of the year, which we disregarded, very few trout smaller than 250 mm were present. Small numbers of redside shiners (*Richardsonius balteatus*), longnose suckers (*Catostomus catostomus*), and longnose dace (*Rhinichthys cataractae*) also were present in the study area.

Methods

Estimates of natural and hooking mortality were obtained by counting dead fish along an established route through the study sites. Two weeks

TABLE 1. - Physical parameters and estimated numbers of cutthroat trout present in the Yellowstone River study sites during 1981.

Study site	Maximum depth (m)	Length (m)	Channel width (m)	Area (hectares)	Substrate	Population estimates July 11-12	Aug 4-5
Cable Car	2.5	350	86	3.01	Cobble, boulders	494	3,250
Big Eddy	2.5	1,316	73	10.03	Gravel, cobble, boulders	665	1,364
Buffalo Ford	2.0	750	99[a]	8.87	Cobble, gravel	1,225	1,067
Entire study area		2,416		21.91		4,510	10,489

[a] Excluding side channels.

prior to the opening of the angling season in 1980, we conducted a snorkel survey of the study area to locate areas in which cutthroat trout carcasses would most likely settle. Deep pools, eddies, and deadfalls were considered likely areas. After the initial snorkel survey, we established a route through each study section that included 10-15 of such areas. The same observer snorkeled the route three times per week from 10 July to 24 August 1980. The carcass search was conducted from 10 to 14 July to assess the number of dead cutthroat trout prior to the 15 July opening of the angling season. The number and location of all dead cutthroat trout located during the study period were recorded on an underwater slate and the carcasses were removed from the river.

The same general procedure was used during 1981 with the exception that two divers were used in order to increase the area of the river searched. In addition, scuba gear was used to search for carcasses in a pool 7 m deep located at the lower end of the study area. Both divers snorkeled a fixed route in each study section three times a week between 1 July and 24 August.

To assess our efficiency in recovering carcasses, we released 131 dead cutthroat trout (260-500 mm total length, the same sizes taken by anglers) throughout the study area in 1981. These fish were released in two separate groups during July and August. We marked 45 carcasses on 13 July with anchor tags and color-coded survey tape inserted between the gills. These dead trout had been collected in Yellowstone Lake tributaries and then frozen for storage. We released the thawed carcasses individually in areas that traditionally received intensive angler effort or in portions of the river where substantial numbers of adult trout had been located by prior snorkeling observations. The point of release for each carcass was recorded. While snorkeling the river along the established search routes, we noted the tag number and location of these introduced carcasses and removed them from the river.

To determine whether or not these introduced carcasses drifted in a manner similar to trout dying in the study area, we released 86 dead cutthroat trout, obtained from three different sources, on 1 August 1981. Thirty thawed postspawners were used along with an equal number of gill-netted fish collected in Yellowstone Lake 2 d before the release trial. The gill-netted fish had not been frozen but had a longitudinal slit in the peritoneal cavity which had been used to sex the fish. The final group of 26 fish were obtained by angling the day before the trial and were sacrificed just prior to their return to the river. Groups of carcasses (one from each source) were released as they were in the first trial. We used a chi-square test of association to evaluate our ability to recover carcasses from each of the three sources. We also released 20 cutthroat trout carcasses in a 2-km portion of the river immediately above the Cable Car study site on 1 August to determine if dead cutthroat trout drifted into the study area from upriver.

We assumed that the percentage of introduced carcasses recovered in the established routes accurately reflected our efficiency in locating carcasses of fish that had died of natural or hooking mortality. By applying our efficiency estimate to the total number of dead Yellowstone River trout found, we estimated mortality in the 4.5-km study area for the period between 15 July and 24 August 1981. We did not apply the 1981 efficiency estimate to 1980 data because underwater visibility and the number of divers differed between years.

Estimates of the number of angler-captured trout were obtained from the Volunteer Angler Report (VAR). This voluntary creel survey system was initiated in Yellowstone Park in 1973 and was conducted concurrently with stratified, random, manned creel surveys. Comparisons of subsequent estimates indicated that mean length of the angler day, landing rate, and creel rate were significantly different. Correction factors derived from these data have enabled the VAR to repeatedly produce values similar to those estimated by the manned creel surveys (Jones et al. 1977). Our estimate of angling mortality in the study area was divided by the number of fish landed during the same time period to provide an estimate of the single-capture hooking mortality rate.

The number of dead fish counted was compared to the total trout population present in the study area. Because electrofishing had proven to be inefficient in the past, we assessed cutthroat trout abundance by snorkeling (Schill and Griffith 1984). Population estimates were made for the three study sites on 11-12 July and 4-5 August 1981. We calculated a mean density estimate (weighted by study site area) for the 2.4-km length of the river actually counted, and expanded this estimate to include the entire study area.

Results

Pattern of Trout Mortality

Snorkeling along the established routes indicated that the chronological pattern of mortality was similar in both years (Figure 2). Totals of 59 and

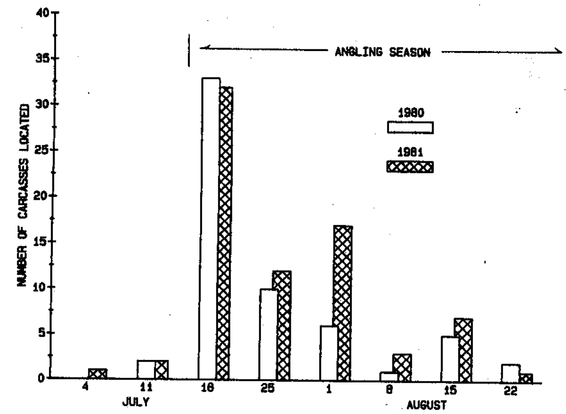

FIGURE 2.-Number of cutthroat trout carcasses located during weekly underwater searches of established routes in the Yellowstone River, 1980 and 1981. Weekly totals are plotted on the midpoint of each week.

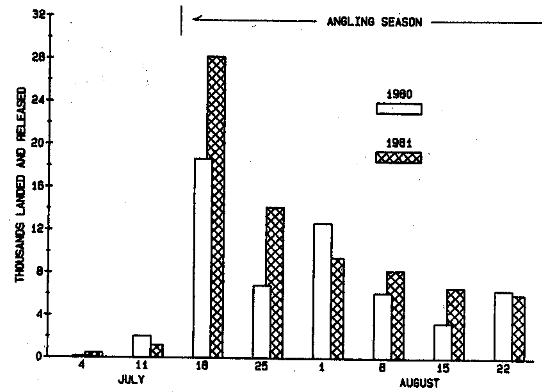

FIGURE 3.-Number of cutthroat trout caught and released by anglers in the study areas of the Yellowstone River, 1980 and 1981. Weekly totals are plotted on the midpoint of each week.

72 dead cutthroat trout were found during the 1980 and 1981 study periods, respectively. Less than 4% of these were found prior to the opening of the angling season in both years; then, during the initial week of the fishing season a sharp increase in numbers was observed. The number of dead cutthroat trout located during the first 3 weeks of the angling season comprised 83 and 81% of all those located during 1980 and 1981, respectively.

This chronological pattern paralleled closely the number of cutthroat trout landed by anglers in the study area during the same time periods. A relatively small number of illegally captured cutthroat trout were reported by anglers prior to the opening of the angling season in both years and landings increased sharply during the opening week (Figure 3). The number of cutthroat trout landed per week declined sharply both years after the opening week of the season in a manner similar to the number of dead trout found. Statistical analysis indicated a significant positive correlation between the number of cutthroat trout landed and the number of dead trout located in each weekly interval in both 1980 ($r = 0.84$; 5 df) and 1981 ($r = 0.92$; 6 df).

Dead cutthroat trout tended to accumulate in three locations within the established snorkeling routes. A large eddy at the downstream end of the study area contained 60 and 64% of all those located in 1980 and 1981, respectively. In addition, a substantial number (21 and 16% in 1980 and 1981, respectively) were found in two 50-m segments of the Big Eddy study site that contained numerous deadfalls along the shoreline. The remaining dead trout found in both study years were distributed throughout the snorkeling routes.

The overall recovery rate of the 131 carcasses we introduced into the study area during 1981 was 31 %, and all but 2 of these fish were found within 3 d of their introduction. Of the 45 carcasses released in the river on 13 July, 31% were recovered and the mean distance they had drifted was 1,298 m. The recovery rate for the 86 carcasses released in the 1 August trial was nearly identical (30%). Recovery rates for each of the three, sources (post-spawning mortality, gill-netting, and angling) of carcasses placed in the river at the same times and locations during the trial were similar. Chi-square analysis indicated no significant difference existed between recovery rates for those three groups ($x^2 = 1.51$; 2 df).

None of the 20 carcasses placed above the Cable Car study site were recovered within the study area downstream. The low gradient and presence of pools over 7 m deep apparently restricted movement from this 2-km segment into the study area.

Mortality Estimate per Capture

By applying the 31% average recovery efficiency to the number of dead cutthroat trout located (72), we estimated that 236 fish died in the study area between 15 July and 25 August 1981. Creel survey data indicate that 72,698 cutthroat trout were caught in the study area between 15 July and 25 August 1981. By dividing the estimated amount of mortality (236 fish) by the number of cutthroat trout landed and released, we calculated a hooking mortality rate of 0.3% per capture in 1981.

Exploitation and Recapture

A substantial amount of cutthroat trout movement occurred in the study area in 1981. The number of cutthroat trout present more than doubled between the time the two population estimates were conducted on 11-12 July and 4-5 August (Table 1). Most of the trout moving into the area in late July were probably fish redistributing themselves following spawning in the river. We divided the average of the two population estimates (7,500 fish) into the estimated loss from hooking mortality in the area (236 fish) to obtain an estimated exploitation rate of 3.2%. This estimate applies only to those fish released and does not include the illegal harvest. Dividing the estimated number of cutthroat trout caught during the same period (72,698) by the mean number of fish present (7, 500) gave a recapture estimate of 9.7 times per individual fish.

Discussion

Pattern and Causes of Mortality

The chronological pattern in which carcasses were found indicated that most of the estimated 236 cutthroat trout that died in the study area between 15 July and 25 August 1981 did so after having been caught and released by anglers. Because a strong correlation existed in both years between the number of carcasses located and numbers of cutthroat trout caught by anglers, we believe that most of the dead cutthroat trout found in the study area died as a result of hooking mortality. We treated all the mortalities as angling-related, while acknowledging that a small unknown number may have been natural deaths.

Trout taken by predators would not affect the hooking mortality rate reported in this study unless substantial numbers received fatal wounds from predators but were not captured or only partly consumed. In that event, those carcasses presumably would drift in a manner similar to those of fish killed by hooking. A number of potential predators were present in the vicinity of the Yellowstone River catch-and-release area, including bald eagles (*Haliaeetus leucocephalus*), white pelicans (*Pelecanus erythrorhynchos*), otter (*Lutra canadensis*), common mergansers (*Merues merganser*), and California gulls (*Larus californicus*). Only the latter commonly were observed within the study area, but we did not observe gulls preying upon adult cutthroat trout. More importantly, wounds inflicted by predators generally are obvious (Alexander 1979) and we did not observe puncture wounds or lacerations on any of the carcasses located in the river during both years.

Additional natural mortality in the study area would be expected from either delayed spawning stress, natural aging processes, or disease. We found a small number of carcasses prior to the opening of the angling season in both years (Figure 2) and assumed those fish died from spawning-induced stress or from the illegal angling that occurred during that time.

We believe that few of the dead trout we observed during the angling seasons in both 1980 and 1981 died of natural causes. Conditions in the Yellowstone River from mid-July to the end of August are probably near the optimum for cutthroat trout survival. Water temperatures typically remained below 14.5°C in July and August, and food availability peaked during this period as a result of aquatic invertebrate emergence and the discharge of plankton from Yellowstone Lake.

We assume that some scavenging occurred, but that scavenging of introduced carcasses occurred at a rate similar to that of trout that died in the study area. Scavenging appeared to be minimal during 1980 when carcasses were not introduced into the river. The only scavenger commonly observed was the California gull, and these birds appeared to prefer the shallow Buffalo Ford portion of the river.

Mortality Rate per Capture

The hooking mortality rate reported in this study was calculated from estimates of both angler catch and instream mortality. As a result, an unknown amount of experimental error is incorporated into the 0.3% estimate. However, it is important to note that large errors in both the creel survey data and our estimate of hooking mortality in the study area would have little effect on the mortality rate per single capture. For example, a 50% reduction in the estimated number of cutthroat trout caught and a 50% increase in the estimated number of fish killed by anglers would still result in a hooking mortality rate of less than 1 %.

Our estimate of hooking mortality rate is lower than results obtained for salmonids by most previous investigators. The mortality rate for hatchery-reared Atlantic salmon (*Salmo salar)* was 6.0% for fish caught once on treble hook lures and 4.2% for those captured with artificial flies (Warner 1979). Test fish in that study were caught from hatchery rearing ponds at Enfield, Maine, and were held for 10-14 d. Hooking mortality rates for wild Yellowstone cutthroat trout caught in Yellowstone Lake and held in floating livecars were of a similar magnitude; 4% of the fish captured with flies and 2.7% of those captured with lures died after 10 30 days of observation (Marnell and Hunsaker 1970). Bouck and Ball (1966) reported a hooking mortality rate of 87% for hatchery rainbow trout (*Salmo gairdneri*) caught with artificial lures and played to exhaustion.

Several investigators, however, have obtained hooking mortality estimates of less than 1%. Hatchery west-slope cutthroat trout (*Salmo clarki lewisi*) caught with single and treble hook flies at the Yellowstone River Trout Hatchery in Montana died at a rate of 0.3% (Dotson 1982). At an Idaho hatchery, biologists who captured and released 520 hatchery west-slope cutthroat trout on barbed and barbless flies recorded mortalities of 0.4% and 0.8%, respectively (T. Bjornn, Idaho Cooperative Fishery Research Unit, personal communication).

The variability that exists in the hooking mortality rates reported for salmonids probably is due to factors, such as type of hook; water temperature, size of fish, fish species, experimental handling and holding procedures, and length of playing time, that varied among these studies. We believe the relatively low hooking mortality rate experienced by Yellowstone River cutthroat trout may be related to several of these factors, especially the latter three. Studies with cutthroat trout seem to consistently indicate low mortality rates. Also, stress from the holding of fish in cages after hooking may be confounding the results of those studies where that procedure was employed.

Stress-related deaths appear to be the result of severe muscular exertion (Parker and Black 1959). Therefore, an increase in the length of playing time could result in elevated mortality rates. A characteristic of the Yellowstone catch-and-release fishery is the short time in which most fish are landed after hooking. We recorded the time required for 58 anglers to land cutthroat trout in the study area in July 1980, and the average landing time was 1.7 min, shorter than might be expected for fish of this size in a large river. Playing times of such short duration have little effect on the blood chemistry parameters used as indices of physiological stress by Wydoski et al. (1976). In that study, changes in plasma glucose levels and plasma osmolality of wild and hatchery rainbow trout did not increase significantly from initial levels when fish were played for 1, 2,. or 3 min but fish played for 4 and 5 min had significantly higher levels. Marnell and Hunsaker (1970), however, reported no significant difference in mortality rates of cutthroat trout played for 5 or 10 min before release.

Exploitation and Recapture

The results of this study indicate that 3% of the population died in 1981 as a result of hooking. Evaluating the effects of this exploitation rate on the Yellowstone River cutthroat trout population is hindered by a lack of information on unfished populations in large rivers. It is clear that human impact on cutthroat trout in the Yellowstone River has been drastically reduced since catch-and-release regulations were implemented in 1973. Prior to that time, about 14,000 fish were killed annually by anglers as compared with a few hundred now. The average age of cutthroat trout in the Yellowstone catch-and-release area has increased from 3.8 to 5.0 years since the inception of the current regulations, and the mean length of fish landed has increased from 363 to 391 mm (Jones et al. 1982).

Yellowstone River cutthroat trout were caught an average of 10 times during, the 1981 study period, or the equivalent of once every 5 d. Because 85% of the fish caught in the study area during the 1981 season were captured between 15 July and 25 August, our recapture estimate is probably representative of recapture rates for the entire season. Obviously the potential for inaccuracy in this value exists because it was calculated from two widely varying population estimates and assumes negligible emigration during the study period. It is indicative, however, of the extreme vulnerability of cutthroat trout in the Yellowstone River. In the week prior to the opening of the 1981 angling season, we captured 76 cutthroat trout with artificial flies in a 50-m section of the river and marked them with anchor tags. While marking these fish, we captured one individual fish four times within 24 h and recaptured two others within 2 h of their original capture. Anglers removed most of the tags in the first few days of the season, preventing us from examining cumulative recapture rates from individual fish during the entire season. One angler, for example, removed tags from 12 cutthroat trout. The observation that a single angler recaptured 16% of the original marked fish during the first 2 d of the angling season is, we believe, an indication of that vulnerability.

Acknowledgments

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