EVALUATION OF THE EFFECTS OF MAN-MADE MEANDERS ON A TROUT STREAM*

Al Elser
Fisheries Biologist, Montana Fish and Game Department

ABSTRACT

The physical parameters and fish populations were measured in a segment of Prickly Pear Creek (Jefferson County) in 1967, 1968 and 1969. The construction of Interstate Highway 15 was responsible for a 3,300-foot channel change in 1968. However, the stream was artificially meandered in the floodplain to retain its original channel length. Prior to construction, the average depth and width was 1.4 and 26.4 feet, respectively. Average depth in 1968 was reduced by 28.6% (1.4 to 1.0 feet) and remained unchanged in 1969. The average width of the section remained about the same following construction. Pool-riffle periodicity or the spacing of successive pools was 6.6 times the average stream width before construction (1967); 15.7 widths one year following construction (1968); and 8.8 widths two years after construction (1969). Fish populations were estimated by means of a simple mark-and-recapture census. Rough fish predominated all three sampling periods, contributing over 62 and 77% of the total number and weight, respectively. Longnose suckers were the most abundant fish collected. Numerically, rainbow trout were the dominant game fish prior to construction, while brown trout dominated following construction. Brown trout were the dominant game fish by weight all three sampling periods. The total standing crops prior to construction, one year and two years following construction were: 169, 81 and 74 pounds per acre, respectively. A statistical test indicated a significant difference numerically between the fish population before and after alteration. Suggestions for future channel design are given.

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INTRODUCTION

In the mountainous regions of the Western United States, major transportation lines have long followed water level routes. The natural courses laid out by streams and rivers most often offered least resistance because of alignment and grade. When it became a question of preserving the stream or the right-of-way, the railroad or highway generally won out at the expense of the waterway. In the past, construction of highways and railroads left shorter, straight channels for the roadside stream and stripped the willows and other streamside vegetation.

The ultimate result of forcing a naturally meandering stream into a straight channel is a loss of valuable stream length. A study of channel alterations on 13 Montana streams revealed that their total length was shortened by 68 miles when 137 miles of natural stream was re-routed into 69 miles of inferior man-made channel (Alvord and Peters, 1963). Such channel disturbances are undoubtedly detrimental to the indigenous fish populations. Following habitat alteration of a small stream for highway construction, Whitney and Bailey (1959) showed a 94% reduction in number and weight of trout greater than 6.0 inches in length. In Little Prickly Pear Creek, Elser (1968) reported the number and weight of brown and rainbow trout were about 78% less in a segment of stream straightened by railroad construction than in a natural section.

A great aid in preventing losses to fish habitat by channel alterations in Montana has been the Stream Preservation Law. Since 1963, this law has required agencies of the state and local government to notify the Fish and Game Department of any construction activity that encroaches in any manner on a river or stream. If the construction activities are judged detrimental to the stream, alternate plans or recommendations for mitigating habitat losses are presented.

A 3,300-foot channel change was proposed for Prickly Pear Creek as a result of the location of Interstate Highway 15 that would have greatly modified a sizeable stretch of valuable fishing water. To mitigate fishery losses, we asked that the new channel be meandered in the floodplain to retain its existing length. The man-made meanders were designed to be built alongside existing brushy vegetation to retain streamside cover. During the construction process, most existing brushy vegetation in the floodplain was removed by mistake. However, the artificial meanders did retain original channel length and hence, for the first time, there was as much stream following construction as before construction.

The objective of the study was to evaluate the effectiveness of artificially meandering a stream to retain its original channel length. Highway construction began in the late fall of 1967 and was completed in 1968. Measurements made in 1967 are considered pre-alteration, while those made in 1968 and 1969 are one and two years post-alteration, respectively.

METHODS

Stream morphology of the original channel was measured in 1967 and on the relocated channel in 1968 and 1969 to determine differences following alteration. Transects were established perpendicular to the main current at 50-foot intervals, and depths were measured to the nearest 0.1 foot at 2-foot intervals on each transect. Pool-riffle periodicity was determined by plotting the bed profile along the thalweg, the line connecting the deepest points of the channel. A pool was arbitrarily defined as a vertical drop in the stream bed greater than the average thalweg depth. Sinuosity, or the ratio of channel length to valley length, was measured prior to and following alteration .

Fish populations were censused by electrofishing. All fish captured were anesthetized, measured, weighed, marked and released near the capture sites. Estimates of the fish population were based on the mark-and-recapture technique of Petersen, using formula 3.5 of Ricker (1958). Confidence intervals at the 95% level were calculated for each estimate by formula 6 of the Michigan Institute for Fisheries Research (1960). Coefficient of condition was calculated for the three sampling periods using the formula $K = W \times 10^5/L^3$; where W = weight in pounds and L = length in inches.

FINDINGS

Stream Morphology

The analysis of field data showed that the channel length was retained, and was actually increased in the area of construction by approximately 3% (Table 1). Average stream depth and average thalweg depth were reduced by 28.6 and 21.7%, respectively, in 1968, and remained unchanged in 1969.

In natural stream conditions, the thalweg tends to wander back and forth across the channel opposite the bars, even in straight reaches. The degree of wandering is indicated by the sinuosity. This ratio of channel length to mean downvalley distance for the natural channel prior to alteration was 1.05, indicating an almost non-sinuous channel. The ratio increased to 1.09 in 1968 and 1.10 in 1969.

The bed profile along the thalweg was plotted to show changes in the pool-riffle periodicity (Figure 1). Prior to construction, there was a pool every 180 feet of stream, for a periodicity of 6.6 times the average stream width. Leopold and Langbein (1966) reported the spacing of successive pools as ordinarily in the magnitude of from 5 to 7 stream widths. In 1968, the spacing of successive pools was increased to a pool every 380 feet or a periodicity of 15.7 widths. Two years following construction, the periodicity had adjusted to 8.8 widths or a pool every 210 feet.

Table 1. Channel measurements obtained from Prickly Pear Creek, prior to (1967), one year following (1968), and two years following relocation (1969).

Parameter	1967	1968	1969
Length (ft.)	3,150	3,250	3,250
Average depth (ft.)	1.4	1.0	1.0
Average thalweg depth (ft.)	2.3	1.8	1.8
Average width (ft.)	26	25	25
Sinuosity	1.05	1.09	1.10
Pool-riffle periodicity 1/	6.6	15.7	8.8

1/ Average distance between successive pools divided by average width, expressed in widths.

Fish Populations

The ultimate measures of the effects of channel alterations on the stream fishery lies in the response of the fish populations to changes in their habitat. It was shown that changes in stream morphology did occur with the channel relocation. Changes in the fish populations following alteration must be evaluated in terms of the populations that were present prior to construction.

Rough fish dominated the population prior to and following construction, contributing from 62.4 to 67.6% of the total number and from 74.0 to 79.3% of the total weight (Table 2). The longnose sucker was the most abundant species collected in all three sampling periods, comprising over 54% of the total number and over 72% of the total weight. White suckers made up less than 12% of the total number and less than 7% of the total weight.

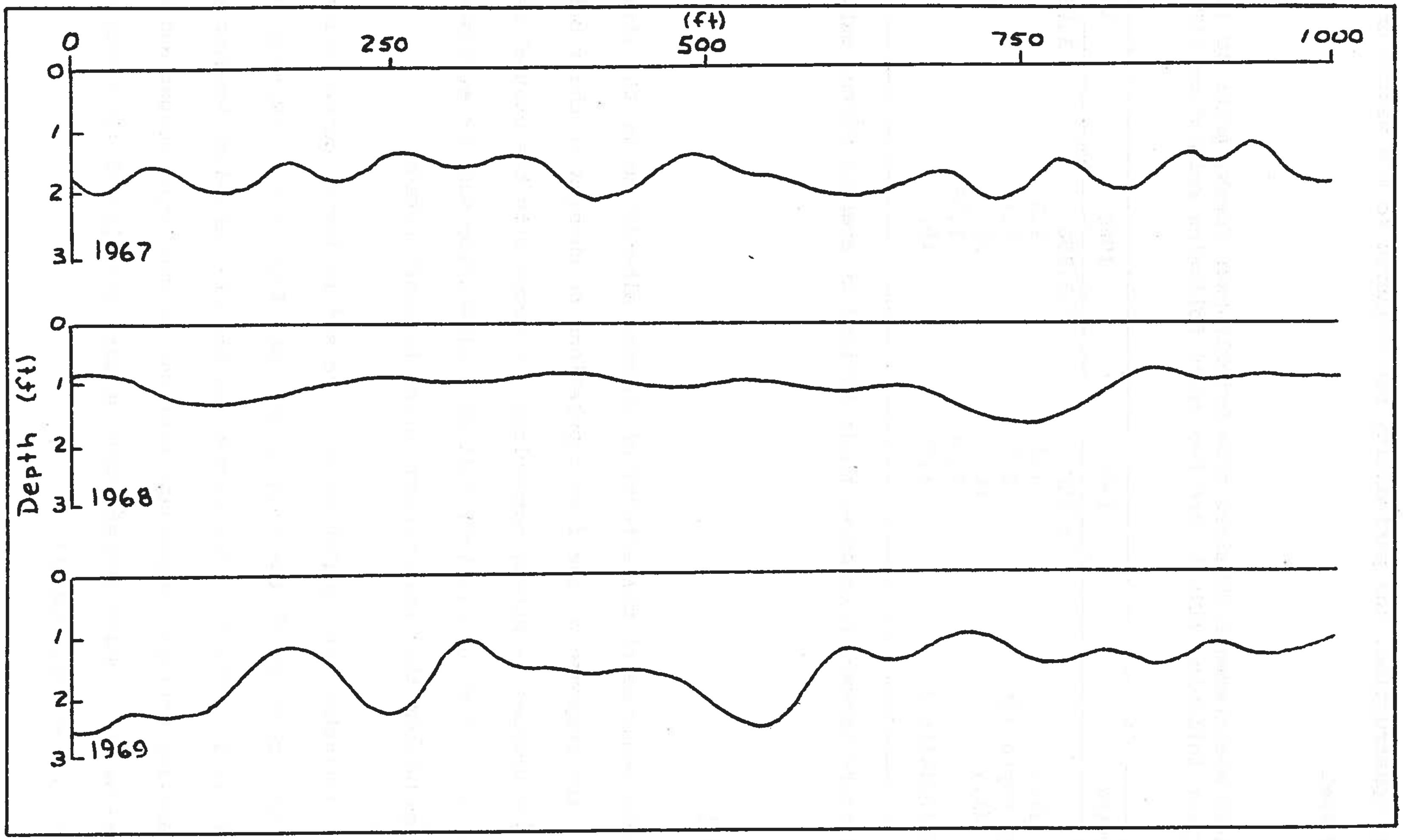

Figure 1. Bed profile along the thalweg for a portion of Prickly Pear Creek, showing the pool-riffle periodicity, pre-construction (1967), one year post-construction (1968) and two years post-construction (1969).

Table 2. Estimated fish populations for Prickly Pear Creek pre- (1967) and post-construction (1968 and 1969), expressed as numbers per acre with pounds per acre in parentheses. Confidence intervals at 95% level.

Species	1967	1968	1969
Rainbow trout	98 (12)	31 (4)	19 (4)
Brown trout	61 (24)	47 (13)	55 (15)
Longnose sucker	234 (125)	128 (59)	147 (53)
White sucker	39 (7)	28 (6)	7 (1)
Total trout	159 (36)	78 (17)	74 (19)
Confidence interval (±)	38	11	18
Total non-trout	264 (132)	156 (65)	154 (54)
Confidence interval (±)	62	30	28
Grand total	423 (168)	234 (82)	228 (73)

Game fish made up approximately one-third of the total population number, both before and after construction. Numerically, rainbow trout were the most abundant game fish prior to alteration, contributing 23.2% of the total. Following construction, predominance shifted to brown trout, which made up 20.1 and 24.1% of the total number in 1968 and 1969, respectively. Brown trout were the dominant game fish by weight all three years.

The study section supported an estimated total standing crop of 168 pounds per acre prior to construction. One year after alteration, the biomass was reduced by 51.2% to 82 pounds per acre. In 1969, it was reduced by an additional 11.0%. The total weight of rough fish was reduced from 1967 to 1969 by 59.1% as compared to a 47.2% decrease for the game fish population. Rainbow trout showed the greatest decline for the two-year period following alteration, with an 80.6% reduction in numbers. Numerically, white and longnose suckers decreased 82.1% and 37.2%, respectively, while brown trout were reduced by 9.8%.

A comparison of calculated confidence intervals at the 95% level indicates that the rainbow trout and longnose sucker populations were significantly reduced following channel alteration in 1968 (Figure 2). However, population changes found in 1969 could not be considered significant. The white sucker population demonstrated the only significant change from 1968 to 1969.

The coefficient of condition is a useful parameter for comparing the well-being of a fish. Condition factors were computed for each species of the fish population as another measure of the effects of channel alteration on the fish population. Since populations were sampled at nearly the same time each year, seasonal differences were eliminated. The mean condition factor for each species decreased the first year following alteration (Table 3). The brown trout population showed the least change (2.7%) and the white sucker population demonstrated the greatest (11.3%). Two years following alteration, the brown trout and the longnose sucker populations showed an improved condition and an increase in numbers. The mean condition factor of the rainbow trout population was further reduced as were population numbers. Inspection of the data indicates that differences between mean condition factors from year to year for any one species are statistically significant.

DISCUSSION

The 50% reduction of the game fish population following alteration is smaller than losses reported by others. However, these losses are based on population numbers present prior to alteration, and not on differences found between altered and unaltered segments of a stream. In sections of Little Prickly Pear Creek (Lewis and Clark County) straightened by railroad construction, rough fish were almost completely absent, but made up 30 and 58% of the total number and weight,

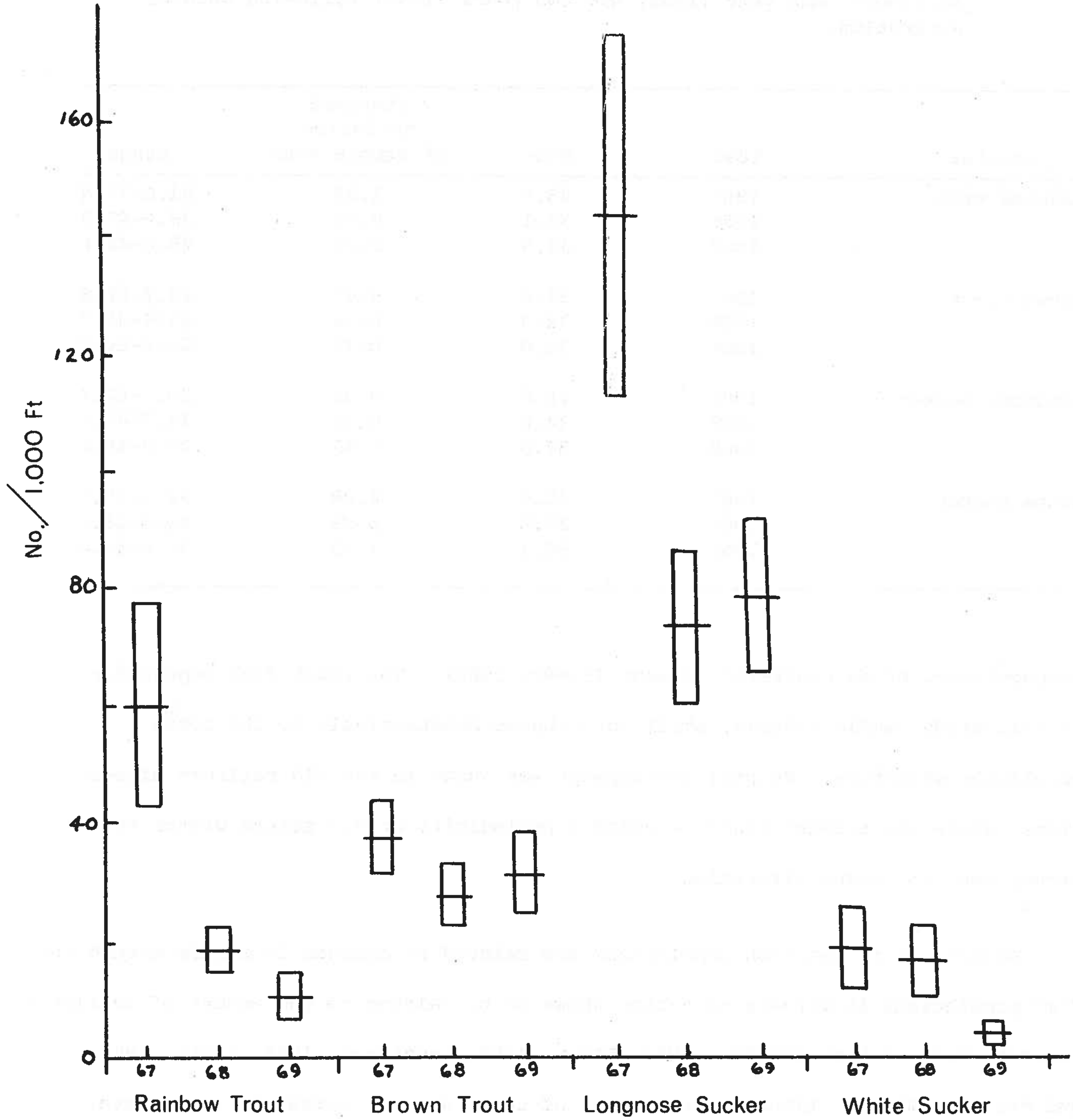

Figure 2. Comparison of population estimates (horizontal line) and calculated confidence intervals (vertical bar) for Prickly Pear Creek, pre-construction (1967), one year post-construction (1968) and two years post-construction (1969).

Table 3. Change in mean condition factor of fish from Prickly Pear Creek prior to (1967), one year (1968) and two years (1969) following channel alteration.

Species	Year	Mean	Standard deviation of sample mean	Range
Rainbow trout	1967	38.5	1.25	21.0-70.4
	1968	36.1	0.57	28.6-47.3
	1969	34.9	0.63	28.6-42.6
Brown trout	1967	33.8	0.47	23.7-52.8
	1968	32.9	0.54	25.4-41.7
	1969	36.0	0.77	22.5-60.0
Longnose sucker	1967	36.0	0.38	20.5-62.5
	1968	34.6	0.39	24.7-45.8
	1969	37.6	0.33	27.2-49.2
White sucker	1967	42.4	2.08	32.7-79.3
	1968	37.6	0.98	29.0-43.8
	1969	38.2	1.23	33.6-43.4

respectively, of an unaltered segment (Elser, 1968). The rough fish population in this study, while reduced, still contributes substantially to the total population structure. No pool development was shown in the old railroad alterations, while the present study revealed a periodicity of 8.8 stream widths the second year following alteration.

Reductions in the fish populations are related to changes in stream morphology. Fish populations in streams have been shown to be related to the amount of available cover by many workers (Bossou, 1954; Elser, 1968; Gunderson, 1968; Lewis, 1969; and Marcoux, 1969). Although the amount of cover was not measured, the removal of most existing brush during construction activities greatly reduced the quantity and quality of cover for fish. Leopold, Wolman and Miller (1964) reported that straight as well as meandering channels usually have an undulating bed, alternating along its length between deeps and shallows, at a repeating distance of 5 to 7 stream widths. Periodicity prior to construction was within this magnitude (6.6 widths), but was increased to 15.7 and 8.8 widths one and two years following construction, respectively. This improper balance of pools and riffles also probably had an adverse effect on the fish population.

Along with evaluating the man-made meanders, an important task was to suggest modifications of present techniques that may further reduce losses and hasten recovery for aquatic biota. Since this was the first time original channel length had been retained, several additional improvements are believed necessary. The most obvious was the importance of salvaging as much brushy streamside vegetation as possible. The man-made meanders were constructed on a uniform grade with a constant depth. Future channels should be designed to include the deeps and shallows at the same periodicity found in natural channels. Further, since the concave bank of a meander is considered the eroding bank and naturally has the deepest water, why not tilt the channel bed this way to facilitate pool development?

Attempts to re-establish vegetation on the channel banks have failed, primarily due to the unsuitable substrate provided by the conventional steep 1½:1 slopes. We are now planning to go into the channel and construct a berm. This berm should provide a stable site for vegetation.

Although the stream morphology was changed, some brush lost and the fish population reduced, the man-made meanders did retain the original channel length. No longer is it necessary for the roadside stream to be a straight, naked sluice, for with cooperation it can be an attractive meandering channel with fish.

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