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Associate Professor of Fisheries and Wildlife

Research Project Technical Completion Report
(B-177-UT)

UTAH CENTER FOR WATER RESOURCES RESEARCH

AND THE

ECOLOGY CENTER

UTAH STATE UNIVERSITY

Prepared for

UNITED STATES DEPARTMENT OF THE INTERIOR

Defining Stream Fish Microhabitat Requirements for Water Project Planning

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ABSTRACT

Brown trout daily activities were divided into two broad categories, resting and feeding, and the population was divided into three size groups (one of which is reported on here), based on the timing and location of these activities. Microhabitat components, measured previously in four rivers at sites occupied by fish, were utilized to develop usable component ranges for each size group and activity to illustrate the breadth of component values utilized out of the total range available. Microhabitat is thus described as a range of numerical values for each component of a specific set of components.

A 90 meter section of the Blacksmith Fork River in northern Utah was mapped by measuring depth, current velocity and light. A scuba diver searched the area, locating and identifying brown trout according to size group and activity. A comparison of fish locations with the maps indicates the maps correctly identified a high percentage of the sites occupied by brown trout. A chi-square test of the probability of uniform distribution of fish was significant for both feeding and resting sites.

Microhabitat components which most effectively regulate brown trout distribution in this type of intermountain stream can thus be described and measured, and used to estimate the proportion of a stream which is habitable. These quantified components should enable the designing of stream channel alterations to provide proper trout microhabitat.

INTRODUCTION

Growing environmental concern is leading to rigid requirements for protecting the environment. Design criteria are proposed to protect natural stream habitats against the adverse effects of water resources development, but their ability to insure the desired protection is severely limited by lack of information on how proposed development plans will affect the environment. As a result, many plans that would generate substantial economic benefit have been unnecessarily delayed, interrupted, or even abandoned, not because they would actually lead to environmental harm but rather because of the inability to be sure that irreparable harm would not occur.

Much of the past environmental opposition to water resources development has been generated because project planners failed to deal adequately with environmental considerations. A principal reason was that they did not know how. A logical approach to environmental protection in the situation where a project threatens stream channel conditions (all projects that add or subtract from stream flow or change the channel cross section do so to some extent) is either to leave sufficient habitat, after completion of a project, to support an adequate population of the desired fish or to replace habitat eliminated by the project. Unfortunately, we do not have working specifications to define adequacy for habitat protection or replacement design.

For example, the information on habitat protection for brown trout is presented in general terms like cover, adequate depth, moderate current and suitable bottom. Given this lack of specificity, it is not surprising that effective designs have not been incorporated into project planning.

However, quantitative descriptions can be scientifically developed to define precisely what comprises adequate fish habitat. Ranges and means for such parameters as water velocity, depth, and light permit design of projects which keep these parameters within an acceptable range and hence are less detrimental, or even beneficial to valuable target species such as brown trout. Measurements of habitat characteristics where trout are found need to be evaluated to determine how applicable they may be in establishing design criteria for environmental protection. How many locations in a stream would have similar habitat values yet no trout? Are there other values, as yet unrecognized, which also must be measured? Does the present list of values apply well enough to be used in planning for future water-related projects?

To answer the above questions we must examine a variety of types of stream habitat, plot the distribution of values of each parameter, and the distribution of fish in relation to the parameters. A moderate to high proportion of the fish in "desirable" sites would indicate good predictability, while few or none would indicate either poor predictability or an incomplete description of what comprises habitat. If microhabitat requirements are to be used in planning and designing water-related projects, reliability and predictability must be assured.

Problem Statement

Virtually all studies conducted to evaluate the effects of modification of trout habitat by such actions as channelization, drastic increases or decreases in flow, large additions of silt, changing the sinuousity or cross sectional shape or proportion or increasing the slope, and thus current velocity, by shortening the stream have shown a decrease in numbers of fish (Wydoski and Helm 1980). This decrease ranges from about 50 to more than 90 percent fewer fish in altered than good habitat. The very small fish usually are unable to survive in such modified habitats, so natural reproduction is greatly reduced. Very large fish can leave the modified area and compete successfully for space in better habitat. This leaves a few fish of intermediate size to occupy the remaining acceptable habitat.

Considerable emphasis is being placed on development of component suitability ranges to define the various microhabitat components important to fish. Refinement and validation of these component ranges prior to their use is essential. Definitions of the acceptable ranges of the various components will permit application in planning projects which would otherwise harm the natural habitat of these fish.

Once the hydraulic characteristics of good habitat are known, engineers can design changes to channels and rates of flow within the channels to conform to the desired characteristics. In this way project objectives can be achieved simultaneously with protection of the environment. With quantitative microhabitat definitions available, planners can determine which alternatives are least damaging to the environment, and what kinds of special treatment would provide the proper ranges of desirable microhabitat components. The objective of this study was to determine the specific microhabitat requirements of brown trout in a stream environment as a necessary first step in developing criteria for environmental protection that can be used in the design of water resource projects and the formulation of management plans.

Generalized Daily Routines for Brown Trout

Beginning at a fundamental level, what do brown trout do each day? A knowledge of their activities should lead to a better understanding of their habitat requirements. Adults feed most intensively during crepuscular periods and darkness. They are less active during daylight, spending much of their time resting in regions of low current velocity and dim light (Gosse 1981).

Subadults (sexually immature) and age 0 (less than 1 year old) fish feed during periods and/or in locations which minimize contact with the adults. Interactions between subadults and adults are usually competitive in nature, with the dominant adults merely chasing the smaller fish out of the choice feeding stations. Interactions between age 0 fish and adults may be quite different. Many adult brown trout will feed on unwary age 0 browns if the opportunity arises. As a consequence, age 0 fish and many subadults feed during daylight, occupying areas with higher light intensities than generally occupied by adults (Gosse 1981, Gosse and Helm 1979).

Such activity patterns would find adults moving from regions of low velocity, deeply shaded and often shallow water where they have been resting, into somewhat faster water to feed, and back to resting habitat again one or more times each 24 hours. Although there are no specific measurements of the distances these fish will travel between resting and feeding sites, they must be within the movement radius of the fish (Baldes and Vincent 1969), and circumstantial evidence suggests a maximum distance much less than 100 meters (Gosse 1981). Subadults occupy much the same total habitat, but by a temporal adjustment avoid direct spatial competition.

Age 0 fish have greater limitations on their habitat than do adults and subadults. Distances between resting and feeding areas must be shorter, and resting areas must have either structural complexity (interspersion of habitat components - refuges, depth, light) (Fraser and Cerri 1982) or shallow water depths where predaceous adults seldom venture (Gosse and Helm 1979).

Quantifying Habitat

Three primary elements in the process of quantifying habitat for a species are:

a) Separation of that fish population into size groups, classified according to behavioral differences,

b) Identification of the various activities which compose the daily routine for each size group, and

c) Identification of seasonal differences in their activities.

Microhabitat components measured at the sites occupied by fish describe numerically the microhabitat utilized by each size group for each of the various activities. The variation in measurements can be used to define a usable range (Voos 1981, Helm and Gosse 1982) for each activity and each age group for each component. These usable ranges illustrate the breadth of component values utilized in comparison to the total range of available component values. Microhabitat can thus be described as a range of numerical values for each component of a specific set of components. There is no evidence that the range for one component will be affected by the range selected for some other component.

In this procedure, the fish play an active role in establishing the quantitative description of their microhabitat, and subjective categorization of stream features is eliminated. There is still a subjective element in designating the bounds of usable habitat for each component, but the degree of subjectivity is reduced.

Data collected at sites occupied by fish, provide a range of values for each component for each activity over which each size group of fish was found in a number of streams. Usable microhabitat may be defined as that range of a component selected by some percentage (say 70 or 80) of the fish. Since there may be some variation in both the mean and the range of values for each component from stream to stream, component values within the range should be equally weighted in computing microhabitat values. Values outside the range should be assigned a value of zero.

Once the ranges of usable values for the important components are established, potential brown trout microhabitat may be identified by measuring the various components at intervals along cross-stream transects. Stream means, i.e., mean depth and mean velocity for locations on a transect do not describe the microhabitat actually occupied by the trout. To be applicable, measurements must be made at depths in the water column similar to those occupied by fish, and related to fish size and activity. A limited number of components, measured in this fashion, may be adequate to describe brown trout microhabitat.

Predicting Brown Trout Distribution From Microhabitat Measurements

With the usable ranges for depth, fish velocity and light which had been developed by measuring microhabitat occupied by fish in four rivers in two river systems (Table 1 and Appendix), the utility of a component map to predict correctly the distribution of brown trout can be tested. A 90 m section of the Blacksmith Fork River in northern Utah was mapped, utilizing a transect spacing of two meters in reaches of non-uniform conformation, and four meters where the channel section was relatively uniform. Total stream depth and current velocity and light intensity at fish depth were measured at half-meter intervals along each transect. Maps were then constructed depicting the areas usable for resting and for feeding trout (Gosse 1981). Usable habitat components were depths greater than 20 cm, current velocity less than 24cm sec^{-1} (for resting trout) and less than 45 cm sec^{-1} (for feeding trout), and light intensities less than 5 percent of incident (for resting trout) and less than 50 percent (for feeding trout). Upper limits for fish velocity and light ranges were the mean plus one standard deviation (Table 1).

A modified scuba technique (Gosse and Helm 1982) was used to locate brown trout in the reach of stream studied. A series of 15 dives over a 35 day period insured coverage of all parts of the area. Stream discharge varied little during this period. Some 116 brown trout were observed and measured at 68 locations. The same component measurements mentioned above were made at the location of each fish sighted. Fish locations for various activities and fish sizes were then transferred to maps. Finally, fish location maps were overlayed on maps of depth, current velocity and light intensity.

Table 1. Mean values with standard deviations ( ) for selected components describing adult brown trout microhabitat in the Logan and Provo River systems.[a,b]

	Activity		
Component	Logan Feeding	Provo Feeding	Logan Resting
Sample size	20	57	222
Fish velocity (cm/s)	21 (7.8)	30 (15.1)	15 (9.4)
Mean velocity (cm/s)	43 (25.3)	43 (22.9)	27 (16.6)
Water depth (cm)	106 (28.1)	168 (77.0)	88 (62.5)
Overhead light (% full sunlight)	7.4	13.0	1.2
lower	5	10	0.01
upper	50	50	5

[a]Overhead light is presented with the upper and lower 80 percent range.

[b]From Gosse 1981.

Most fish observed were in areas identified as usable habitat (Figure 1). Predicting usable microhabitat from usable component ranges is not expected to be perfect. Usable microhabitat, as used here, is within the range of a component selected by a large majority of the fish observed; some fish choose sites outside the range.

Examination of the components measured at sites occupied by resting brown trout compared to component values previously mapped for those sites (Table 2) indicated that a high percentage of the sites occupied by brown trout were identified as usable habitat on the map, but other sites shown as unacceptable on the map proved acceptable according to measurements made at fish sites. Seventeen of 19 occupied sites were in usable component ranges for resting trout, although only 14 of those 19 sites were so mapped. Thus the map showed 5 of 19 sites (26%) in unusable microhabitat, when in reality only 2 of 19 (11%) were so situated, for a mapping error of 3/19 or 16 percent. The incorrectly identified sites were situated between transects, and an increased mapping intensity would be required to reduce this error.

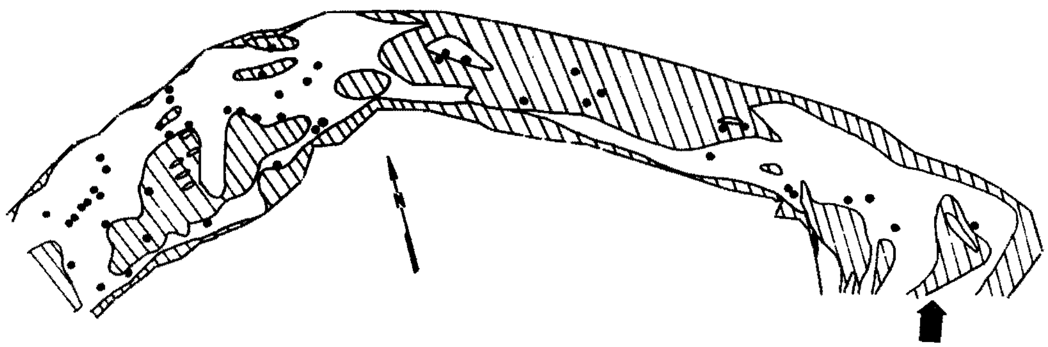

Figure 1. Feeding brown trout locations (dots) in the Blacksmith Fork, Utah. Hatched areas represent regions where depth, velocity and/or light were outside the defined suitable ranges.

Altogether 45 of 49 sites occupied by feeding trout were in usable component ranges, although only 37 of the 49 sites were so mapped. In this case the map showed 12 of 49 sites (25%) in unusable microhabitat, when by measurement only 4 of 49 (8%) were so situated, for a mapping error of 8/49 or 16 percent. For both resting and feeding fish, mapped microhabitat components correctly identified brown trout locations with an accuracy of 84 percent.

There is the possibility that fish were not actually selecting locations based on microhabitat component values, but instead were located randomly in the stream, in proportion to the amount of usable and unusable microhabitat. A chi-square test of the hypothesis that sites were distributed uniformly in the study area, that is, proportionally in both usable and unusable microhabitat, was significant ($p < 0.01$) for both feeding and resting sites (Table 3). This indicates that random distribution is very unlikely.

Table 2. Habitat components at sites occupied by brown trout compared to components as mapped at those locations.

RESTING

Current Velocity cm sec^{-1}	Light: 0-5 % of incident	Light: above 5% of incident
0-24	14/17[1]	4/1
Above 24	0/1	1/0

FEEDING

Current Velocity cm sec^{-1}	Light: 0-50% of incident	Light: above 50% incident
0-15	15/20	1/1
16-30	12/20	1/2
31-45	10/5	2/0
Above 45	5/1	3/0

[1]Values above the diagonal line are the number of occupied sites which were located in the designated component ranges on the map; below the line the number of occupied sites which were located in the designated component ranges according to measurements at each site regardless of map location. Usable microhabitat values are underlined. All fish were in usable depths.

Table 3. Comparison between distribution of brown trout and of usable and unusable habitat.

Activity	Chi-Square	P
Feeding	31.2	less than .01
Resting	98.9	less than .01

Increasing the resting fish velocity and light ranges by as little as 6 cm/second for current velocity and 20 percent for light would change the classification of three (16%) fish locations. Increasing the ranges for feeding fish by 6 cm/second for current velocity and 15 percent for light would change the classification of 7 (14%) fish locations. Thus the ranges of the physical components which are considered usable have a marked effect on the extent of the area classified as usable habitat.

According to the usable ranges, a portion of the depth and current ranges occupied by resting trout are also satisfactory for feeding trout. Light ranges however do not overlap. Fish were seldom found feeding in resting microhabitat. Areas of both very low current velocity and light intensity, typically close to the stream bank where brushy vegetation extended closely over and often into water of 20 cm or more in depth are ideal resting microhabitat.

Brown trout were not uniformly distributed throughout the microhabitat classified as usable. This may indicate that some unmeasured component influences selection of sites within usable areas. We do not yet know enough about the utilization of habitat, and the affect of small differenes in component values to explain this.

Feeding and resting microhabitat in two contrasting sections of river were compared. The area discussed above was section one, and a nearby area 56 m long was section two. Section one had 8.2 percent resting microhabitat, 59.3 percent feeding microhabitat and a trout population density of 726 fish larger than age 0 per 160 m of stream. Section two had no resting microhabitat, only 11.8 percent feeding microhabitat and a trout density of 101 per 160 m. The combination of five times the amount of feeding microhabitat plus an apparently adequate amount of resting microhabitat supported a population density seven times greater in section one than in section two.

Implications

It is clear that brown trout selectively occupy and utilize a predictable portion of the total range of microhabitat components available to them. Further, given reliable suitability ranges, microhabitat components can be measured in a stream to determine the amount of usable habitat. If such evaluations are performed on streams where population densities are known, a relationship between the proportion of usable area and fish density can be derived.

The applicability of suitability ranges derived from one region for use in another is not yet known. To be generally useful such information should be widely applicable, but considerable variability from region to region, or stream type to stream type would decrease the accuracy of evaluation in any one region or stream type. Such a determination must await further testing.

The mapping procedures described here, such as two meter spacing between transects, would not be suitable for practical applications. Some practical projections can be made, however. Spacing transects more than 10 meters apart produced maps with insufficient detail to identify accurately the microhabitat between transects, as did spacing measurements at more than two meter intervals along transects on this 13 meter wide stream. Transect spacing was not critical for calculating the amount of usable habitat however, so long as a sufficient number (five or more) of randomly selected transects was used, because such sampling utilizes only information on the transects and the area between transects is ignored.

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In addition the Instream Flow Group of the U. S. Fish and Wildlife Service in Fort Collins has issued electivity curves and tables of parameter values related to a number of species of fish, including brown trout.

APPENDIX

Table 1. Mean values for selected parameters describing brown trout microhabitat in the Logan and Provo River systems.[a]

ADULT

	Logan River		Provo River
Parameter	Feeding	Resting	Feeding
Sample size	20	222	57
Fish velocity (cm/s)	21	15	30
Water depth (cm)	106	88	168
Overhead light (% full sunlight)	7.4	1.2	13.0
range-lower	5	0.01	10
range-upper	50	5	50

SUBADULT

Sample size	52	78	88
Fish velocity (cm/s)	24	9	24
Water depth (cm)	77	71	189
Overhead light (% full sunlight)	4.6	3.2	8.4
range-lower	5	0.05	5
range-upper	10	50	50

AGE 0

Sample size	76	41
Fish velocity (cm/s)	18	6
Water depth (cm)	73	47
Overhead light (% full sunlight)	20.0	4.2
range-lower	5	.05
range-upper	50	50

[a]Overhead light is presented with the upper and lower 80 percent range.