ALBINO BROOK TROUT, LITTLE BEAVER CREEK, SEPTEMBER 1966

THESIS

PHYSICAL MICROHABITAT OF TROUT

Submitted by

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In partial fulfillment of the requirements

for the degree of Master of Science

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ABSTRACT OF THESIS

PHYSICAL MICROHABITAT OF STREAM TROUT

The physical microhabitat of stream-dwelling fishes is relatively unknown. Work done with albino brook trout suggests the operation of a previously unreported scheme of fish habitation, the focal point concept. This concept is expressed in focal point residency and in movements away from the focal point. Both focal point and movements have quantitative parameters. Each focal point is a relatively small area representing less than 3% of the area over which the fish ranged. During a 50 day study period, an average of 15% of each study section was utilized 95% of the time. Most focal points had a slow water area (0.33 ft./sec. average) overlain by a swift water mass (0.86 ft./sec. average). Study fish occupied the slow water area almost exclusively with the exception of occasional, short (time) trips into the swifter layer. All focal points show a high spatial correlation with cover. A high percentage of time (94%) was spent in shaded areas.

Movements are characterized by the occupation of small amounts of time (6% of all observational time) and relatively large areas of the stream (up to 25% of the available stream area). A large percentage of the movements (66%) go away from and directly back to a focal point.

Results from a number of one-way analysis of variance computations indicate important relationships between overlying physical factors and the microhabitat chosen by study fishes.

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INTRODUCTION

The necessity for an animal to exist in an environment is a primary biological consideration. An extensive number of environments are used for animal habitation, but none is as unique as the inland stream. A continually moving water mass presents an environment requiring specific adaptation. An important family of stream associated fishes is the Salmonidae. Few of these fishes fail to encounter inland streams during some phase of their life history. In the Rocky Mountain states, where streams are plentiful, trouts are important because they often represent the highest trophic level. Of the trouts, perhaps none is more well known than the ubiquitous brook trout (*Salvelinus fontinalis* Mitchill). Because of the importance and availability of the brook trout, it was chosen to be the study animal for this project.

Inland streams exhibit wide variability in physical and chemical characteristics. This is reflected in the streams' being open ended in terms of energy dynamics. The stream serves as an energy transport system through terrestrial ecosystems, and reflects the physio-chemical characteristics of those ecosystems. Chemical characters vary with the rock composition and terrestrial productivity of the drainage basin. The volume of water carried is dependent upon rain, snowmelt, and ground water. These variables produce fluctuations in the stream ecosystem that are both cyclic and unpredictable. Snowfall causes seasonal and diurnal cycles while rain storms produce irregular changes. Ground water provides base flow but may experience historical variations.

The combined influences of gradient and water volume overlie all other channel characteristics. However, in any specific situation, substrate distribution, cover formation, water depths, and water velocities are all dependent upon water volume. In addition, water temperature is functionally related to the water source of the stream. Thus, the total environment of a stream trout is subject to the variations of a single environmental factor. Despite a variable environment, stable assemblages of organisms exist and prosper in streams (Minckley, 1963). One of the major factors allowing community stability in a fluctuating environment is the concept of microhabitat.

The spatial plasticity of salmonid fishes is noted by Chapman (1966). Chapman presented data showing the influence of environment quality upon population numbers. This plasticity implies that spatial tolerance limits of salmonids are wide, but the limits are real. Tolerance ranges are the basic facets of the microhabitat concept. Microhabitat is a fairly recent term (Allee, et. al., 1949) that defines the exact geographic location and conditions where an animal lives. It partially represents the term niche when niche is used in the sense of geographic location. A complete microhabitat description for a particular species should include tolerance limits for all environmental factors in a given situation. Microhabitat is not only a good concept to use in the study of the environmental relationships of individual animals in natural situations (Odum, 1959), but it also accounts for the individuality of streams. Although this paper is concerned with brook trout, the importance of the microhabitat concept to stream invertebrates has been documented (Cummins, 1964).

Fishery investigations have tended to follow a gross approach utilizing population dynamics and community relationships. Although these population and community approaches have been productive, a consideration of the activities of individual fish is needed to explain numbers and fluctuations. Microhabitat studies show promise of delineating the quantitative aspects of habitat choice by fish. Knowledge of this nature would help to explain habitat variables as recorded by Peters and Alvord (1964) and Lewis (1967). Peters and Alvord found that man-altered stream channels were much less suitable as trout habitat than natural, meandering channels. Lewis tried to establish the physical factors governing trout habitation in stream pools and found different factors to have importance for different trout species.

Another recent trend in fisheries has been home range investigations. Home range is microhabitat experienced over a defined length of time. However, the quantitative definition of home range for trout has yet to be formulated. The closest approach to microhabitat research was reported by Miller (1958). By showing that a stream can be locally saturated with cutthroat trout (<u>Salmo clarkii</u> Richardson), Miller acknowledged the presence of spatial limits. Miller also implied that the study of individual fish would be beneficial. This benefit is to elucidate previously formed concepts of stream communities.

The specific purpose of this study was to gather basic information on the physical microhabitat occupied by brook trout. No attempt was made to experimentally assess the biological reason for the microhabitat characteristics. Interspecific and intraspecific competition was limited by fish removal, so that the study fish could potentially utilize any part of the environment. The relative simplicity of measuring the physical environment coupled with a scarcity of literature on the aquatic microhabitat were the determining factors for the choice of the physical microhabitat. A small stream was chosen for three reasons: (1) to enhance the chances of visual observation, (2) to simplify measurement of the environment, (3) to further knowledge of small stream ecology.

LOCATION OF STUDY

This investigation took place in Little Beaver Creek (T7N, R73W, 6^{th} P Mer.) a tributary to the Little South Poudre River. Little Beaver Creek is 26 miles west of Fort Collins, Colorado, on the east slope of the Rocky Mountains. The watershed area is 18.11 square miles, and permanent stream length is 12.2 miles (Miller, 1966). The stream rises at an elevation of 10,800 ft. and enters the Little South Poudre at 7,900 ft. The stream gradient is 7.5%. The study area is 2.6 miles upstream from the mouth at an elevation of 8,350 ft. During the sampling period, the mean daily discharge was 3.5 c.f.s., the maximum daily discharge was 9.2 c.f.s., and the minimum daily discharge was 2.0 c.f.s.

METHODS AND MATERIALS

A study involving movements of individual fish must have a method of ascertaining the position of the study animal. A literature review revealed no practical instrumental method of fish location with the precision needed for this study. Visual location by the observer was concluded to be the simplest and most accurate observational technique.

Although the study had originally been designed to utilize the natural fish in Little Beaver Creek, these fishes were difficult to see well enough to locate and follow movements because of protective coloration. A series of experiments was conducted using various dyes and tags in an attempt to make the natural fishes more visible. However, no satisfactory method of color alteration could be found that rendered the fish more visible without reducing physiological condition.

Albino brook trout were then chosen as study animals. One hundred of these fish were obtained from the Saratoga National Fish Hatchery in Saratoga, Wyoming, in October, 1965. The albino fish had an average length of 8.5 inches and were comparable in size to four-year-old brook trout in Little Beaver Creek (Miller, 1966). However, the albino trout were only one-year old. Although albinism is unnatural to the species and the hatchery fish unnatural to the stream, the overwhelming value of visibility compensated for these faults. The albino trout were from an inbred strain and were as genetically similar as any fish population. The genetic homogeneity served as a control in this study. Limitations imposed upon extrapolation from these fish to natural fish and from individuals to populations must be clearly recognized.

The study site (2,836 ft. long) was bounded by a United States Geological Survey weir upstream and small rapids downstream. The site was marked with stakes every 100 ft. starting at the downstream limit. At the upper and lower extremeties of the study site, 500 ft. neutral (fish-free) barriers were incorporated. These barriers were intended to reduce fish movement into the study area, but because of high population levels in Little Beaver Creek (Miller, 1966), migration resulted. The upper 56 ft. of the site were dammed and made into a deepened pool in which albino trout stock and other experimental fishes were kept. Tagging and dyeing experiments were carried out in this pool. All fishes were removed from the study site by electrofishing in September, 1965. In June, 1966, the study site was electrofished again. Because of the many fish recovered on this occasion, electrofishing was carried out periodically thereafter.

Forty albino trout were stocked in the middle 1,000 ft. of the study site at the rate of 4/100 ft. in October, 1965, and they were allowed to overwinter. Eleven of the original forty were recovered in June, 1966, and returned to the study site. A census was maintained for two weeks to find the areas occupied by albino trout. Initially, four areas (one fish/area) were found and later introductions added a fifth. Due to a seemingly delicate imbalance in population density pressures, many of the fish moved downstream out of the study site.

During the preliminary collection of data, the fish were observed using some areas much more extensively than others. Originally, this area was referred to as the resting area, but the anthropormorphic associations of this term were unjustifiable. The area was then renamed the focal point because the fish seemed to use it as a central place.

Aside from the focal point, there were also movements occurring outside of the focal point. These are simply referred to in this paper as movements. The focal point and associated movements are combined in the focal point concept (synonymous with microhabitat concept).

When the areas of fish residence were ascertained, each was mapped to facilitate data collection. Known limits of movement represented the upstream and downstream boundaries of the study sections. Standard surveying techniques were used to map the study section. Transects were established at 5 ft. intervals along the base line. At 1 ft. intervals along each transect, the depth, surface velocity, and velocity near the bottom were measured. The measurement of water velocities was done with a Pygmy Gurley instrument. All visible morphological features were included. A relatively simple scheme was used to denote bottom type. Because of the lack of large rocks, the two major bottom types were rock (1-4 inches diameter) and sand. In addition, measurable areas were present where intergrades existed, but one type predominated. These areas were called rock-sand and sand-rock. Mapping was at three levels of water flow.

The study sections (stations) exhibited different morphometric characteristics (Table 1). Each had specific flow patterns caused by differences in channel morphology. Study section 1 consisted of a large eddy and a swift shallow area. A log jam and a submerged log provided cover. Section 2 was characterized by three large rocks in the center of the stream. These rocks created patterns of swift water interspersed with low velocity pockets. Section 3 had turbulent surface waters and several submerged logs. Section 4 was comparatively uniform with high

Table 1. Study Section Characteristics

Character	Section				
	1	2	3	4	5
Length - ft.	20.	20.	20.	25.	22.5
Max. Width - ft.	11.5	12.	13.	11.	16.
Average Area - sq. ft.	129.3	167.8	210.1	185.5	237.7
Max. Sunlight - %	75.	50.	25.	25.	25.
Rock Bottom - %	45.	45.	45.	40.	50.
Rock-Sand Bottom - %	5.	25.	10.	30.	15.
Sand-Rock Bottom - %	5.	25.	20.	20.	15.
Sand Bottom - %	45.	5.	25.	10.	20.
Orientation - compass	S to N	SW to NE	W to E	W to E	W to E

current velocities. Section 5 represented the most diverse environment. A large eddy and several submerged logs offered a variable habitat.

Ninety hours of usable observation were accumulated. Data were collected by ten-day periods with 18 hours of usable observation per period. A schedule of two-hour observational periods, beginning at sunrise was used to relate time to day length. Eight two-hour periods covered the daylight hours on all days. An attempt was made to have each sampling period last 2 hours. Water volume data were obtained from the USGS weir at the upper end of the study site. The amount of cloud cover and type of cloud cover was estimated at the start of each observation period. These data were later used as indications of weather. Observations were conducted during all four moon phases. A recording thermograph was maintained just above station 1. Polaroid sunglasses were used to cut glare and surface distortion. The principal investigator collected 70% of the data while an assistant collected 30%.

To make a sample, the observer would carefully approach within 10 ft. of a study section. Movements of the study fish were then recorded on a replicate map (Figure 1) of that particular study section. Distance and area measurements were a combination of observer judgment and mapping. The critical linear distance outside the focal point that could be measured in this manner was 1 ft. Distances around focal points could be measured to an accuracy of 0.5 ft. because of the proximity and number of landmarks (cover). Data are prejudiced toward maxima because a movement was not recorded as a linear distance but as an area (the distance times 1 ft.). Focal points were also noted as areas.

Data compiled from field forms and replicate maps were translated into quantitative values. Because the microhabitat is essentially a concept of limits, not all of the data collected were used in this paper. Only logical expressions of delimitation were used. All data except index values and movement class values are computed by focal point rather than observation period. Compiling the data by focal point made analysis more flexible.

Some of the study fish used as many as four focal points concurrently. All focal points shared two common characteristics:

(1) fish left and returned to area two or more times during observation period.

(2) fish occupied area for at least 10 minutes during observation period.

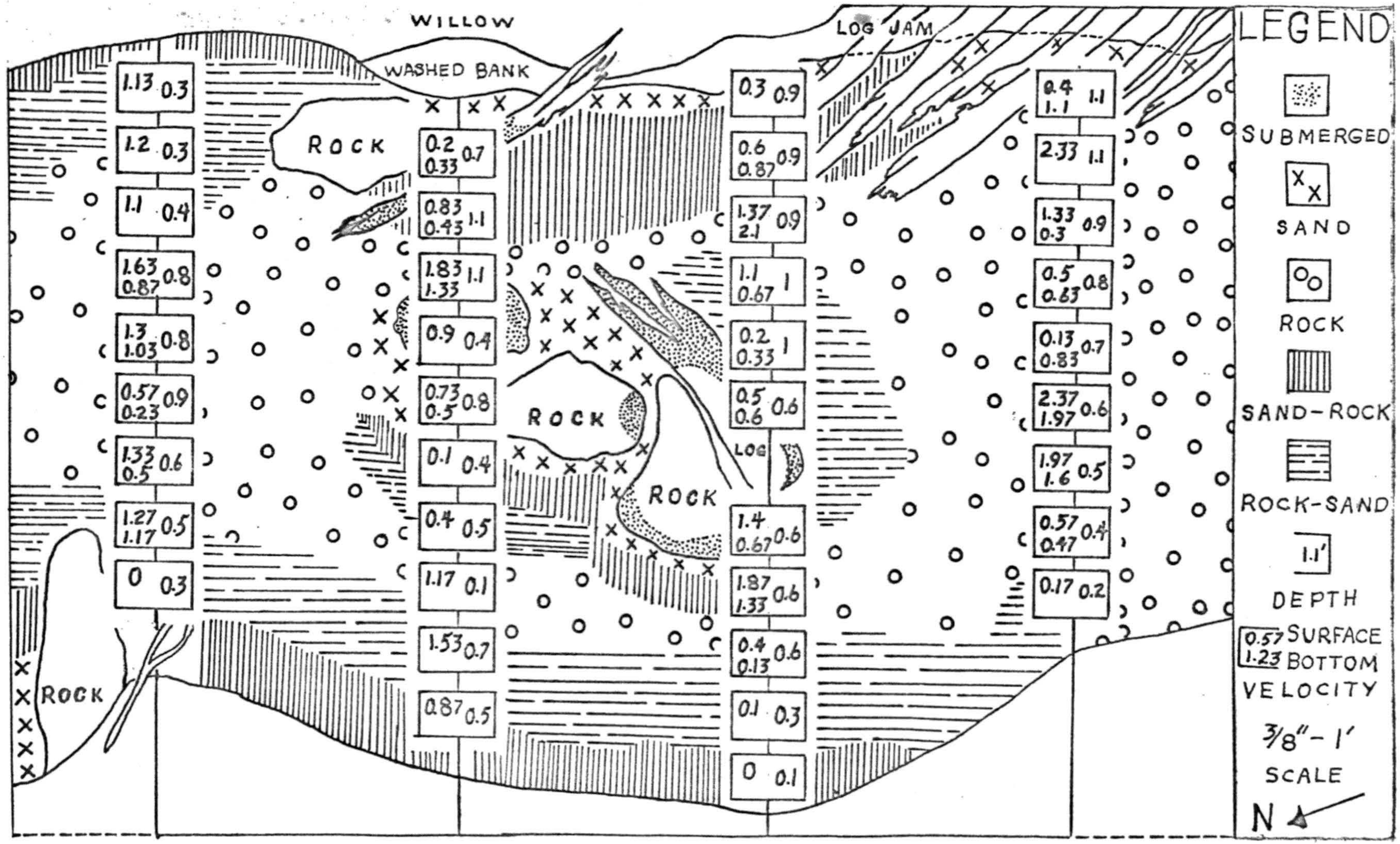

Figure 1. Replicate Map of Study Section 2.

However loose these rules may seem, only a limited area in each station was used for focal points. Occupation of more than one specific focal point area is attributed to reduced competition for space in the study sections.

The focal point is represented in the data analysis as an area measurement. This, of course, assumes that the study fish occupied a single water stratum. Although this assumption is basically untrue, it is functionally correct for the fish spent most of the time in the focal point near the stream bottom. Only in the case of eddy focal points is area an unwieldy term. In addition, few water depths over 1 ft. were recorded in the study sections. This makes area and volume subequal at most focal points. Area also allows less complicated data manipulation in the field.

Focal point location was noted on a station map. Each time a movement or a focal point entry was made the time of day was recorded. From these data, the percentages of time spent in movements and in focal points were obtained.

To express focal point velocity, only maximum and modal velocity were used. Modal velocity is the velocity of the specific location within the focal point most frequented by the study fish. Maximum velocity is the swiftest current passing over, by, or through the focal point. High velocity currents are potential food transport mechanisms. Although the study fish spend little time in these swifter places, they are essential to the focal point concept.

Depth introduces a third dimension of channel morphology that was included in data collection but was conceptually ignored. The shallowness of Little Beaver Creek precluded the use of maximum depth values.

Therefore, focal point depth is represented by minimum and mean depth values. Fish habitation generally occurred at the bottom of the stream. Mean depth is the average of the various depths in the focal point. Minimum depth is the shallowest part of the focal point.

The station mapping criteria were used to classify bottom type of focal points.

Sunlight relationships were recorded on the basis of absence or presence of the fish in a given light condition. No light measuring instrument was used, and the light conditions presented are judgment values. In the focal point, only three light conditions were recorded: (1) sun-shade, (2) shade-sun, (3) shade.

Movements consisted of two parts, the movement proper and the destination. The destination could be called a sub-focal point because it represented a stopping point from which a fish could make another movement or return to the focal point.

Movements were typed in two ways: (1) direction with respect to current flow, (2) objective. Direction of movement away from the focal point is expressed as four types:

(1) downstream and downstream across-stream (A)

(2) upstream and upstream across-stream (C)

(3) across-stream (E)

(4) circular (F)

Only the percentage of time spent in each type is analyzed.

Movement classes express the objective reached through an individual movement. Four classes are possible when two focal points are successively used. These are:

(1) class 1 - focal point one to destination one to focal point one

(2) class 2 - focal point one to destination one to destination two, to focal point one

(3) class 3 - focal point one to destination one to destination two to focal point two

(4) class 4 - focal point one to focal point two

The major consideration is the percentage of time spent in these movements.

Spatial considerations of movements were recorded as areas. Movements were swift, single plane actions that can be properly referred to in terms of area. As mentioned previously, spatial factors were maximized by recording movements as foot-wide paths. Two area measures were used to describe the movements. The first, mutually exclusive area (MEA), connotes the entry of the fish into a previously unused portion of the stream during each focal point occupancy. That is to say, the MEA represents "new" territory entered, but "new" territory only in terms of what had previously been used during the same temporal focal point occupancy. The second, total area, includes all movement areas whether or not they are repetitious. Four identical movements might be made during a single focal point occupancy, but only one of these movements could be included in the MEA while all four movements should be included in total area. MEA is thought to be tied with investigative behavior while total area is an excellent indicator of activity. Time in hours spent moving, percentage of time spent moving, and average time per trip in minutes adequately express temporal considerations of movement. The number of movements per focal point gives meaning to temporal and spatial factors.

Delimitations of water velocity are represented both in the movement proper and in the destination. For movements proper, data on the maximum velocity and mean velocity encountered are presented. Only modal velocity is included for the destination. The mean velocity of movement and the destination modal velocity represent conditions actually encountered by the study fish. Maximum velocity is the highest velocity possibly encountered by the study fish during movement.

To adequately express depth factors, minimum and mean depth were recorded for the movement proper. For the destination depth description only mean depth is used.

Bottom type and sunlight relationships were noted only at the destination. Station mapping criteria and focal point concept were used to describe these features.

An index is useful to compare values directly. Five different indices were formulated and compared by observation period. All of the indices were computed using the same general formula: (x area/total area of the study section)/(percentage of time spent in x area). The indices were the focal point area index, the movement MEA index, the movement total area index, the overall MEA index (focal point and movement combined), and the grand total area index (focal point and movement combined). The index values carry meaning by themselves and also supplement the other values presented.

DATA ANALYSIS TECHNIQUES

Eleven "independent" variables were used to compare the previously mentioned characteristics of the focal points and movements. None of these variables were guides by which the data were collected while two were computed from the data themselves. Five study sections were utilized. Five ten-day periods covered the field portion of the study (July and August, 1966). Eight two-hour periods adequately expressed the light hours of a day. Four phases of the moon are represented in the data analysis. Four weather types by cloud cover were used: (1) clear, (2) less than one-half cloudy, (3) greater than one-half cloudy, (4) overcast. Water temperature data were divided into two categories: at start of observation period, and the change during the observation period. The four classes in the water temperature at start category were (1) 45-49° F, (2) 50-54° F, (3) 55-59° F, (4) 60-65° F. In the water temperature change category, the three classes were: (1) gain, (2) loss, (3) no change. The water volume data were divided into three classes: (1) 2.1 c.f.s. to 3.69 c.f.s., (2) 3.7 c.f.s. to 5.29 c.f.s., (3) 5.3 c.f.s. to 6.89 c.f.s. Mapping measurements were made at volume classes 1 and 3, and interpolation was used to obtain map values for class 2. Bottom type of the focal point and the number of focal points were taken from the data.

All logical combinations of "independent" and dependent variables were compared in one-way AOV (Analysis of Variance) computations using a Colorado State University computer center program and an IBM 1401 computer. Means, standard deviations, and variances were also obtained using this program. A total of 600 one-way AOV computations were done.

PRESENTATION OF DATA

Mean values for focal point characteristics, movement characteristics and index values are presented by study section. Because the study section is the major experimental unit, mean values have the most comparability by study section. These data are derived from a natural situation, and the variance components are large. This is reflected in the large standard deviations. The significant F values from the one-way AOV computations are analyzed. In the presentation of the AOV data, judgments were made in the assessment of relative importance of F values in those cases where more than one "independent" factor showed significance. This is done only on the basis of the information collected. No attempt is made to present the factors of ultimate importance because this is beyond the scope of the study.

Mean Values

Focal Point

The mean values for focal point characteristics are listed in Table 2.

The most striking feature of the focal point is the great amount of time spent in a small area. Percentages of time spent range from 92 to 96 with an average of 94. These high percentages of time were spent in areas representing less than 3% (average 3.1 sq. ft.) of each study section. To further stress focal point usage, only 10% to 18% of the study section areas were used over time (Table 3). That is, over the 50 day study period, 15% of each study section was utilized 94% of the time. All of the focal point areas had a high spatial correlation with cover

Table 2. Focal Point Attributes

Character	Station 1		Station 2		Station 3		Station 4		Station 5		Average
	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	
Area - Sq. ft.	3.1	1.1	3.1	1.2	3.1	1.3	3.1	1.3	2.9	1.8	3.1
Time - hours	1.19	0.70	0.96	0.52	1.04	0.79	1.34	0.71	0.98	0.72	1.10
Time - %	96.	6.	93.	11.	95.	8.	96.	7.	92.	13.	94.
Max. Velocity - ft./sec.	0.82	1.10	0.93	0.56	1.20	0.56	0.76	0.23	0.61	0.56	0.86
Modal Velocity - ft./sec.	0.06	0.15	0.41	0.21	0.53	0.26	0.39	0.16	0.26	0.19	0.33
Min. Depth - ft.	0.47	0.18	0.65	0.26	0.63	0.20	0.27	0.21	0.52	0.25	0.51
Mean Depth - ft.	0.57	0.15	0.76	0.21	0.74	0.18	0.37	0.17	0.71	0.21	0.63
Rock	0.	0.	17.	15.	63.	25.	29.	24.	18.	15.	25.
Rock-Sand Bottom - %	13.	12.	39.	25.	5.	5.	29.	24.	11.	10.	19.
Sand-Rock Bottom - %	12.	12.	39.	25.	16.	14.	29.	24.	14.	13.	22.
Sand Bottom - %	75.	20.	5.	5.	16.	14.	14.	14.	57.	25.	34.
Sun-Shade - %	6.	6.	0.	0.	0.	0.	0.	0.	7.	7.	3.
Shade-Sun - %	13.	12.	0.	0.	0.	0.	0.	0.	4.	4.	3.
Shade - %	81.	16.	100.	10.	100.	0.	100.	0.	89.	10.	94.

Table 3. Composite Focal Point Usage

Station	Percentage of Study Section Area Utilized
Station 1	18.
Station 2	14.
Station 3	16.
Station 4	10.
Station 5	17.
Average	15.

features in the stream. Focal point areas were associated with large rocks, turbulent suface waters, and submerged logs. The extensive usage of small areas and the observed cover relationships substantiate the results of habitat and home range studies.

To make optimum use of a habitat it is essential that minimum effort be rewarded with maximum gain. In the case of albino brook trout, this was achieved by selection of water velocities. Although trout are streamlined, swift water still requires large energy expenditures to maintain position. At the same time, more drift food should be carried by swift currents. The optimum place would be an area with both slow and swift currents so that the fish could spend most of its time in the slow current with occasional trips into the fast current. This essentially describes the observed focal point water velocities. Modal velocities ranged from 0.06 ft./sec. to 0.53 ft./sec. with an average of 0.33 ft./sec. Maximum velocities ranged from 0.61 ft./sec. to 1.20 ft./sec. with an average of 0.86 ft./sec. In most cases the averages accurately represent individual observations. The major exceptions were eddy focal points in which the water column was both slow and uniform. In all cases the modal velocities were recorded near the stream bottom with the swifter water mass moving above.

Little Beaver Creek is relatively shallow with a maximum depth in the study site of 1.3 ft. The minimum and mean depths encountered at each study section reflect this uniformity more than they show fish choice. Minimum depth means ranged from 0.27 ft. to 0.65 ft. while mean depth means varied from 0.37 ft. to 0.76 ft.

Bottom type of the focal point reflects available substrate usage in contrast to fish preference. Station 3 had maximum rock bottom usage and station 1 had no rock bottom usage. In contrast, station 1 had 75% sand bottom usage while station 3 was among the lowest for sand bottom usage. Although availability of bottom type is quite important, cover relationships and water velocities interact to determine focal point site. Thus, correlations between study section bottom type and focal point bottom type are vague. In terms of overall averages, sand is the most used substrate (34%), rock and sand-rock are semiequal, and rock-sand is the least used substrate (19%).

The preferred sunlight relationship in all cases was shade. Mean percentages of shade usage varied from 81% to 100% with an average value of 94%. Photonegative responses have been recorded by other investigators for young rainbow trout (<u>Salmo gairdnerii</u> Richardson) (McCrimmon Kwain, 1966) and for young brook trout (Gibson and Keenleyside, 1966) and are well known in adult trout. Albino trout lack eye pigmentation and have an increased sensitivity to light.

Movements

The movements (Table 4) represent radiations from the focal point areas that serve to increase stream usage. The movements probably were feeding actions, investigative behavior, and travel to other focal points. Because the movements often involved travel across areas where there was little cover, the movement is the part of the microhabitat where the fish has the least protection from predation. Much of the movement data is expressed in numbers per focal point rather than numbers per time. This is a logical continuation of the use of focal point as the major factor of data collection.

Relatively small amounts of time were spent in moving. This is a reflection of the large time periods spent in the focal point. The mean number of movements varied from 3.93/focal point in station 1 to 2.00/ focal point in station 4. The average number of movements/focal point was 3.06. These movements occupied mean time periods ranging from 0.11 hours in station 2 to 0.05 hours in station 4 with an average of 0.08 hours. Time percentages were correspondingly low with a high value of 8 in station 5 and a low value of 3 in station 1. The average percentage of time spent in movement was 5. Another facet of time consideration is the average time per trip. A high mean value of 1.52 min. was recorded in station 2 while the low mean value of 0.77 min. occurred in station 1. The average value was 1.08 min. When movements occurred, they covered relatively large stream areas. While a single focal point area averaged 3 sq. ft. (less than 2% of stream area), the average MEA per trip was 9.8 sq. ft. (approximately 5% of stream area). In addition, total area covered averaged 27 sq. ft. or more than 13% of

Table 4. Movement Attributes

CHARACTER	STATION 1 mean	STATION 1 SD	STATION 2 mean	STATION 2 SD	STATION 3 mean	STATION 3 SD	STATION 4 mean	STATION 4 SD	STATION 5 mean	STATION 5 SD	AVERAGE
Time - hours	0.08	0.11	0.11	0.19	0.06	0.10	0.04	0.08	0.08	0.19	0.08
Time - %	4.	6.	7.	11.	4.	8.	4.	7.	8.	13.	5.
Average Time/Trip - min.	0.77	0.82	1.52	2.23	1.06	1.59	0.83	0.52	1.20	1.42	1.08
MEA - sq. ft.	8.	12.	8.	10.	11.	13.	8.	10.	13.	15.	10.
Total Area - sq. ft.	31.	55.	34.	42.	22.	29.	19.	26.	30.	31.	27.
Number of Movements	3.93	6.91	3.55	3.97	2.68	3.04	2.00	2.52	3.14	2.61	3.06
Max. Velocity - ft./sec.	1.24	1.17	1.59	0.49	1.37	0.34	1.34	0.37	1.30	0.59	1.37
Mean Velocity - ft./sec.	0.30	0.21	0.70	0.21	0.71	0.26	0.46	0.13	0.57	0.25	0.55
Destination Modal Velocity ft./sec.	0.06	0.08	0.46	0.14	0.44	0.19	0.30	0.10	0.38	0.22	0.33
Min. Depth - ft.	0.47	0.18	0.51	0.23	0.58	0.24	0.28	0.21	0.44	0.30	0.46
Mean Depth - ft.	0.70	0.07	0.82	0.10	0.75	0.19	0.48	0.06	0.80	0.18	0.71
Destination Mean Depth ft.	0.70	0.18	0.83	0.16	0.79	0.23	0.47	0.07	0.82	0.19	0.72
Sun - no./focal point	1.00	2.41	0.08	0.28	0.00	0.00	0.25	0.50	0.11	0.42	0.29
Sun-Shade - no./focal point	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shade-Sun - no.	1.36	4.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27
Shade - no.	3.09	5.44	3.85	3.8-	3.33	3.09	3.25	2.22	2.59	2.32	3.22
Rock Bottom - no.	1.91	3.18	1.54	1.39	2.67	2.74	1.75	1.26	1.44	1.74	1.86
Rock-Sand Bottom - no.	0.18	0.60	0.15	0.38	0.13	0.52	0.25	0.50	0.07	0.27	0.16
Sand-Rock Bottom - no.	1.09	2.43	1.76	1.54	0.27	0.59	0.50	1.00	0.11	0.42	0.75
Sand Bottom - no.	2.45	2.54	3.55	3.97	2.68	3.04	2.00	2.52	3.14	2.61	3.06
A & B - %	64.	48.	42.	43.	45.	42.	10.	8.	39.	43.	40.
C & D - %	32.	46.	53.	44.	43.	44.	85.	18.	42.	47.	51.
E - %	1.	3.	1.	3.	11.	26.	5.	10.	18.	33.	7.
F - %	3.	7.	4.	11.	1.	6.	0.	0.	1.	5.	2.
Class 1 - %	74.	39.	58.	49.	81.	3.	55.	52.	60.	38.	66.
Class 2 - %	10.	25.	15.	33.	12.	30.	20.	40.	17.	28.	15.
Class 3 - %	3.	8.	18.	40.	3.	10.	0.	0.	17.	34.	8.
Class 4 - %	13.	35.	9.	30.	4.	4.	25.	50.	6.	18.	12.

the stream area. Thus, the movements are low time/high area parts of the microhabitat. Extrapolation of these data would allow several fishes to have interlocking home ranges.

Maximum water velocities possibly encountered during movements are higher at all stations than the maximum focal point velocities. The mean velocities encountered are also higher than the focal point counterparts, modal velocity. However, destination modal velocities (0.06 ft./sec. to 0.46 ft./sec. with an average of 0.33 ft./sec.) compare favorably with the focal point modal velocities (0.06 ft./sec. to 0.53 ft./sec.) with an average of 0.33 ft./sec.). Thus, movements represent transfer from one favorable area to another over an intervening less favorable area.

Because of the depth uniformity in Little Beaver Creek, no measurable difference exists between focal point depths and movement depths. The mean minimum depth ranged from 0.23 ft. in station 4 to 0.58 ft. in station 3. Mean depth of movement and destination mean depth were almost equal with average values of 0.71 ft. and 0.72 ft. respectively.

The bottom type encountered at the destination reflects a loose correlation with available substrate. Station 3 had the most movements over rock (2.67/focal point) and station 5 had the least (1.44/focal point). Station 2 had the highest mean value for movements over sand bottom (3.55/focal point) while station 4 had the lowest (2.00/focal point). Movements over rock-sand and sand-rock show much smaller mean values than rock and sand. In terms of overall averages rock bottom shows 1.86/focal point, and rock-sand shows 0.16/focal point, sand-rock has 0.74/focal point and sand has 3.06/focal point. Trips were most often made to sand bottom areas and thus to areas of low velocity.

Sunlight conditions encountered show a definite trend toward selection of shade. Shade has the largest number of movements/focal point in all cases. The photonegativity of adult trout and albino trout was mentioned in the focal point description. The movement data serve to reinforce this point. Sun averaged 0.29 movements/focal point and no movements were made to sun-shade areas. Shade-sun averaged 0.27 movements/focal point while shade shows 3.22 movements/focal point.

The last considerations of movements are the direction and objective of moving. Direction was recorded as outlined in the methods and materials section (refer to page 13). A and C movements predominated in all cases, but neither one showed dominance. In station 1 A movements occupied a mean of 64% while a mean of only 10% was recorded in station 4. Conversely, C had a high mean of 85% in station 4 and a low mean of 40% in station 1. A had an average value of 40% and C averaged 51%. E and F movements were relatively unimportant with average values of 7% and 2% respectively. The major conclusion from the movement direction data is the importance of current flow upon fish orientation. These data coincide with the commonly held concept of a rheotactic orientation of fish. Another point to be made is that regardless of whether an A or C movement is made, the fish had to eventually encounter current resistance. Neither direction would have any energy expenditure advantage.

The second movement consideration, objective, was worked by observation period. This was done to properly assess all movements including focal point to focal point movements. The prevalent class at every station was class 1. The largest mean time percentage for class 1 was 81% in station 3 and the lowest was 55% in station 4. Class 1 had an overall time average of 66%. Class 2 and class 4 were subequal in most stations. Class 2 showed an average time percentage of 15 while class 4 had an average of 11%. Class 3 was the least encountered objective and had an average time percentage of 8. The data on movement objective reinforce the focal point concept. Class 1 movements are radiating excursions that start and end in the same focal point. Movement classes 2 and 3 indicate a longer time period spent outside of the focal point. Class 4 allows extensive focal point residence, but in different places. Thus, the high percentage time spent in class 1 movements indicates that the focal point is truly a locus for fish activity.

Index Values

The five index values (Table 5) show easily comparable values that substantiate previously mentioned time and area considerations. However, the index values were worked by observation period to establish a control over the data worked by focal point. The overall MEA index and the overall total index represent actual percentage values while the focal point index values are almost percentage figures. The MEA index and total index are movement terms with small time percentages involved. As index values become smaller, usage of smaller areas becomes greater. Conversely, as index values increase, larger areas receive lesser amounts of usage.

Mean values for the focal point exhibit very little variability. The largest value is 0.03, the smallest is 0.02, and the average is 0.02. This conformity is a result of high time percentages spent in small areas. The MEA index and the total index also reflect time and area percentages presented earlier. However, the difference between

Table 5. Index Values

Character	Station 1		Station 2		Station 3		Station 4		Station 5		Average
	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	
Focal Point Index	0.03	0.02	0.02	0.01	0.03	0.03	0.02	0.01	0.02	0.01	0.03
MEA Index	2.35	1.03	4.30	4.20	6.65	6.22	4.76	4.50	5.45	5.22	4.70
Total Index	8.32	8.80	11.58	11.29	19.24	21.66	7.09	4.32	11.60	10.84	11.57
Overall MEA Index	0.12	0.48	0.28	0.33	0.22	0.14	0.16	0.15	0.24	0.16	0.25
Overall Total Index	0.35	0.11	0.10	0.09	0.11	0.07	0.08	0.52	0.12	0.08	0.11

focal points and movements are more apparent in the index values. The average MEA value is 4.70 while the average total index value is 11.57. Two orders of magnitude separate the focal point index average and the MEA index average, and three orders of magnitude separate focal point index average and total index average. The overall indices are a combination of focal point and movement data. Once again there is conformity in values between stations. The overall MEA index value is 0.11. This also implies that 11% of section area was used per observation period. The total index values are larger than the MEA values because of repetitious movements. Although the overall total index values exhibit more variability, differences between study sections are relatively small. Also implicit in the overall total index is the repetitious usage of 25% of the study section per observation period.

Analysis of Variance Results

The significant F values at the 5% level indicate a 95% confidence that significant differences exist between different levels of an "independent" variable. For instance in study section there are five levels (different stations) being tested against a single dependent variable. The highest computed F in any single case should imply responsibility for the most variance. Because these "independent" variables interact, a series of F values with different "independent" variables being tested against the same dependent variable should indicate various levels of variance cause. However, a large number of one way AOV computations were done and it is possible to get significant values by chance alone. The following values have been selected on the basis of logical choice and F value.

Focal Point

The mean F values for the focal point data are listed in Table 6.

Four factors gave signifîcent F values when tested against time in hours spent in the focal point. These are date, hour period, moon phase, and number of focal points. Of these factors, number of focal points seems to be most important because of its high F value (15.70). Number of focal points would also be the logical choice for the major cause of variation. The mean time in hours for single focal points per observation period is 1.49 while only 0.50 hours were spent per focal point when four focal points occurred in a single observation period. Even though less time per focal point was spent, more time was spent in focal point residence.

Significant F values are obtained when area is tested against date, water volume, water temperature at start, and moon phase. Moon phase shows the largest F value (10.62), but water volume and date also have comparatively large F values. This is an example of factor interaction. Ostensibly any of the four factors could be responsible for the variance. However, moon phase is also the logical choice for variance cause. The smallest mean area is during full moon while the highest mean areas are in the new moon and 1st quarter phases. Nighttime activity should be at a maximum during the full moon whereas daytime activity would be at a minimum.

A single factor showed significance when tested against maximum velocity. Focal point bottom gave a high F value (12.06). Highest velocities were over rock (mean 1.25 ft./sec.) and lowest velocities over sand (mean 0.38 ft./sec.). Rock-sand had a mean velocity of 1.18 ft./sec. while sand-rock had a mean velocity of 0.96 ft./sec.

Table 6. Significant F Values - Focal Point

Test	Computed F	Table F
Time by Hour Period	3.29	2.15
Time by Date	3.50	2.51
Time by Moon Phase	3.58	2.74
Time by Number of Focal Points	15.70	2.74
Area by Water Temp. at Start	2.85	2.74
Area by Volume	5.50	3.21
Area by Date	6.87	2.51
Area by Moon Phase	10.62	2.74
Max. Velocity by Focal Point Bottom	12.06	2.74
Modal Velocity by Moon Phase	3.68	2.74
Modal Velocity by Study Section	13.36	2.51
Modal Velocity by Focal Point Bottom	20.43	2.74
Min. Depth by Study Section	4.52	2.51
Min. Depth by Date	7.02	2.51
Min. Depth by Volume	9.91	3.21
Mean Depth by Moon Phase	4.63	2.74
Mean Depth by Study Section	7.15	2.51
Mean Depth by Date	8.58	2.51
Mean Depth by Volume	11.12	3.21
Sand-Rock by Study Section	2.54	2.51
Rock by Study Section	6.74	2.51
Sand by Study Section	9.42	2.51

Modal velocity gave significance when tested against study section, focal point bottom and moon phase. Although both focal point bottom and study section had large significant F values (20.43 and 13.36), focal point bottom is the logical choice as the more important factor. A velocity stratification occurred among the various bottom types with rock bottom having the highest mean (0.53 ft./sec.) and sand bottom having the lowest mean (0.13 ft./sec.). The high F value for study section is a result of interaction between it and focal point bottom.

Minimum depth had significance when tested against study section, date and water volume. Once again interfactor interaction clouds the choice of a most important factor. However, water volume has the highest F value (9.91) and is the logical choice as the most important factor. Stream depths for study sections are lower at slower water velocities.

Mean depth showed significance when tested against study section, date, moon phase, and water volume. As noted previously, factor interaction causes chance for error on important assessment. Nevertheless, water volume appears to be the most important factor. Water volume has the highest F value (11.12) and is the logical choice as the most important factor because depth must vary with changing water volume.

Rock bottom, sand-rock bottom, and sand bottom give significance when tested against study section. This is an indication that the study fish tended to utilize the available substrate in each study section.

Movements

The F values for the movements data are listed in Table 7.

The number of movements had significance when tested against focal point bottom and observer. Observer has the highest F value (12.58) and is the most important source of variation. Because movements occurred infrequently and took short periods of time, some movements were possibly missed. Neither the focal point nor the movement data are seriously affected by the absent data.

Maximum velocity showed significance when tested against data and water volume. Water volume is the more important factor. Because water volume changed with date, date gave a significant value.

Mean velocity gave significance when tested against study section and focal point bottom. Although focal point bottom has the highest F value (6.61), the relationship of focal point bottom and study section renders an assignment of importance to be impossible.

Destination modal velocity had significance when tested against study section, weather, and focal point bottom. Study section is both the logical and mathematical (F value 9.44) choice as the most important factor.

Minimum depth varies only with observer. This is a direct result of the variation in the number of movements recorded by the two observers.

Study section, date, water volume, and moon phase have significant F values when tested with mean depth. No single factor stands out as the most important cause of variance. Study section and water volume are the logical choices to explain variation within mean depth but all the F values are within a limited range.

Table 7. Significant F Tests - Movements

Test	Computed F	Table F
Number by Focal Point Bottom	3.51	2.74
Number by Observer	12.58	3.96
Max. Velocity by Date	2.69	2.51
Max. Velocity by Water Volume	6.44	3.13
Mean Velocity by Study Section	4.16	2.51
Mean Velocity by Focal Point Bottom	6.61	2.74
Dest. Modal Velocity by Focal Point Bottom	3.39	2.74
Dest. Modal Velocity by Weather	4.07	2.74
Dest. Modal Velocity by Study Section	9.44	2.51
Min. Depth by Observer	7.24	3.96
Mean Depth by Date	2.60	2.51
Mean Depth by Water Volume	3.86	3.13
Mean Depth by Moon Phase	4.48	2.74
Mean Depth by Study Section	4.89	2.51
Dest. Mean Depth by Moon Phase	2.97	2.74
Dest. Mean Depth by Study Section	3.61	2.51
MEA by Observer	10.31	3.96
Total Area by Moon Phase	5.24	2.74
Total Area by Observer	11.82	4.00
Class 4 - % by Number of Focal Points	5.15	2.84
Shade by Moon Phase	2.76	3.74
Shade by Date	3.01	2.51
Shade by Observer	5.57	3.96
Sand-Rock Bottom by Focal Point Bottom	2.79	2.74
Rock-Sand Bottom by Water Temp. at Start	2.80	2.74
Rock Bottom by Date	3.23	2.51
Rock Bottom by Focal Point Bottom	3.57	2.74
Sand-Rock Bottom by Study Section	4.64	2.51
Rock Bottom by Observer	6.03	3.96
Sand Bottom by Observer	13.25	3.96

Destination mean depth gives significant F values with study section and moon phase. The importance of moon phase is difficult to assess, but it must have been forced to significance through interaction with other "independent" factors. Study section (F of 3.61) is the most important factor.

MEA varies only with observer. Once again this reflects the number of movement difference between observers. The same is true for total area. Observer is the dominant factor.

Class 4 shows significance when tested against number of focal points. That is, of course, only logical.

Shade has significance when tested against date, moon phase, and observer. It is impossible to sort out the most important factor in this case. The second ten day period of date has a high mean value in comparison to the other four mean values, but there is no basis to think that sunlight was more or less intense during this period. Similarly there is no logical basis to choose either moon phase or observer as the most important factor.

Destination bottom types show a number of significant F values. Rock bottom shows significance when tested with date, focal point bottom, and observer. More movements were made from focal point rock bottom to destination rock bottom than to any other destination bottom type. At the same time the observer difference is still present so it is difficult to name any one most important factor. However, the choice has to be focal point bottom. Rock-sand has significance when tested against water temperature at start. This is probably a chance occurrence of significance. Sand-rock bottom shows significance with focal point bottom and study section. Once more it is difficult to name the more important factor because of the intimate relationship between factors.

Index Values

Significant F values (Table 8) were obtained when focal point index was tested against moon phase, water volume, and number of focal points. Moon phase showed significance when tested against focal point areas as did water volume. However, the number of focal points per observation period has a definite effect on the focal point index. This makes it difficult to assign relative importance, and the effects of the three factors are considered equal.

Movement total index gives significant F values when tested against hour period and water temperature change. Factor interaction again conceals factor importance. Hour period shows high mean values in hour periods, 1, 2, 6, and 7 indicating a time of day activity response. Water temperature change has a high mean value at water temperature loss with smaller values at no change and gain. Logically, hours periods 6 and 7 should encompass that part of the day when water temperatures decrease. Whatever the major factor, the significant F values indicate a cyclic activity pattern.

Overall MEA index and total index have significant F values when tested against observer. This is another facet of the number of movements recorded by observers.

Table 8. Significant F Tests - Index Values

Test	Computed F	Table F
Focal Point Index by Moon Phase	4.63	2.88
Focal Point Index by Volume	5.21	3.15
Focal Point Index by Number of Focal Points	5.27	2.88
Movement Total Index by Hour Period	2.40	2.25
Movement Total Index by Water Temp. Change	3.86	3.19
Total Index by Observer	8.62	4.00
Overall MEA Index by Observer	9.80	4.00

DISCUSSION AND SUMMARY

This study was limited to observation on a single size group of albino brook trout, but limited extrapolation has been made from the data. Because of the stereotyped behavioral patterns common to lower vertebrates, this extrapolation seems in order.

The focal point concept is the major result of this investigation. Any part or all of the area covered by a focal point and its associated movements could be territorial and/or home range. The implications of this are far-reaching because of the potential differences between fish species. An animal (in a limited habitat) that defended all of its microhabitat should have lower population numbers than an animal with a partial territory.

Of importance to the focal point concept is the relatively high usage of limited areas over long spans of time. The composite time-spent-in-focal-point percentage of 94 is a tremendously significant value in a science where percentages of 50 or 60 are often acceptable. This high percentage was spent in an average of 15% of the available habitat in each study section. Although each focal point area averaged less than 3% of the study section area, the use of several focal points increased the average area used to 15%.

Use of cover also relates to the focal point concept. Cover was an intimate part of every focal point. Not a single focal point existed away from cover. Cover consisted of objects that the fish were by and under. Large rocks (+ 18 inches diameter), logs, and turbulent surface waters all served as cover.

Focal point areas occurred in two major water types with reference to velocity. The first and most common situation was a swift water mass (average - 0.86 ft./sec.) next to a slower water mass (average - 0.33 ft./sec.). Study fish utilized the slow water mass most. The second type was an eddy. All eddies surveyed were slow current areas moving counter to the main water flow. Because a great percentage of fish food consists of aquatic drift organisms (Nilsson, 1957) and more drift should be carried by swifter currents, both of these situations serve to increase feeding efficiency. The first condition allows a fish closeness to food carrying currents without also subjecting the fish to those currents. Because an eddy is intimately connected with swift currents, it too should contain many food organisms.

Depth and bottom type were relatively unimportant as factors. Depth was limited in Little Beaver Creek. Bottom type preferences were closely related to available bottom type.

A definite preference for shade was recorded. This was due both to the photonegativity of adult trout and to the lack of eye pigmentation in albino trout.

Movements increased stream usage as evidenced by the larger areas utilized, lower time percentages spent moving, and higher mean water velocities encountered during the trip. The reasons for movements were not experimentally assessed and their explanation is unclear. The focal point has been described as an optimum feeding place so movements seem to have little value as feeding excursions. More logical explanations would be those of territorial defense and investigative behavior. Investigative behavior should lead to the establishment of more than one focal point, and more than one focal point per observation was common.

Orientation of study fish to current is evident in the data on direction of movement. Upstream and downstream movements were nearly equal in most cases. Each has a complement of current resistance and neither offers real advantage.

A large percentage (66) of the movements were made out of and directly back to the original focal point. This fact further establishes the focal point as the microhabitat locus.

Movements also tended to be disassociated with cover. Fish often passed through areas where they were completely exposed. Thus, movement might play a large role in attrition rates of a fish population.

The index values are important in serving to put other data into perspective. Because a time factor is included, important aspects of area measurements become readily apparent. The most striking example of this is the movement total index by hour period combination. Total area values have no significance when worked by time of day. However, total index values express two activity peaks when worked with the same parameter (Figure 2).

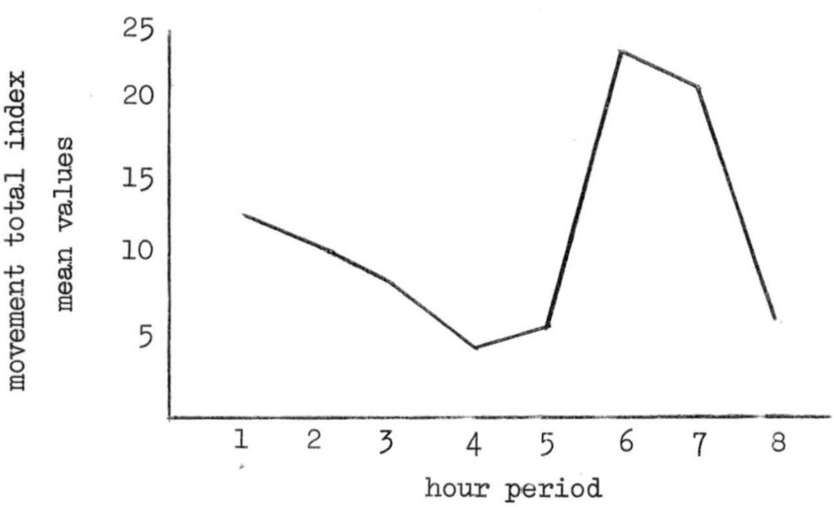

Figure 2. Movement total index (mean values) plotted against two-hour periods after sunrise.

A lack of exhaustive sampling precluded the use of multi-variate analysis techniques. A number of one-way AOV computations (600) was done in an effort to obtain results similar to those of the multiple regression technique. The beta error is a real part of the analysis of variance tests, and I hesitate to make any absolute judgments on variance causes. However, station difference, time of day, moon phase, water volume, date, and focal point substrate are important. The effects of water temperature and weather are unexpressed in the data presented in this paper. Perhaps the most striking variance is in the results by observer, but this is true only for movements. I feel that the difference is due solely to the limited time taken by movements. Any factor distracting an observer could cause him to miss a movement. For this reason, the observer differences are believed to have little effect on the thesis of this paper.

In addition to assessment of "independent" factor importance, AOV tests also establish some pertinent facts about focal point and movement characteristics. Although modal velocities of the focal point show significance by study section and bottom type, there is no apparent difference over the 50 day study period. Thus, certain water velocities are being utilized regardless of date and water volume.

Focal point area varied with moon phase, date, water volume, and water temperature at start, but it did not vary by study section. This indicates there was less variation between stations than within them and that a relatively constant area size was used.

Movement maximum velocity varied with date and water volume, but not with study section. Conversely, movement mean velocity and destination modal velocity had variation with study section and focal point bottom but not with date or water volume. The logical conclusion is that while velocities changed over time, individual fish did not change their preferences.

AOV tests comparing destination bottom type with "independent" variables is confusing. No clear trends are present, but focal point bottom and study section seem to be important governing factors.

AOV results from index characteristics merely serve to reinforce previous conclusions.

The importance of the focal point concept is most striking when viewed against the results of previous fishery investigations. Mechanisms supporting habitat choice have not previously been elaborated. The focal point concept allows for maximum usage of available habitat. Spatial plasticity (Chapman, 1966) also fits well with the focal point movement concept. Focal point availability might serve as a primary limiting factor in the density of stream fish populations. Through the life history of a single fish, several radically different stream areas could function as focal point.

The home range principle (Gerking, 1959) states that for a fish to have a home range, it must spend a certain part of a large time period (a year) in one limited area. Although population density may serve to alter the size of the home range, there could be no home range without the physical orientation of the fish to a certain microhabitat type. Thus, the basic mode of fish home range choice appears to be encompassed in the focal point concept.

Although the data on which this paper is based are not exhaustive, a limited number of conclusions are valid for stream-dwelling brook trout. These are as follows:

(1) Definite water velocity preferences are observable. These preferences are not exhibited as rigid values but as tolerance ranges.

(2) The method of habitation is expressed in the focal point concept. This concept is one of spatial and conditional limits with two major expressions, focal point area and movements.

(3) Only a small percentage of the available environment is utilized over time at any specific time by a single fish.

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