DAYTIME BEHAVIORAL RESPONSES OF ADULT BROWN TROUT (*Salmo trutta*) TO COVER STIMULI IN STREAM CHANNELS

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ABSTRACT

DAYTIME BEHAVIORAL RESPONSES OF ADULT BROWN TROUT (*Salmo trutta*) TO COVER STIMULI IN STREAM CHANNELS

By

Philip Wayne DeVore

Experiments were conducted in controlled-flow stream channels to identify the stimuli to which adult brown trout (*Salmo trutta*) respond in cover occupation. Groups of 25-30 cm trout were offered pairs of cover types with occupation of a specific type representing a choice of known stimuli. The trout preferred overhead cover which was low (10 cm) rather than high (15 or 20 cm) in the water column ($P<0.001$). The response was to the close visual proximity of overhead cover to the stream bed, with which brown trout are generally associated. The trout also showed a preference for overhead cover which offered a tactile feature in the form of clear plastic streamers ($P<0.03$). The trout exhibited no preference when given a choice of overhead cover devices under which were fastened clear or dark plastic streamers, even though the dark streamers offered an additional visual reference and lateral cover.

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INTRODUCTION

The brown trout (*Salmo trutta*) has evolved as an organism which spends all or most of its life cycle in the lotic environment. This has necessitated physical and behavioral adaptations to constantly moving water. Its reliance on invertebrate drift for food has reduced the need for an aspect of behavior common to most of the animal kingdom - that of actively moving about in search of food. The motivation for this phase of appetitive behavior has manifested itself as a response to position which provides food and shelter. The dependence on a fairly stationary position for all of its needs has resulted in a territoritality based on a space-food or space-cover mechanism whereby competition for food has been replaced by competition for space (Chapman, 1966). The territory thus serves as an isolation mechanism toward insuring a sufficient supply of food and cover for individual fish.

The number of territories which may be held in a given stream channel is largely dependent upon the stream topography (Keenlyside, 1962). More relief creates cover, eddies, and depressions and generally increases physical diversity and visual isolation. The physical microhabitat is therefore a primary regulator of population size when biologic factors such as food are not limiting. Because of the rigorous and relatively unstable condition of the stream environment, the physical features characterizing the microhabitat are frequently changing. Position occupation is a reactive rather than a spontaneous response (Lindroth, 1955), and it is necessary for a species to respond to definite stimuli presented by environmental features in choosing positions for feeding, resting, hiding, or spawning.

The environmental features to which a fish reacts may be subdivided into characteristics of the macrohabitat and those of the microhabitat. The macrohabitat includes features such as stream velocity, temperature, and oxygen level which determine whether a species will occur within a system. The microhabitat is defined by local features of depth, cover, microvelocities, and streambed materials. It is the stimuli presented by the microhabitat that are critical in releasing motor patterns leading to fixation at a position or territory (Edmundson et. al., 1968). The fixation is so rigid that brook trout (*Salvelinus fontinalis*) were found to spend about 95% of their time at the preferred position within their territory (Wickham, 1966). The definition of this complex of interacting stimuli could enable the biologist to enhance stream carrying capacity by habitat alteration.

Some biologists have begun to qualify and quantify the characteristics of the microhabitat. Jenkins (1969) illustrated the importance of the relative velocity in determining a position's desirability when he noted that all preferred feeding positions were maintained under principal currents. Lewis (1969) studied several stream parameters and found cover and current velocity to be the most important factors in regulation of population size. These two variables have been fairly well documented as the primary influences on position choice (Vincent, 1969; Everest and Chapman, 1972). Velocity functions directly as a determinant of food supply, and the trout responds to the regime of velocities which offers the most efficient compromise of food/unit time and energy required to maintain position. The response to cover is motivated by a need for security from predators or competition. Wesche (1973) felt that a primary function of cover was to minimize the force of the currents, but this response is here considered as a response to velocity, not concealment. The specific stimuli to which the fish reacts in cover occupation are difficult to identify.

Brown trout are the most cover-oriented of the salmonids (Butler and Hawthorne, 1968; Lewis, 1969). Suitable cover is a major factor in determining stream carrying capacity (Lewis, 1969; Rigler, 1972). The most important characteristic of brown trout cover seems to be concealment from above, and it has been treated as such in many instances where artificial cover has been created or studied (MacCrimmon and Kwain, 1966; Butler and Hawthorne, 1968). Cover may consist of water depth, turbulence, turbidity, submerged or overhanging vegetation, boulders, undercut banks, and submerged objects. To be selected and used as cover, the stream feature must present definite stimuli which result in its use and occupation.

Light intensity has been cited as a factor in the use of cover by rainbow trout (MacCrimmon and Kwain, 1966; Kwain and MacCrimmon, 1969). Negative phototaxis was evident both in choice of overhead cover and in selection of background. This negative phototropism was not evident in fry but developed with age. Increased response to cover with age has also been noted in brown trout (Wesche, 1973). Brown trout up to a size of about 15 cm showed little propensity for cover and occupied positions in shallow open water (P.W. DeVore, snorkeling obs., Springbrook Creek, Michigan, 1973).

Size of overhead cover is another factor affecting selection (Butler and Hawthorne, 1968). This again could be some function of light intensities under cover of different sizes. Hartman (1963) presented several forms of cover to brown trout fingerlings and showed selection to be dependent on rheotactic, visual, and thigmotactic stimuli.

This study was designed to define some of the specific stimuli to which the adult brown trout responds as it seeks cover. To accurately identify these stimuli, the experiments were conducted in an environment in which features known to affect position choice could be manipulated. The controlled features included:

1) uniform depth

2) uniform velocity

3) elimination of any cover which could not be controlled

The experiments were designed to ascertain the indirect effects of channel velocity and incident light and the cover-associated stimuli of velocity, light intensity, touch, and visual reference.

The specific hypotheses were:

1) Overhead cover is preferred when low rather than high in the water column.

2) There is a significant tactual response to cover.

3) Cover offering a visual reference will be preferred to cover without.

FACILITIES AND METHODS

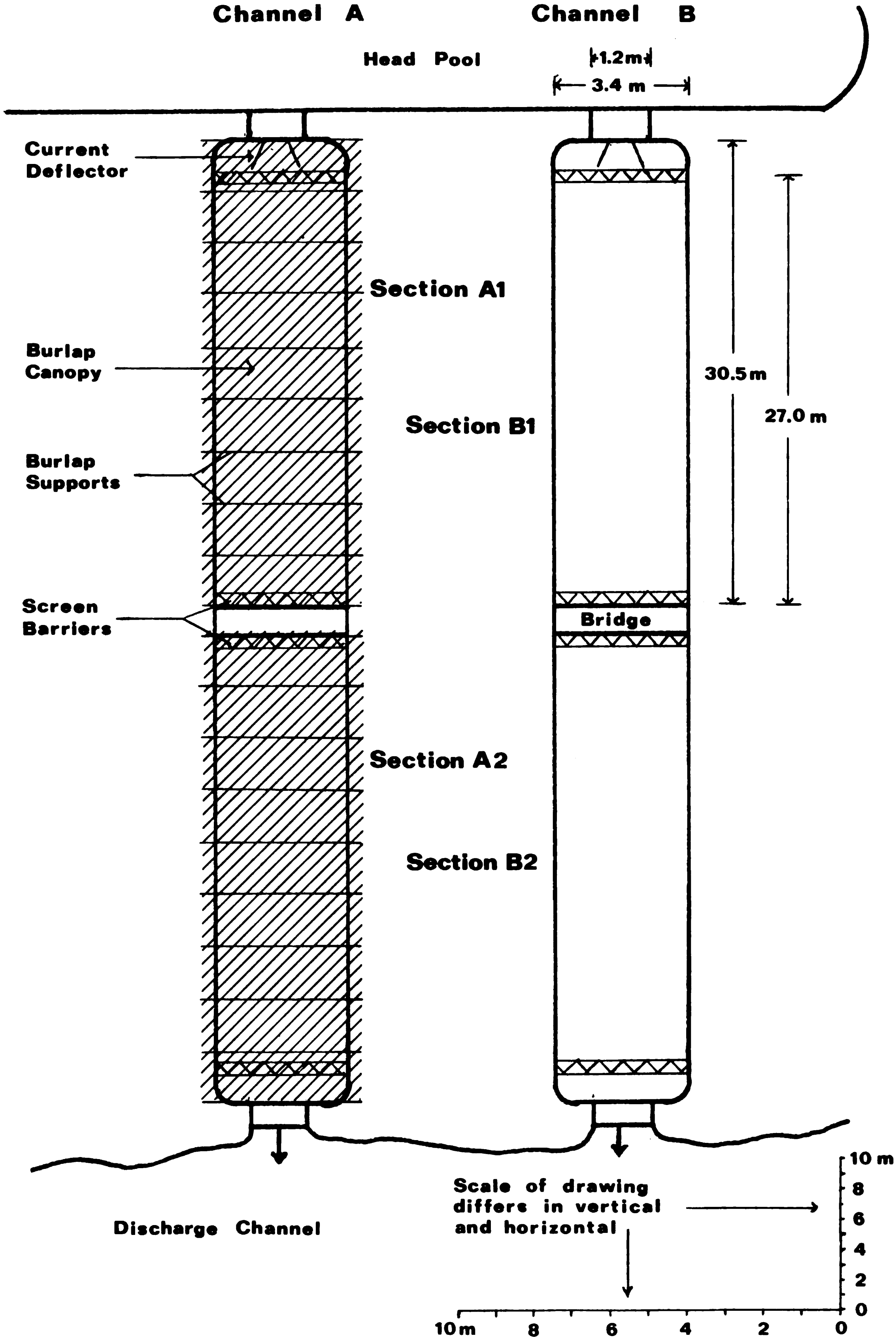
The subjects for this experiment were five groups of twenty brown trout with body length (TL) ranging from 25 to 30 cm. All fish were collected within a four-mile section of the Au Sable River below Grayling, Michigan, by electro-fishing (115 volt D.C., 4.4 amp). Fish were held in a channel near the experimental channels for at least six days before being tested. Groups 1 and 2 were cold branded by the method of Everest and Edmondson (1967) in an attempt to identify the responses of individual fish. The brands could not be seen when the fish were beneath the cover devices and were not used for subsequent groups.

Facilities

The study took place at the Grayling Field Office of the Michigan Department of Natural Resources in Grayling, Michigan. The site is a former fish hatchery. Old raceways served as controlled-flow stream channels. The channels were supplied with water from the East Branch of the Au Sable River. The East Branch supports a mixed population of brown, brook, and rainbow trout, with brown trout the predominant species. Maximum daily water temperatures ranged from 10° to 20.5° C. during the period of study, June-September, 1974 (Appendix I).

Two channels, 3.4 m (11 ft.) wide and 61 m (200 ft.) long, were used (Fig. 1). Each channel was divided into two 30.5 m (100

Figure 1. Controlled-flow channels with burlap canopy and positions of current deflectors and screen barriers.


Channel A
Channel B
Head Pool
1.2m
3.4 m
Current Deflector
Section A1
Burlap Canopy
30.5m
27.0 m
Section B1
Burlap Supports
Screen Barriers
Bridge
Section A2
Section B2
Discharge Channel
Scale of drawing differs in vertical and horizontal
10 m
8
6
4
2
0
10m
8
6
4
2
0

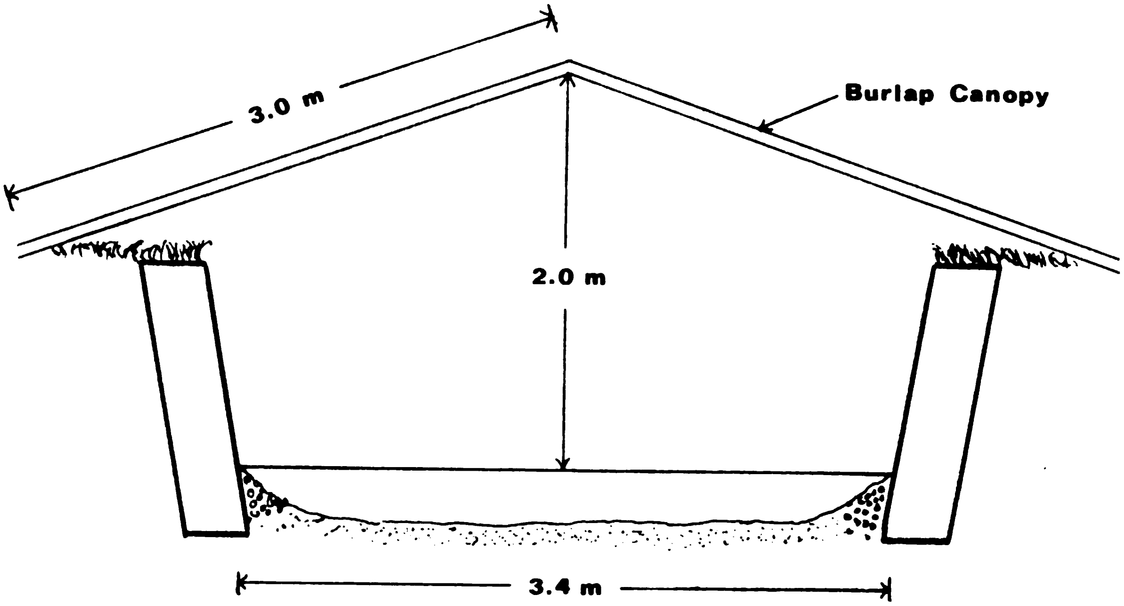
ft.) sections. Hereafter the channels and sections will be designated as in Figure 1. The substrate changed from gravel in the upstream half of sections A1 and B1 to sand in the remainder of both channels. The channel sides were concrete slab and sloped approximately 100° to the water surface. Water depth at the channel edges was 2.5 cm or less (Fig. 2). The shallowness at the margins was to eliminate the channel walls as a source of cover. A fairly uniform cross-section was maintained within each section. Depth and velocity differed among the sections but were fairly constant within each (Table 1). By using straight channels with consistently-sloped bed cross-section, I hoped to achieve a significant degree of spatial and hydraulic uniformity.

Table 1. - Sectional discharge and average depth and velocity of the channel cross-section.

Section	Average Depth (cm)	Average Velocity (fps)	Discharge (cfs)
A1	21.4	1.00	6.3
A2	30.5	0.73	6.3
B1	19.8	1.20	6.6
B2	23.0	0.95	6.6

Constant streamflow discharge was maintained throughout the study of regulating depth of the head pool above the channels. Water entered the channels through openings 1.2 m (4 ft.) wide. Current deflectors in the entry sluices dispersed the flow evenly in the channel cross-section before it entered the sections containing fish (Fig. 1). Discharge was measured with a pygmy current

Figure 2. Cross-sectional view of channel showing dimensions and burlap canopy.


3.0 m
Burlap Canopy
2.0 m
3.4 m

meter at a transect at the mid-point of each section. Measurement was made after the study was completed. Discharge was 6.3 cfs in channel A and 6.6 cfs in channel B (Table 1).

To provide two regimes of incident light intensity, channel A was shaded with a burlap canopy and channel B was left open (Fig. 1). The canopy did not totally exclude the light from the sky, but greatly reduced its intensity.

One-inch wire mesh screen fish barriers blocked the head and foot of each section (Figure 1). The bases of the screens were buried. The screens were cleaned daily to prevent debris damming which would form pools and depressions attractive to fish.

The overhead cover devices used in all experiments were 25 x 61 x .06 cm sections of dark brown marlite, a water-resistant bathroom siding. Each rectangle was supported by two 6 mm threaded galvanized rods, centered 5 cm from either end.

An electromagnetic current meter (Velmeter, Cushing Engineering, Inc.) with a 3/8" diameter probe was used to measure the velocities under the high and low cover devices in experiment 1.

Methods

The general experimental approach was to assign five brown trout to each of the four sections with five paired sets of cover devices, 10 devices in all, representing two cover options per experiment. Sections A1 and A2 were shaded and had the same light regimes. Sections B1 and B2 were open to the sky. All sections differed in velocity (Table 1). Three experiments were conducted with three different pairs of cover types. The experiments were repeated with five groups of fish during the summer. Each experiment lasted two to three days with each fish group. During this time the positions of the trout were recorded three times daily.

The five fish in each section were randomly assigned from the group of 20 for each set of experiments. Five pairs of cover devices were spaced evenly along the 27 m of effective section length. Within each pair, the devices were randomly assigned to right or left sides at a position 1 m from the channel wall (Fig. 4).

The three experiments were:

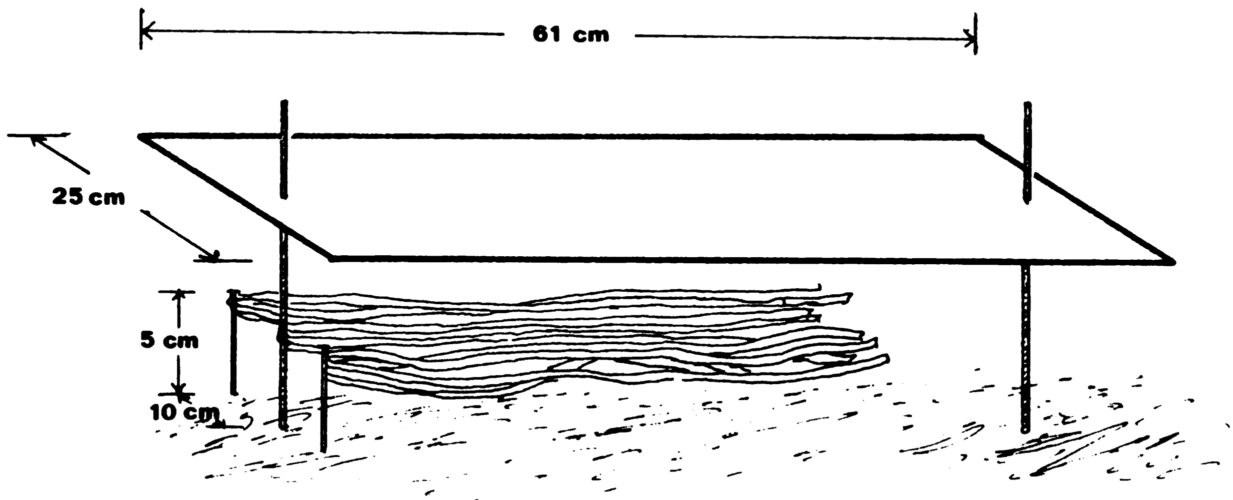
Experiment 1: "High vs. low". This refers to position of the overhead covers in the water column. For the first group of fish, high covers were 20 cm (8 in.) above the channel bed and low covers were at 10 cm (4 in.). In all subsequent groups, high covers were 15 cm (6 in.) above the bed.

Experiment 2: "Streamers vs. none". This involved the same overhead covers, placed 10 cm above the stream bed with and without 16 clear plastic streamers, 1.25 cm wide by 37 cm long. These streamers were invisible to the human eye when beneath the water. Eight streamers were on the upstream threaded rod, 5-7 cm above the bed. Four more were supported by nails 5 cm above the substrate and 10 cm to either side of the center rod (Fig. 3). The covers with no plastic streamers had nails in the same positions.

Experiment 3: "Dark streamers vs. clear streamers". Both cover types had 16 plastic streamers affixed as above. The dark plastic was brown. Both covers were supported 10 cm above the bed.

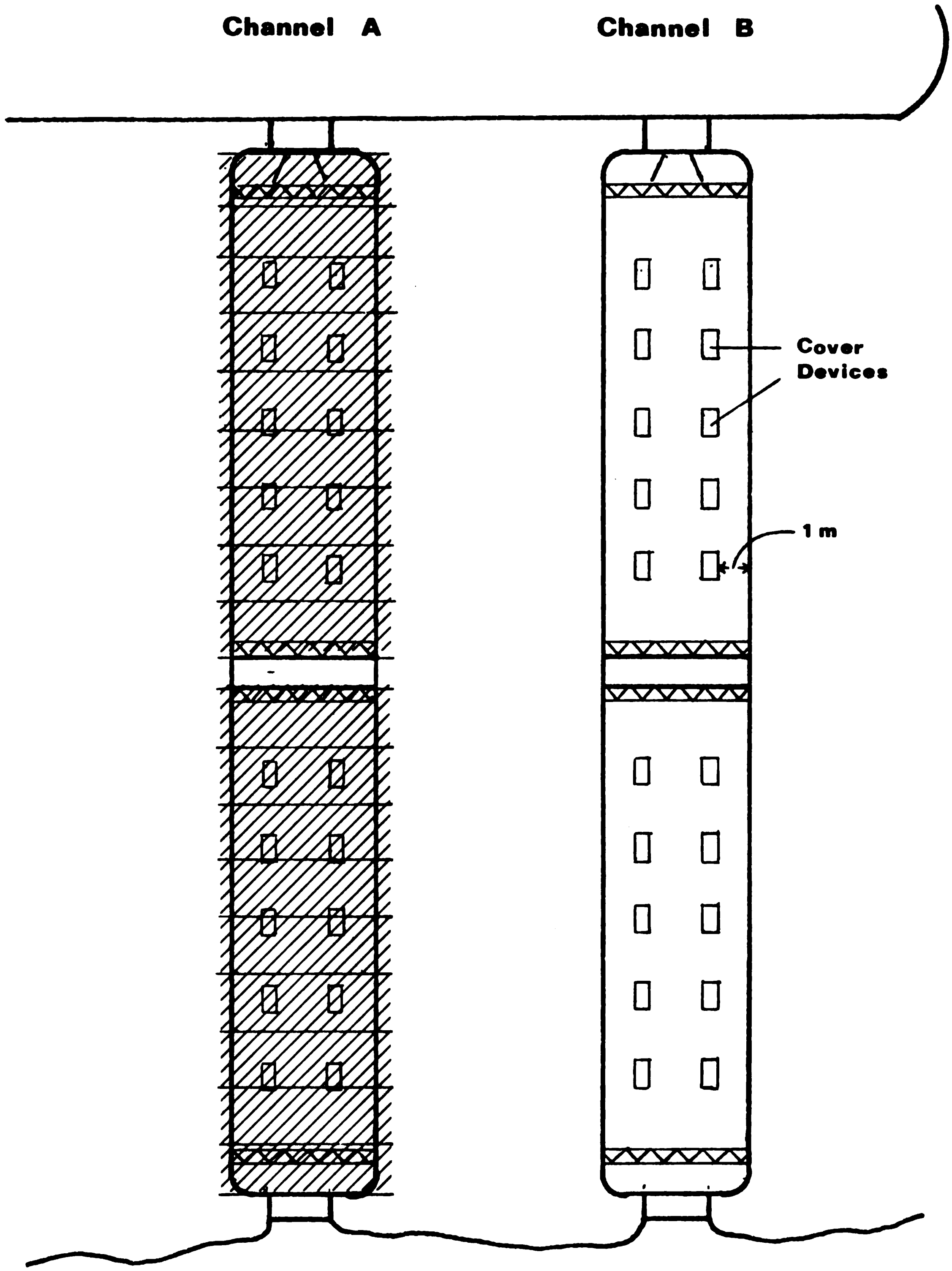
The order in which the experiments were presented to each group of fish was randomly assigned. The test for preference of dark streamers vs. clear streamers was not begun until the second round

Figure 3. Overhead cover device with placement of plastic streamers.



61 cm
25 cm
5 cm
10 cm

Figure 4. Positions of overhead cover devices in the controlled flow channels (see Fig. 1 for channel dimensions).


Channel A
Channel B
Cover
Devices
1 m

of experiments (fish group 2). Group 5 was tested only for streamers vs. none. All other groups of fish were presented with all three cover alternatives (Table 2).

After transferring a group of fish from the holding channel, the trout were allowed three days to acclimate to the channels and the first pair of cover types. The fish were then observed for two to three days. The fish remained in the channel while the cover devices were changed for the next experiment, and two to three days of acclimation were then allowed.

Positions of the fish were recorded three times daily at 1100 hrs., 1300 hrs., and 1500 hrs. (EDST). Each round of observations took about 1 hour to complete. Observation before 1100 hrs. and after 1600 hrs. was difficult because of water surface glare.

A mirror affixed to the end of a 2-m pole aided observation. By holding the mirror underwater beside a cover, the observer could see, from a channel bank position, any fish that might be under the cover. The trout seldom showed that the pole and mirror disturbed them. Any fish seen to move was recorded as having the pre-movement position.

Statistical methods

As individual fish could not be identified, observations of the five trout in each section were combined for a group total. This total represents (number of fish per section) x (number of observation periods/day) x (number of days observed). Owing to loss of fish (predation of mink) and change in the number of observation days per experiment at the midpoint of the study, the total number of sightings/group/experiment was not constant. This was not a critical factor,

Table 2 - Experimental design for separation of effects of velocity, incident light, and cover type on cover selection.

Experimental Treatment	Number of Tests (Groups of 5 Fish)
Shaded (Channel A)	
1.00 fps (Sec. A1)	
1. High vs. low	
10 cm vs. 20 cm	1
10 cm vs. 15 cm	3
2. Streamers vs. none	5
3. Dark vs. clear streamers	3
0.73 fps (Sec. A2)	
1. High vs. low	
10 cm vs. 20 cm	1
10 cm vs. 15 cm	3
2. Streamers vs. none	5
3. Dark vs. clear streamers	3
Open to Sky (Channel B)	
1.20 fps (Sec. B1)	
1. High vs. low	
10 cm vs. 20 cm	1
10 cm vs. 15 cm	3
2. Streamers vs. none	5
3. Dark vs. clear streamers	3
0.95 fps (Sec. B2)	
1. High vs. low	
10 cm vs. 20 cm	1
10 cm vs. 15 cm	3
2. Streamers vs. none	5
3. Dark vs. clear streamers	3

as the data used for analysis were in the form of derived variables representing a ratio of the sightings under one cover type to those under either type. Sightings of fish not under a cover device were disregarded, as only cover use was of interest in this study.

The use of derived variables is generally subject to some limitations, namely: 1) inaccuracy when the ratio is composed of non-discrete numbers; 2) non-normal distributions; 3) sacrifice of information on the relationship between the two variables in the ratio; and 4) the creation of curious distributions due to the higher probability of occurence of some percentages than others (Sokal and Rohlf, 1969). Factors 1 and 3 do not apply to the data of this study. The Shapiro-Wilkes test for normality was applied before analysis. Percentages were not subject to great repetition, as there was variability in the number of sightings under cover and under each cover type (the two values composing the ratio).

The choices that were available to each fish - the use of cover type I, type II, or no cover - could not be considered independent events, as the use of one precluded the choice of any other. The use of cover type I could not be compared directly to the use of type II due to the lack of independence. The third event, occupation of positions other than the offered cover devices, was not considered. With only two events considered, it was possible to compare the number of sightings under one cover type to the 50% or "no preference" level of cover occupation.

The experimental design made it possible to test for: 1) difference in response to cover types due to incident light, 2) differences due to average sectional water velocity, and 3) preference for specific cover types. Factorial analysis was used to test for the effect of incident light. Degrees of freedom were determined by combining data from the two sections in each channel (light regime) and by the number of groups of trout with which each experiment was conducted. Where there was a significant difference in response due to light intensity, the effect of water velocity was ascertained by covariance. Where there was no such difference, the effect of light was not considered and a regression analysis was used, correlating average sectional water velocity and response to cover. A one-tailed t-test was used for the test of preference for a specific cover type. Degrees of freedom were derived from: 1) the number of times the experiment was repeated, 2) combining the data from the two sections under the same light regime if there was no significant difference due to velocity, and 3) combining data from all sections if there was additionally no difference due to incident light.

RESULTS

The relative use of cover was a fairly constant proportion of total sightings for all experiments with 81, 82 and 83 percent of total sightings in experiments 1, 2, and 3 respectively being under cover. The hypothesis of normality was not rejected ($P>0.05$) for the data in any of the three experiments.

Experiment 1 - In fish group 1 (10 cm vs. 20 cm), there was a positive response to the low cover devices ($P<0.02$). For groups 2, 3, and 4 (10 cm vs. 15 cm), the null hypothesis was rejected with very high confidence ($P<0.001$) that the low cover was preferred over the high. There was no significant difference ($P>0.5$)in response due to either incident light or sectional velocity. The data were expressed as a ratio of the sightings under the low cover to those under either high or low cover (Table 3). The velocities under the two cover types were measured with an electromagnetic current meter. There was no significant difference in the velocities (Fig. 5., Table 4).

Experiment 2 - There was a significant positive response to the cover with clear streamers ($P<0.03$). No significant difference was found in cover selection due to light or velocity ($P>0.5$). The data were expressed as percent of time that the cover devices with plastic streamers were used (Table 5).

Table 3. - Number of sightings of brown trout under low and high cover or not under cover. High cover was 20 cm for group 1, 15 cm for all others. Percent use calculated without those sightings not under cover.

	Positions of Trout			
	Under Low Covers		Under High Covers	Not Under Covers
Fish Group	Number of Sightings	% Use Between Covers	Number of Sightings	Number of Sightings
		Shaded Section A1		
1	52	96.3	2	6
2	8	44.4	10	6
3	21	80.8	5	4
4	21	75.0	7	2
		Shaded Section A2		
1	39	84.8	7	14
2	17	68.0	8	5
3	16	59.3	11	3
4	20	71.4	8	2
		Open Section B1		
1	29	85.3	5	2
2	20	80.0	5	5
3	14	70.0	6	10
4	20	71.4	8	2
		Open Section B2		
1	22	64.7	12	26
2	17	85.0	3	10
3	24	82.8	5	1
4	17	77.3	5	8

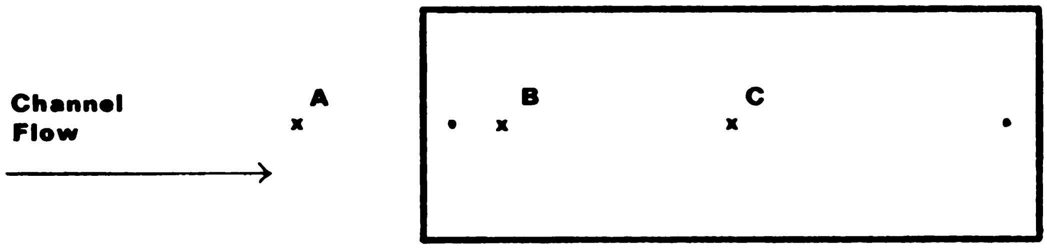


Figure 5. Top view of cover device showing points A, B and C where velocity was measured. Measurements were taken 5 cm above the stream bed on both the high and low cover types (see Table 4).

Table 4. Velocities at two points under the high and low covers.

Point Measured	Velocity (fps) Under Covers	
	High	Low
A	1.21	1.21
B	1.16	1.20
C	0.95	0.91

Table 5. - Number of sightings of brown trout under cover with and without clear streamers or not under cover. Percent use calculated without those sighting not under cover.

	Positions of Trout			
	Under Cover With Streamers		Under Cover Without Streamers	Not Under Covers
Fish Group	Number of Sightings	% Use Between Covers	Number of Sightings	Number of Sightings
		Shaded Section A1		
1	13	34.2	25	7
2	18	72.0	7	14
3	10	100.0	0	8
4	8	36.4	14	5
5	18	66.7	9	8
		Shaded Section A2		
1	20	52.6	18	7
2	26	60.5	17	2
3	16	55.2	13	6
4	10	33.3	20	0
5	21	60.0	14	0
		Open Section B1		
1	21	63.6	12	3
2	24	60.0	16	5
3	27	84.4	5	10
4	10	47.6	11	6
5	9	39.1	14	5
		Open Section B2		
1	17	65.4	9	19
2	21	60.0	14	10
3	19	63.3	11	5
4	15	62.5	9	6
5	15	60.0	10	3

<u>Experiment 3</u> - There was no significant difference in response to overhead covers with dark and clear streamers ($P>0.3$). There was no difference in cover selection due to light or velocity ($P>0.5$). The data were expressed as the ratio of number of fish sightings under cover devices with dark streamers to number sighted under either type (Table 6).

The variance of the data is inflated due to the nature of the substrate in the channels. Depressions and irregularities were sometimes formed in the sand beneath the cover devices, creating attractive stimuli, as reflected by the increased use of these covers. This was not characteristic of any one cover type and would not bias the results, but could by a masking factor in detection of a true difference due to the artifically expanded random variation. Rejection of the null hypothesis is therefore stronger than the alpha level might indicate.

Table 6. - Number of sightings of brown trout under cover with dark and clear streamers or not under cover. Percent use calculated without those sightings not under cover.

	Positions of Trout			
	Under Cover With Dark Streamers		Under Cover With Clear Streamers	Not Under Cover
Fish Group	Number of Sightings	% Use Between Covers	Number of Sightings	Number of Sightings
		Shaded Section A1		
2	15	62.5	9	7
3	11	47.8	12	7
4	12	35.3	22	2
		Shaded Section A2		
2	9	25.0	27	4
3	5	22.7	17	8
4	21	72.8	8	1
		Open Section B1		
2	16	45.7	19	8
3	12	41.4	17	1
4	10	40.0	15	14
		Open Section B2		
2	15	51.7	14	11
3	14	56.0	11	5
4	16	61.5	10	4

DISCUSSION

Attempts to identify basic behavioral responses have inherent problems, whether they are conducted in a natural or artificial situation. Studies relying on observation of organisms in their natural environment are generally hampered by the complexity of the features which must be considered. Often the only means of making deductions is by statistical analysis of observed features in which the conclusions are an artifact of the data. There are some advantages in using a more controlled situation. Those stimuli known from field experience to be highly significant may be controlled, and stimuli of more subtle types may be tested. Identifying the behavioral characteristics of an organism in this manner depends on the artificial manipulation of those stimuli which evoke the response.

Two basic categories of stimuli are important in determining the brown trout's choice of position: water velocity and hiding cover. Velocity was therefore a primary variable to control and monitor when attempting to identify the attractive stimuli of cover. Relative depth is significant in position choice (Everest, 1967; Baldes and Vincent, 1969), perhaps in both components of cover and velocity. Depth was therefore held constant within each section by maintaining rather uniform cross-sectional shape. The creation of uniform regimes of velocity and depth should not stress the fish, as long as the regimes are within acceptable natural limits.

The next necessary control was that of any cover derived from the channel shape. Raceways typically have straight, perpendicular walls which are not only an artificial feature of the channel, but act as attractive stimuli (MacCrimmon and Kwain, 1966). I therefore built up the channel margins with gravel and sand so that the juncture of bed and wall was too shallow to harbor fish of the size used. The screen barriers at the head and foot of each channel were designed to offer no current shadow or cover. This total elimination of cover might have imposed an element of stress on the wild trout which were used, but cover was reintroduced to the channels in a form which could be controlled so that the choice of a particular cover type would represent response to a known group of stimuli.

Another imposed limit was the size of the trout. Previous research in identifying the stimuli to which brown trout respond in cover selection has been conducted with fingerlings (Hartman, 1963). Response to cover changes significantly with age (Le Cren, pres. comm. in Chapman and Bjornn, 1969). Brown trout of 25-30 cm (10-12 in.) were used, as this is generally the minimum size of interest to fishermen. Such fish should represent the response of a large segment of the adult population.

The number of trout was limited to five in each section and ten cover devices in five pairs were offered to minimize the effect of agonistic behavior on position selection. For the size fish used, the amount of space available (18.5 m^2/fish) was within the lower limit of the spatial requirement according to Allen (1969). The response should therefore be representative of the individual fish's choice.

Interpretation of the results of the three experiments provides direct and indirect measures of the importance of velocity, light intensity, tactile response, and visual reference in selection of the available cover devices. Incident light and sectional velocity were stimuli that could be confounded with those offered by the cover types. In experiment 1, the high and low covers, these two stimuli could have varied with height of the cover device. No instrument was available to measure light underwater. Measurement with an electromagnetic current meter indicated no significant difference between the two cover types in the magnitude of the velocities (Fig. 5, Table 4).

In experiment 2, the clear plastic streamers were intended to offer a tactile feature with no visual stimulus or change in velocity. In any of the hard structures which have previously been used to measure the importance of thigmotaxis (Hartman, 1963; Haines, 1969; Baldes and Vincent, 1969), confounding of the importance of touch and relative velocity is inherent. The clear, underwater streamers were invisible to the human eye, and the overhead cover would reduce the possibility of reflected light. Therefore I consider the response to the devices with streamers to have been a true response to tactile stimulus.

Experiment 3, the comparison of responses to clear and dark streamers, was originally intended to measure the importance of a visual reference which had previously been cited as a factor in cover selection (Hartman, 1963; Haines, 1969). The dark streamers also served as a light barrier, reducing the light intensity under these cover devices.

Analysis of the data indicated there was no effect of those stimuli not associated directly with the cover devices - incident light and sectional velocity. Light intensity might affect the use of cover, but did not influence which cover types were preferred. This indicated that the strong preference ($P<0.001$) for the low cover over the high cover might not have been due to a difference in light intensities under the covers. Stronger evidence was provided as no preference was exhibited for the devices with the dark streamers in experiment 3. The difference in light intensities should have been greater here than between the high and low covers. This suggests that a third type of stimulus was responsible for the high motivation to occupy the low cover type. A tactual response does not seem likely, as the trout were always observed in a position on or just above the stream bed, never with their dorsal side close to the overhead cover. In addition, the preference for the cover devices with streamers in experiment 2 was not as great as for the low covers, even though a definite tactual stimulus was offered by the streamers. I therefore infer that the trout were responding to the position of the overhead cover in closer visual proximity to the stream bed, with which they are generally associated. This could be tested by offering two heights of transparent cover devices and determining preferences. In addition, I infer that brown trout have a greater visual response to cover located close overhead than to lateral cover. This was indicated by failure of the fish to respond to the lateral cover afforded by the dark streamers. This seems reasonable, as close lateral cover would obstruct the fish's vision, a sense highly relied upon in detecting food, competitors, or predators. This is probably the reason brown trout seldom use dense stands of aquatic macrophytes (P.W. DeVore, obs. while electrofishing, Au Sable R., Michigan, 1974; R.J. White, obs. while electrofishing, Prairie R., Wisconsin, 1960's), even though such cover apparently offers other desirable or attractive stimuli.

Motivation is important in determining the relative import of a stimulus (Brown, 1957). A frightened or stressed brown strout seems to seek cover which offers a strong tactile stimulus. Frightened fish that have fled to dark, rather stillwater, channel-edge hides occupy positions with no orientation to current or gravity, seeking only to press their ventral or lateral side to the channel bed or wall (P.W. DeVore and R.J. White, snorkeling obs., Springbrook Creek, Kalamazoo County, Michigan, 1973). The unstressed fish apparently exhibits much more visual orientation and responds to positions under cover as it would a feeding position, if cover is available in suitable locations.

The positions which the trout occupied under the cover devices were often at the upstream edge of the device with their heads about even with the supporting rod. This would offer maximum range of vision for fish concealed under these devices. The trout maintained these positions under cover even when disturbed, as I could reach under and touch or even lift the fish slightly without any flight response.

An interesting phenomenon was the occasional simultaneous occupation of a cover device by two or even three fish. Agonistic interactions would seem to make such association unlikely, but it was not at all uncommon. This might have been a result of stress on the fish, but I observed brown trout while snorkeling in streams (Springbrook Cr., Michigan; Au Sable R., Michigan, 1973, 1974), lying together and even touching sides when under cover. While electrofishing on the Au Sable River, 10 to 15 trout were sometimes taken from beneath one cover device which measured approximately 1 x 3 meters. This close association of fish when under cover may raise some question regarding possible inhibition of agonistic behavior when under cover. Should this be the case, it is possible that creation of large cover devices in positions suitable for feeding could increase competition for the food supply by concentrating the fish and reducing competition for space.

Seasonal changes in the physiologic state of the fish may result in a change in the type of cover and positions sought. Different types of habitat are sought in the winter months when the change is induced by low water temperature (Chapman and Bjornn, 1969) and during the spawning season when the fish migrate to areas suitable for spawning. The response of interest in this study was that during the feeding and growing season - that is, before the spawning season and after the relatively inactive winter period when the trout is strongly oriented to deeper water and structure (Hartman, 1963; Chapman and Bjornn, 1969). The experiments were terminated in mid-September due to advent of the brown trout spawning season.

Concealment from above is generally considered a primary function of cover. Suitable depth would seem to serve this purpose to some extent. The importance of water depth as cover is not well understood, however, because the relative effects of depth and velocity on position choice are confounded. Most of those stimuli that have been identified as important in cover selection are not found as a function of depth. There may be some question as to the relative desirability of depth as cover, especially when the pool substrate is depositional and has little topographic diversity. I have seldom seen trout occupy pools in which the bed materials offered no concealment when good cover was available adjacent to the pools (pers. obs. while snorkeling and electrofishing, Au Sable R., Michigan 1974).

These experiments were intended to identify some of the specific stimuli to which the brown trout responds in cover occupation. If the brown trout's response to the stimuli I have identified is instinctive, it should be of value in wide-range habitat management. The evidence of this study indicates that while the features brown trout use as cover vary with the stream type (e.g. mountain vs. lowland), the stimuli they respond to and the specific behavioral patterns are the same. Jenkin's (1969) observation that brown trout preferred cracks in rocks and undercut banks or exhibited "digging" behavior if no cover was available illustrated the importance of tactual and visual stimuli demonstrated in other studies (Hartman, 1963; Baldes and Vincent, 1969). This similarity in response of different populations indicates that cover selection is largely an innate action elicited by simple stimuli among the complex environmental features which serve as cover.

CONCLUSION

The hypothesis that brown trout would prefer overhead cover which was low rather than high in the water column was accepted ($P<0.001$). The preference for the low cover was not due to a lower light intensity or velocity and could not be attributed to a tactile response. The stimulus to which the brown trout responded was the overhead cover in closer visual proximity to the stream bed.

The hypothesis that there was a tactile response to cover was also accepted ($P<0.03$). The cover devices with clear streamers offered a tactile surface without a visual stimulus or a change in velocity. The response to these covers was therefore felt to be a true response to a tactile stimulus.

The third hypothesis, that brown trout would prefer overhead cover offering a visual reference to overhead cover without, was not accepted ($P>0.3$). The cover devices with dark streamers were not preferred over those with clear streamers, even though they offered a lower light intensity, lateral cover, and a visual reference.

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APPENDIX

Table A1. - Daily maximum and minimum water temperatures for the East Branch of the Au Sable River at the Grayling Field Office during the summer of 1974

	Temperature °C	
Date	Low	High
6/21	13.3	17.2
6/22	12.8	15.0
6/23	11.7	12.2
6/24	10.6	14.4
6/25	10.6	14.4
6/26	11.7	16.1
6/27	11.7	16.1
6/28	11.7	16.1
6/29	12.2	16.1
6/30	13.3	17.8
7/1	13.9	18.3
7/2	15.0	16.1
7/3	15.6	17.8
7/4	15.6	16.7
7/5	13.3	17.2
7/6	13.9	18.3
7/7	14.4	16.1
7/8	15.0	20.0
7/9	16.7	20.6
7/10	17.8	18.9
7/11	13.9	17.8
7/12	12.8	17.8
7/13	11.7	17.2
7/14	16.7	17.8
7/15	15.0	17.8
7/16	12.2	17.2
7/18	13.9	19.4
7/19	15.6	18.3
7/20	12.8	20.0
7/21	11.1	16.7
7/22	13.3	13.9
7/23	12.2	15.6
7/24	13.3	17.2
7/25	13.9	14.4
7/26	13.3	16.7
7/27	14.4	18.3
7/28	14.4	17.8
7/29	13.9	16.1
7/30	13.3	15.0
7/31	12.8	15.6
8/1	12.2	15.0
8/2	12.8	17.2
8/3	15.0	16.1
8/4	12.8	13.3
8/5	12.2	18.9
8/6	12.2	16.7
8/7	13.9	16.7
8/8	12.8	14.4
8/9	12.8	16.1
8/10	13.3	16.7
8/11	14.4	15.6
8/12	14.4	16.7
8/13	14.4	17.2
8/14	12.2	15.0
8/15	11.7	16.1
8/16	13.3	15.0
8/17	13.3	16.7
8/18	12.8	16.7
8/19	13.3	17.6
8/20	13.9	18.3
8/21	15.0	18.3
8/22	15.6	17.8
8/23	15.0	16.7
8/24	12.8	13.9
8/25	13.3	15.6
8/26	13.3	15.6
8/27	13.9	15.6
8/28	11.7	13.9
8/29	10.6	13.3
8/30	10.6	13.9
8/31	12.2	13.9
9/1	10.6	12.8
9/2	9.4	10.0
9/3	8.3	11.7
9/4	7.2	10.6
9/5	7.2	11.1
9/6	7.2	10.6
9/7	8.3	11.7
9/8	9.4	13.9
9/9	11.7	13.3
9/10	11.7	15.0
9/11	14.4	17.8
9/12	13.9	15.6
9/13	10.6	13.3
9/14	10.0	11.7
9/15	10.6	12.2
9/16	11.1	11.1