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Trout Movements in a Small Mountain Stream

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TROUT MOVEMENTS IN A SMALL MOUNTAIN STREAM

by

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Thomas Mark Twedt

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ABSTRACT

Trout Movements in a Small Mountain Stream

by

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Utah State University, 1973

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Five groups of 400 hatchery rainbow trout, (Salmo gairdneri), were stocked in a small, mountain stream at 3-week intervals from June to September, 1972. A fish trap captured any fish moving out of a 500 m study section.

Fish began moving at high levels during the first day of each stocking and continued at high rates for 5-8 days (Early Phase), after which movement decreased to low levels for 6-9 days (Late Phase). Early Phase fish moved primarily at night, possibly due to their disoriented state and high subjectivity to stream conditions. Fish moving during Late Phase did so mainly during daylight, probably in response to diurnal periodicity of a day-active food organism in the drift.

Forced movement due to social behavior did not seem to be an influencing factor, but the duration of visible light seemed important to moving fish.

(32 pages)

INTRODUCTION

The movement of fish in freshwater ecosystems is a frequently observed behavioral phenomenon and one which has been studied extensively in a variety of situations for many years. This aspect has been recognized as an important consideration both in the estimation of vital statistics of fish populations (Ricker, 1958) and in production calculations (Northcote, 1967). Movement should also be considered in the management of fish populations, especially in situations where availability to capture by man is an important aspect of the management program.

A significant portion of the fishery management program of many Western states is the stocking of catchable-sized trout in small mountain streams. Movement of stocked trout has been described (for example: Bjornn and Mallet, 1964; Brynildson, 1967; Cooper, 1952; Newell, 1957; Ratledge and Cornell, 1953), but investigators have been primarily concerned with descriptive aspects such as distance moved and percentages of fish moving. Nearly all studies have occurred on relatively wide and slow rivers, rather than on the narrow and swift mountain streams often stocked in the West.

Knowledge pertaining to the factors which initiate or direct fish movement within such streams may be valuable in planning and implementing trout management programs. If the fishery manager could predict the type and amount of movement to be expected under various sets of environmental conditions, he would be better able to make decisions as to the stocking procedures for each individual stream.

As another approach in assisting the fishery manager in his objectives, the Utah Cooperative Fishery Unit, a joint venture among the Bureau of Sport Fisheries and Wildlife, U.S. Department of Interior, the Utah Division of Wildlife Resources, and Utah State University, is involved in a program of developing fish-suitability criteria for hatchery trout. Through the genetic and physiological aspects of this program, it is expected that more suitable trout will be produced for Western streams (Kramer, 1969). The movements of newly-stocked trout in a stream may be an important consideration in evaluating their stamina and ultimately their return to the angler. It is assumed that a more suitable fish would quickly position itself in the stream, rather than exhibit movement because of poor or weakened condition. Information as to the time factors involved in fish movement may be of value in testing fish fitness and may provide the manager with a simple evaluation of his procedures.

The objective of this study was to observe the movements of newly-stocked trout in a small mountain stream and evaluate possible contributing factors to this movement.

The specific objectives of the study were:

1. To determine the time factors involved in trout movement.

2. To assess the role of environmental and behavioral variables suspected of initiating or directing movement.

MATERIALS AND METHODS

Study Area

The study was conducted on Temple Fork of the Logan River, a mountain stream in northern Utah. A complete description of the area was given by Pearson and Kramer (1972). A 500 m study section beginning 2.2 km below the spring source was established. The section had a mean width of 3.8 m and gradient of 35.05 m/km.

Tagging and Stocking

Groups of 400 rainbow trout (Salmo gairdneri) from the Logan Production Hatchery, Utah Division of Wildlife Resources, were moved to raceways in the Logan Experimental Hatchery at 3-week intervals. All fish were tagged the following day with internal anchor tags (Dell, 1968) imprinted with 5-digit numbers for individual identification. Length and weight of each fish was recorded at this time (Table 1). To minimize stress, the fish were anaesthesized with a tricane methanesulfonate (MS-222) and quinaldine mixture before handling.

Five days after tagging, the fish were transported to the stream in an aerated tank. The tank water was acclimated to approximate stream temperature with ice before hauling and tempered to within three degrees centigrade of stream temperature before the fish were released. All stockings were made at the upstream boundary of the study section.

Table 1. Tagging and stocking data for each run made in Temple Fork, 1972

Run	Tagging date	Average length (mm)	Average weight (gm)	Average K factor	Stocking date	Number stocked
1	Jun 9	241.10	152.97	1.08	Jun 14	398
2	Jun 30	256.94	166.77	0.98	Jul 5	392
3	Jul 21	248.04	154.61	1.00	Jul 26	395
4	Aug 11	264.76	199.57	1.07	Aug 16	394
5	Sep 1	281.62	241.05	1.06	Sep 6	398

Fish Trap

Fish movement was considered in terms of fish leaving the section and evaluated with a semi-permanent trap placed in the stream at the downstream boundary of the section. The trap was constructed of aluminum conduit spaced 3/4" apart and formed into a "V" across the stream (Figure 1). A trap box of wire cloth ("hardware cloth") captured any fish attempting to leave the section. Since fish tended to move only downstream, a barrier of conduit was placed diagonally across the stream to form the upper boundary.

Notification System

An electronically-operated notification system[1] was utilized to signal entry of fish into the trap. Fish entering the trap box moved through an electrified tunnel at the entrance, causing an

[1] Loaned by National Marine Fisheries Service, Northwest Fisheries Center, Seattle, Washington.

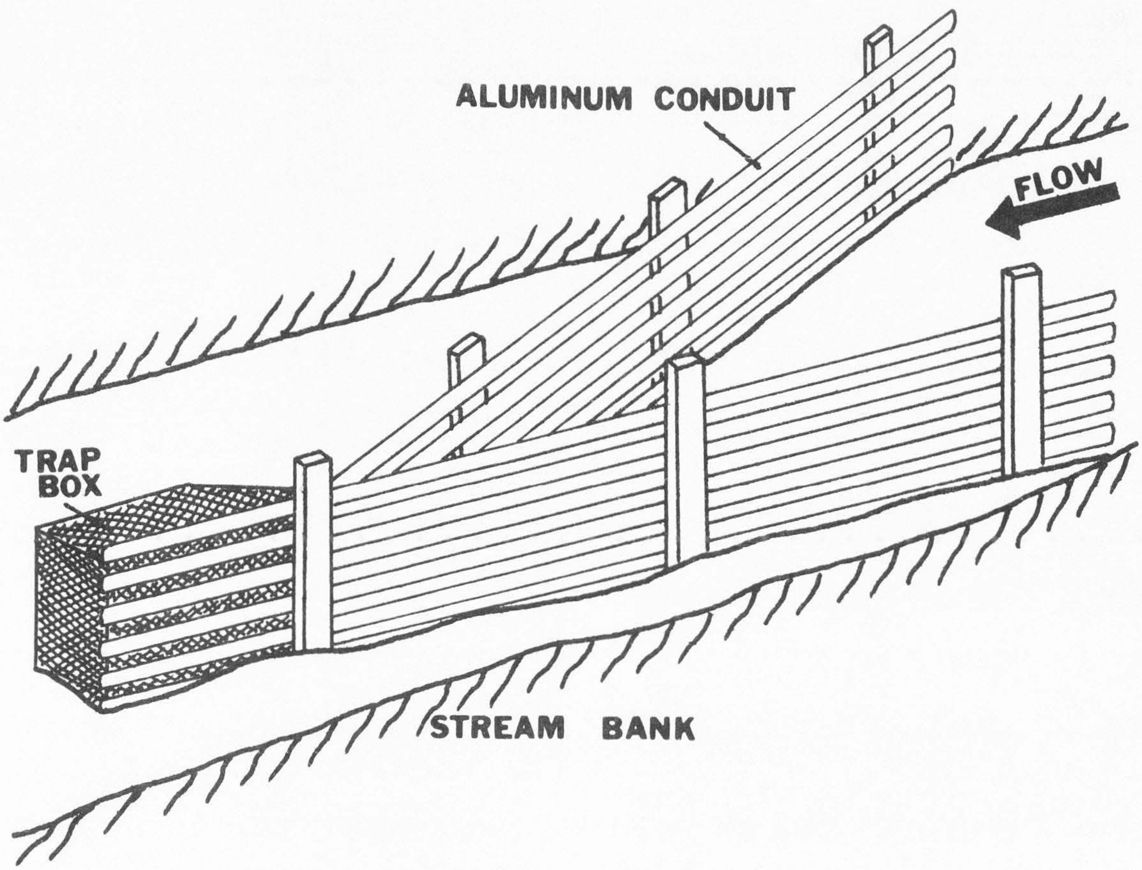

Figure 1. Schematic diagram of Temple Fork fish trap

unbalance in a conductive bridge circuit. The unbalanced circuit caused an alarm bell to ring until manually switched off. Each fish entering the trap was immediately removed and its tag number, time of arrival, length, and weight recorded.

Physical Environment

Water temperature was recorded with a Foxboro recorder and checked periodically by hand thermometer. Daily maximum, mean, and minimum water temperatures were obtained from the thermographs.

Water depth and velocity were recorded daily at the same location with a staff gage and Gurley current meter. Daily discharge or flow rate was calculated from the data.

The daily duration of visible light was estimated from sunrise-sunset tables. All data was collected for fourteen continuous days during each run.

RESULTS

Trap Efficiency Corrections

Post-study sampling in and downstream of the study section indicated that some fish had moved through the trap without detection and that trap efficiency had varied between runs. A number of fish had evidently slipped through the trap bars or moved through areas where stream substrate had washed out under the trap. Several assumptions were made to correct for the unobserved movement. First, it was assumed that all fish not in the section at the end of the study had moved. Also, it was assumed that trap efficiency was constant over a single run.

The number of fish from each stocking remaining in the section was estimated by the Zippin removal method (Zippin, 1958). This number, including any known mortalities, was deducted from the number of fish stocked for that run (Table 2). The result was assumed to be the number of fish moving from the section (D). The number of fish from a run trapped during the entire study period (E) was divided into the number trapped during the run (F) to give a percentage for the run ($G=F\div E$). This percentage, multiplied by the number of assumed movers, yielded the number of fish moving during the run ($H=GxD$). The number of fish moving per run was divided into the actual number of fish trapped during that run to estimate trap efficiency for the run ($I=F\div H$). Fish captures from previous runs were adjusted with the efficiency value from the run in which they were captured (Table 3).

Table 2. Fish trap efficiencies for five runs of 14 days each, Temple Fork, 1972

	A	B	C	D	E	F	G	H	I
				=A-(B+C)			=F÷E	=GxD	=F÷H
Run	Number stocked	Estimated remaining after study[1]	Observed mortalities during study[1]	Estimated movers during study[1]	Number[2] trapped during study[1]	Number trapped during run	Percent trapped during run	Estimated movers during run	Trap efficiency
1	398	68	4	326	123	89	27.4	236	.377
2	392	94	1	297	120	101	84.2	250	.404
3	395	74	0	321	60	48	80.0	257	.187
4	394	94	1	299	90	85	94.4	282	.301
5	398	202	1	195	101	101	100.0	195	.518

[1]Study includes Runs 1-5, from June 14 to September 20.

[2]Includes fish trapped during 1-week intervals between runs.

Table 3. Adjusted capture data for five runs of 14 days each, Temple Fork, 1972[1]

	Run stocked						
Run captured	1	2	3	4	5	Unknown	Total
1	236	0	0	0	0	0	236
2	27	250	0	0	0	37	314
3	16	43	257	0	0	21	337
4	3	13	17	282	0	20	335
5	4	6	0	4	195	2	211
	286	312	274	286	195	80	1433

[1]Values obtained by dividing trap efficiency (Table 2) during run captured into original value.

Time Factors

General movement patterns

The time factors involved in fish movement were analyzed in two ways. First, the general patterns of movement over the entire study period were considered in terms of the numbers of fish moving per day during each of the five runs (Figure 2).

Each run, although varying somewhat in the number of moving fish, exhibited the same general pattern of movement. Movement reached a high level within one day after stocking and remained high for 5 to 8 continuous days, after which it dropped off and continued at a lower level through the remainder of the run.

An instantaneous movement rate, synonymous to an instantaneous mortality rate (Ricker, 1958), was calculated for each run (Figure 3)

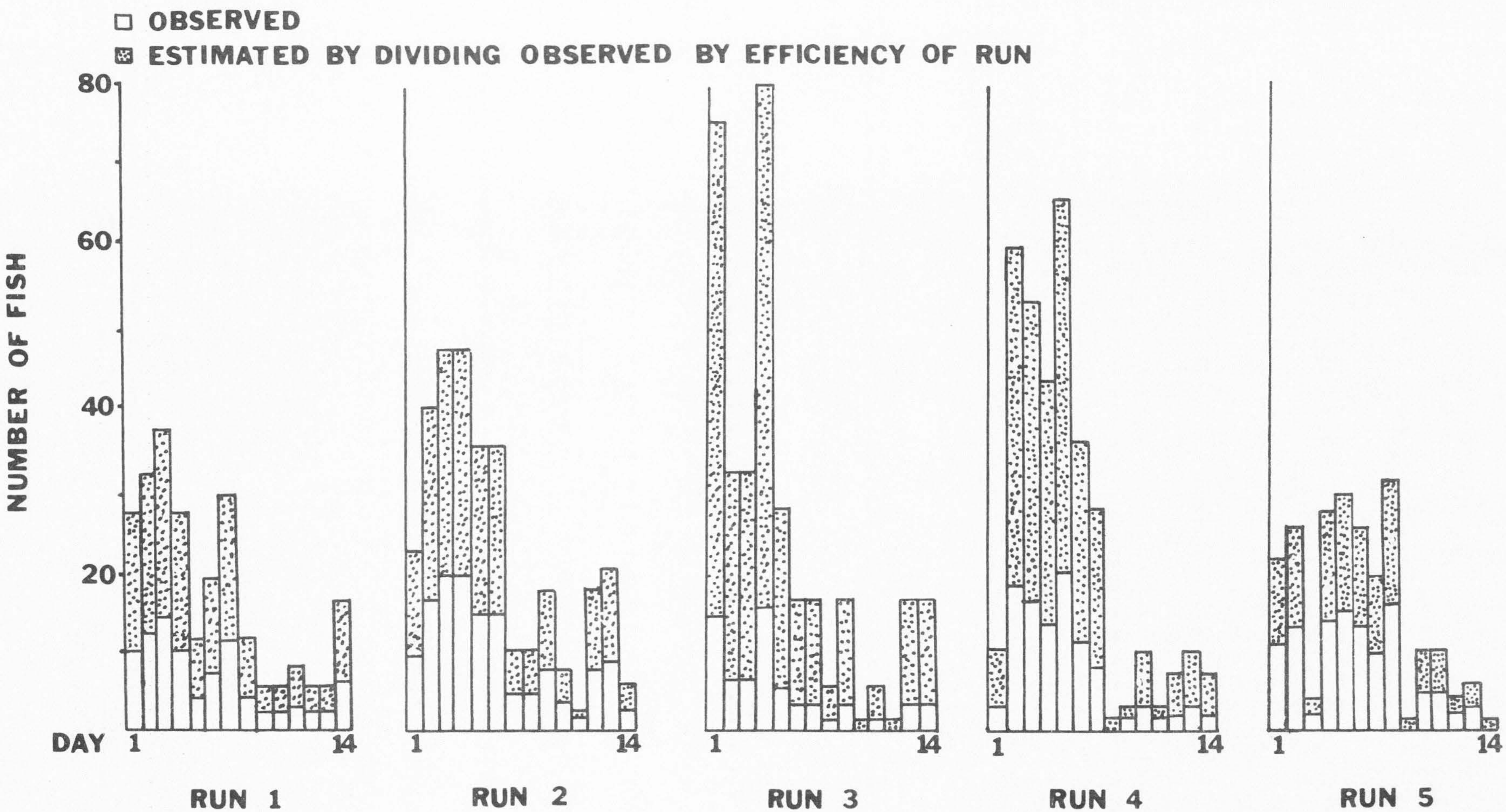

Figure 2. Numbers of fish moving daily during five runs of 14 days each, Temple Fork, 1972

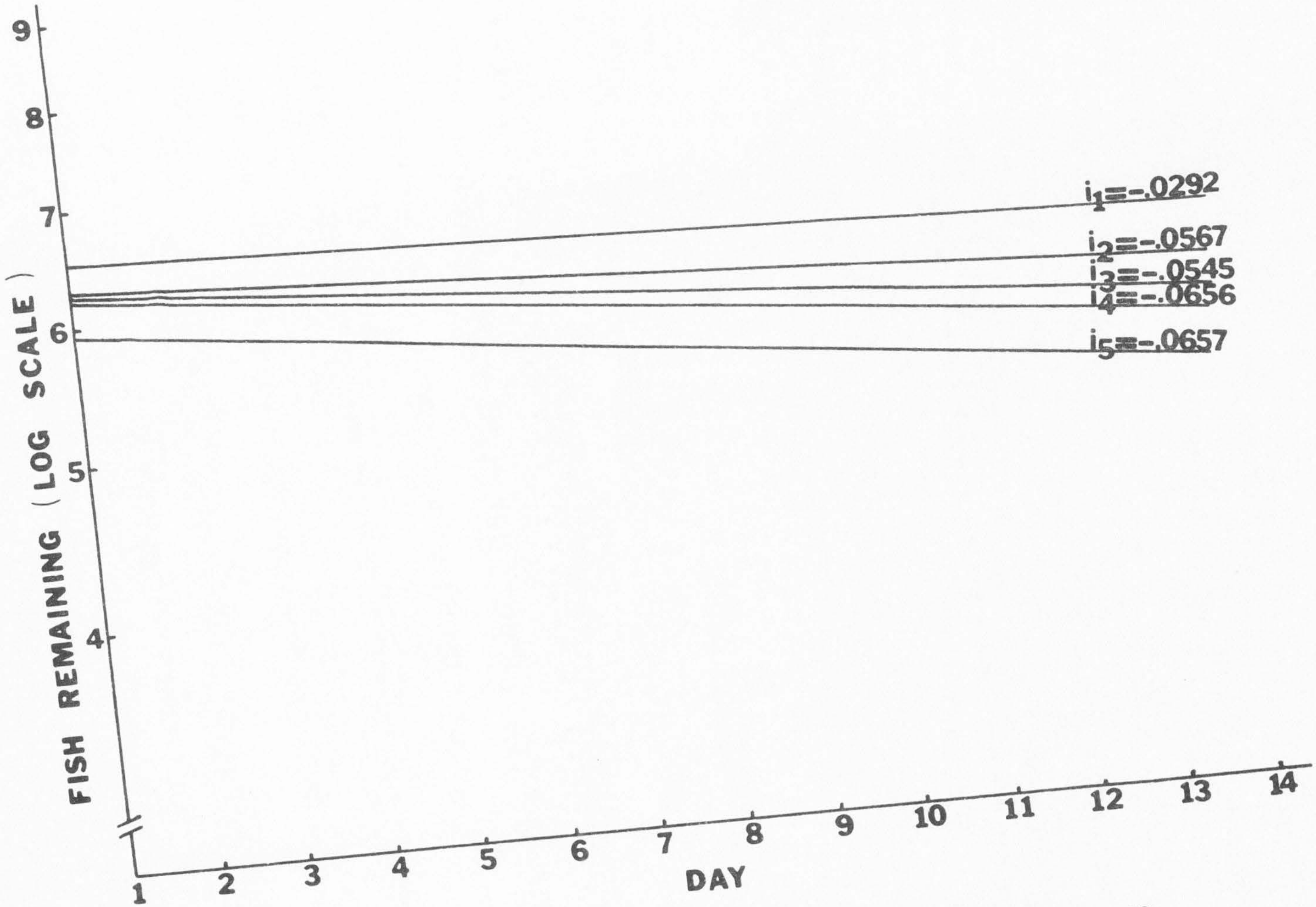

Figure 3. Instaneous rates of movement for five runs of 14 days each, Temple Fork, 1972

from the number of fish remaining at the beginning of each day (Appendix, Table 5). These rates, with the exception of Run 5, also indicated a strong similarity of movement patterns between runs.

No significant size difference was detected between fish which moved and those remaining in the section. Moving fish were virtually random samples of the original plantings.

Diurnal movement patterns

The time factors were also considered on the basis of hours of the day when fish moved. The day was divided into 2-hour intervals, and the numbers of fish moving during each interval were pooled over all runs. Two aspects were considered for each run: the first 5 to 8 days of high movement, termed Early Phase; and the latter 6 to 9 days of decreased movement, termed Late Phase (Figure 4; Appendix, Table 6).

Highest movement during Early Phase occurred between 2100 hours and 2400 hours, beginning immediately after sunset, and increased again between 0700 hours and 0800 hours, beginning immediately after sunrise.

Late Phase movement was lowest during the hours of darkness (between 2100 hours and 0600 hours), and relatively higher during daylight hours. Greatest movement was observed immediately before sunset and after sunrise.

Influencing Variables

Variables considered

A number of environmental and behavioral variables suspected of initiating or directing fish movement were considered. Three

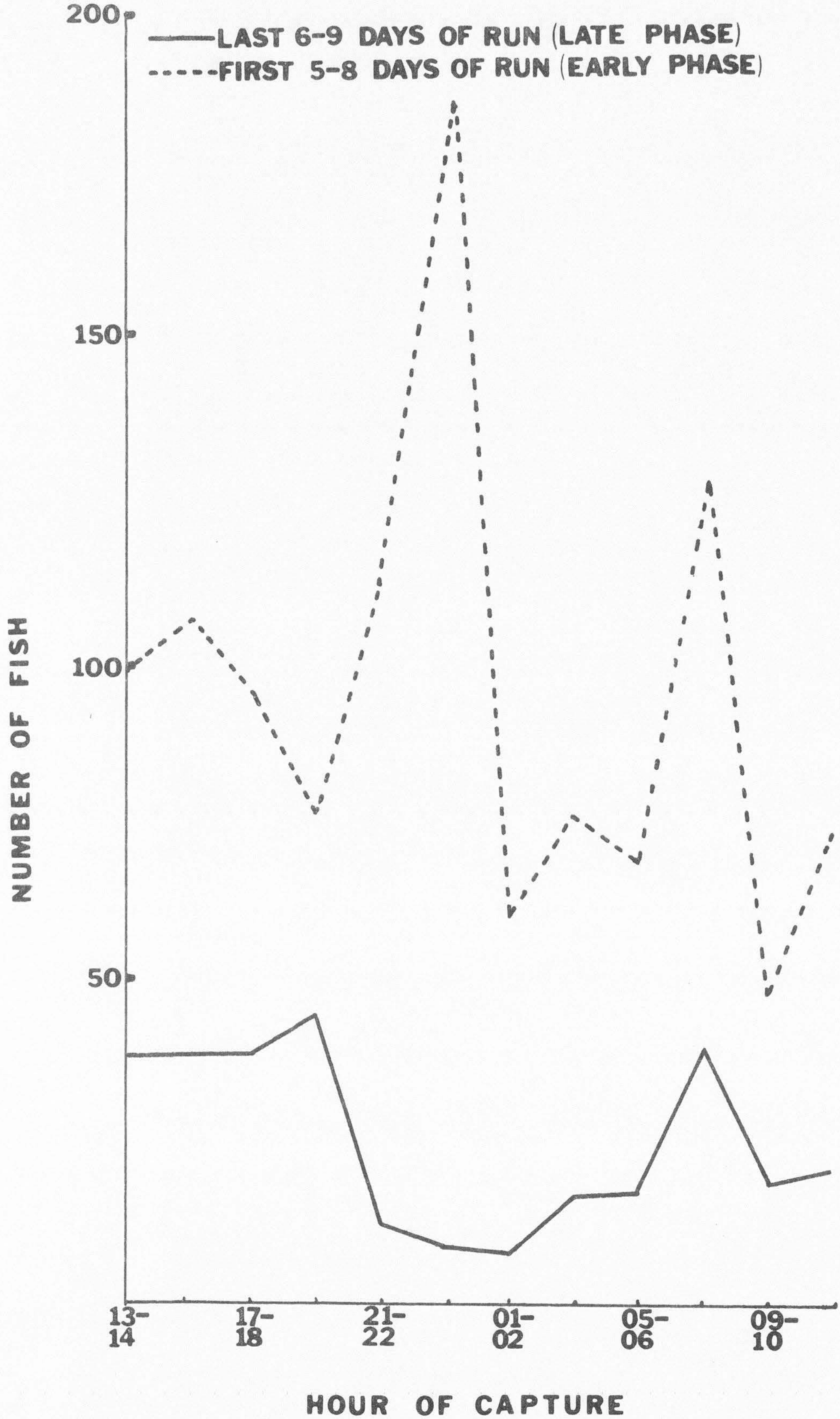

Figure 4. Diurnal fish movement pooled over five runs of 14 days each, Temple Fork, 1972

measures of daily water temperature were utilized: the maximum, minimum, and mean (an average of temperatures at eight 3-hour intervals). Water velocity, depth, and discharge were also considered, as was daylength (duration of visible light). Additional variables were average length, weight, and condition factor (K factor) of fish moving each day and the number of fish remaining in the study section at the beginning of each day.

Multiple regression analysis of variables

The unique contributions of these 11 factors to the variability of fish movement were determined through multiple regression analysis. The number of fish moving each day was used as the dependent variable in the analysis.

A stepwise deletion process was used, in which the independent variable with the smallest mean square was deleted successively until only one independent variable remained. Three separate analyses were made: all days combined, Early Phase alone, and Late Phase alone. The order of deletion and resultant R^2 values (portion of the total variability accounted for by the independent variables) are given in Table 4.

All days combined. The R^2 values indicated that 55% of the variability of fish movement was accounted for by the 11 independent variables. Three variables were significant (at the 0.05 level): fish remaining, daylength, and water depth (Appendix, Table 7). Fish remaining and daylength seemed to be the most important variables in the regression, as the R^2 value decreased only to .47 after deletion of the other 9 variables (Table 4).

Table 4. Order of rejection of independent variables and resultant R^2 values for multiple-regression analyses of fish movement in Temple Fork, 1972

Variable rejected	R^2 value
All days combined	
Intact analysis	.55
Mean temperature	.54
Minimum temperature	.54
Average length	.53
Average K factor	.52
Average weight	.52
Water velocity	.50
Discharge	.50
Maximum temperature	.49
Water depth	.47
Daylength	.16
Fish remaining	
Early Phase alone	
Intact analysis	.47
Maximum temperature	.47
Fish remaining	.45
Mean temperature	.43
Minimum temperature	.41
Average length	.38
Average weight	.38
Average K factor	.36
Discharge	.30
Water velocity	.29
Water depth	.03
Daylength	
Late Phase alone	
Intact analysis	.29
Mean temperature	.29
Maximum temperature	.29
Fish remaining	.28
Water velocity	.27
Water depth	.27
Discharge	.26
Minimum temperature	.25
Average length	.23
Average weight	.19
Daylength	.10
Average K factor	

Early Phase alone. The 11 independent variables accounted for 47% of the variability in this analysis. Water velocity and water depth were the only significant (0.05 level) variables (Appendix, Table 8). Water depth and daylength were the most important variables in the regression. Deletion of the other 9 variables decreased the R^2 value to .29 (Table 4).

Late Phase alone. The R^2 values indicated that 29% of the variability was accounted for by 11 variables. None of the variables were significant (Appendix, Table 9). The most important variables were daylength and average K factor (Table 4).

DISCUSSION

Time Factors

General movement patterns

The general patterns of movement during each run tended to be quite consistent. Although a greater number of fish were present in the study section at the beginning of each subsequent run, the rate of movement tended to decrease with each run. The substantial decrease in both number of movers and movement rate during Run 5 can probably be attributed to the greater size of the experimental fish at the end of the hatchery season (Table 1), allowing them to better maintain position.

A June to September seasonal variation should not be inferred from the above results, although more fish seemed to have moved in mid-summer than during Runs 1 and 5. The corrections for trap efficiency may have erroneously indicated this relationship and further investigation would be necessary in order to draw such conclusions.

The density of salmonids in streams is often assumed to be regulated by social behavior (McFadden, 1969). Several investigators (Chapman, 1962, 1966; Chapman and Bjornn, 1969) have concluded that forced emigration due to aggression is the mechanism of density regulation in some species. However, in a study involving hatchery rainbow trout, Jenkins (1971) concluded that social density limitation through forced movement was inoperative or ineffectual.

The movement patterns in Temple Fork seem to indicate that forced movement as a result of social behavior and aggression did not occur. If such factors were acting, one would expect higher numbers of movers and movement rates as fish density increased with subsequent runs. The absence of a significant size differential between movers and non-movers also indicates that aggression did not force smaller fish to move from the section in greater numbers.

Temple Fork has an abundant amount of drifting food organisms (Pearson and Kramer, 1972; Waters, 1968, 1969b) which may tend to decrease the role of social behavior in forcing movement. Chapman (1966) has noted that stream salmonids seem able to reduce aggression and tolerate contemporaries at closer range if food is very abundant.

Diurnal movement patterns

The definite delineation between Early Phase and Late Phase during all runs may offer an explanation of observed diurnal patterns. Since similar patterns were noted in every run, the number of movers in each 2-hour interval was pooled to indicate differences more clearly.

To explain these differences, one could hypothesize that Early and Late Phase movers constitute two distinct groupings of fish. Movements during Early Phase could be considered the result of disorientation due to handling and stocking stresses and unfamiliarity with the study section. Fish in this group tended to move primarily during the hours of darkness and did so in large numbers. The fish in this disoriented state may have utilized these periods of minimal visible light to move from the study section.

Jenkins (pers. comm.) has observed large groups of trout dispersing gradually from the stocking point during the first day and suddenly making mass movements downstream after dark. In social behavior studies on hatchery rainbow trout, Jenkins (1971) has made a distinction between migration (sudden mass movement of large groups of fish) and dispersal (individual movements at various speeds).

Conversely, the Late Phase movements might be considered as typical, or "normal", activities. This group of fish tended to confine their movements to the daylight hours between dawn and dusk and moved at relatively lower levels than Early Phase fish. Several other salmonid species are normally day-active (Pinsky, 1962; Swift, 1962, 1964) and reach peak activity at dawn and at dusk.

Diurnal patterns observed in this group of fish may indicate a response to food availability. The dominant drift organism in the study section is a day-active caddisfly, (*Oligophlebodes sigma*), as described by Waters (1968). Since it might be expected that day-active drift organisms would be of greater significance in fish feeding activity (Waters, 1969a), one might infer that these fish were moving while utilizing this food source during the periods of maximum visible light.

Influencing Variables

Of primary interest in the analyses of factors possibly influencing fish movement was the fact that a large amount of the variability was not accounted for. Either there were other important factors not included in the analyses, or complex interactions between variables were taking place. The inclusion of a measure of food availability into the analyses would possibly have been of value, but collection of such data was not within the scope of this study.

Of the variables considered, daylength (a measure of the duration of visible light) was quite important in each analysis. Early Phase movement may have occurred primarily during the hours of minimal visible light because the darkness offered these disoriented fish a feeling of security. As indicated above, the fish moving during Late Phase were possibly utilizing the periods of visible light for feeding. Therefore, daylength would seem to be an influencing variable on fish movement, although it may have acted on the two groupings of fish (Early and Late Phase) in different ways.

An obvious difference between the Early Phase and Late Phase analyses occurred regarding the relative importance of the stream physical parameters (water depth, velocity, and discharge) and the physical condition of the fish themselves (average length, weight, and K factor) in the two groups.

Regarding the hypothesis that two distinct groupings of fish were present, one might infer that the disoriented Early Phase movers were affected to a greater extent by these stream parameters and forced to move out of the section irregardless of their physical condition. Conversely, the Late Phase movers seemed more stable and better able to cope with problems presented by the stream environment and were instead responsive to individual variations in physical condition. In both cases, the order of rejection of independent variables and resulting R^2 values (Table 4) indicate that such influences may be occurring.

However, such observations are only possibilities and require further investigation. The danger of assuming causation from correlation of variables is well known in biological research, especially in situations where high amounts of unaccountable variability and few degrees of freedom are present.

Applications and Recommendations

Additional investigation in this area seems necessary in order to apply the results of this study to fishery management. Evidently a high proportion of newly stocked trout begin to move soon after planting and continue to do so at high levels for approximately one week. Consideration and increased knowledge of this phenomenon when planning stocking programs may enable fishery managers to insure that fish remain in an area accessible to anglers.

In order to properly evaluate stocking programs in high gradient streams, further research is required as to the distance fish can be expected to move under various conditions. Previous studies (Bjornn and Mallet, 1964; Cooper, 1952; Newell, 1957; Ratledge and Cornell, 1953) in wide and slow streams have indicated that movement is limited to short distances from the stocking point. Fish in this study obviously moved at least 500m and some study fish were observed over three kilometers downstream of the section.

Studies conducted simultaneously on a number of stream locations could indicate the effects of gradient and other parameters on movement. However, because of manpower requirements, some type of automated monitoring system with recording ability would be desirable. As indicated previously, some measure of food availability also seems warranted in further investigations.

Additionally, the design of more efficient fish traps to preclude loss of moving fish and analysis of subsequent results with more sophisticated statistical and mathematical techniques would enhance the value of further research.

CONCLUSIONS

Large numbers of fish began moving from the study section within one day after stocking and continued at this level for 5-8 days. During this period most movement occurred in the hours of darkness, possibly because of the disoriented state of the fish. Social behavior and aggression did not seem to force movement.

Additional movement occurred at a much lower level for the next 6-9 days. The majority of this latter movement took place during daylight hours, probably in response to the diurnal periodicity of day-active food organisms in the drift.

The variables suspected of initiating or directing fish movement accounted for only 55% of the observed variability. The duration of visible light seemed to be one of the most important variables in all analyses, affecting both Early Phase and Late Phase movers but probably in different ways. Stream physical parameters seemed to affect Early Phase movers to a greater extent than did physical condition of the fish themselves, and vice versa with Late Phase movers.

The need for further investigation with more sophisticated equipment and analytical techniques, as well as inclusion of additional variables and study sites, is indicated.

LITERATURE CITED

Bjornn, T. C., and J. Mallet. 1964. Movements of planted and wild trout in an Idaho river system. Trans. Am. Fish. Soc. 93:70-76.

Brynildson, O. M. 1967. Dispersal of stocked trout in five Wisconsin streams. Wisc. Conser. Dept., Res. Rept. No. 26 (Fisheries), 9 p.

Chapman, D. W. 1962. Aggressive behavior of juvenile coho salmon as a cause of emigration. J. Fish. Res. Bd. Canada 19: 1047-1080.

Chapman, D. W. 1966. Food and space as regulators of salmonid populations in streams. Amer. Nat. 100:345-357.

Chapman, D. W., and T. C. Bjornn. 1969. Distribution of salmon and trout in streams, with special reference to food and feeding, p. 153-176. In T. G. Northcote (ed.) Salmon and trout in streams. H. R. Mac Millan Lectures in Fisheries, Univ. of British Columbia, Vancouver, B.C.

Cooper, E. L. 1952. Returns from plantings of legal-sized brook, brown, and rainbow trout in the Pigeon River, Otsego County, Michigan. Trans. Am. Fish. Soc. 82:265-280.

Dell, M. B. 1968. A new fish tag and rapid, cartridge-fed applicator. Trans. Am. Fish. Soc. 97:57-59.

Jenkins, T. M., Jr. 1971. Role of social behavior in dispersal of introduced rainbow trout (Salmo gairdneri). J. Fish. Res. Bd. Canada 28:1019-1027.

Kramer, R. H. 1969. Approaches to develop fish-suitability criteria. Proc. West. Assn. Game & Fish Comm. 49:225-233.

McFadden, J. T. 1969. Dynamics and regulation of salmonid populations in streams, p. 313-329. In T. G. Northcote (ed.) Salmon and trout in streams. H. R. MacMillan Lectures in Fisheries, Univ. of British Columbia, Vancouver, B.C.

Newell, A. E. 1957. Two-year study of movements of stocked brook trout and rainbow trout in a mountain trout stream. Prog. Fish-Cult. 19:76-80.

Northcote, T. G. 1967. The relation of movements and migrations to production in freshwater fishes, p. 315-344. In Gerkin, S. D. (ed.) The biological basis of freshwater fish production. New York, John Wiley & Sons Inc.

Pearson, W. D., and R. H. Kramer. 1972. Drift and production of two aquatic insects in a mountain stream. Ecol. Mon. 24:365-385.

Pinsky, F. Y. 1962. Migratory behaviour of juvenile rainbow trout, (Salmo gairdneri) in outlet and inlet streams of Loon Lake, British Columbia. J. Fish. Res. Bd. Canada 19:201-270.

Ratledge, H. M., and J. H. Cornell. 1953. Migratory tendencies of the Manchestor (Iowa) strain of rainbow trout. Prog. Fish-Cult. 15:57-63.

Ricker, W. E. 1958. Handbook of computations for the biological statistics of fish populations. Bull. Fish. Res. Bd. Canada 119:1-300.

Swift, D. R. 1962. Activity cycles in the brown trout (Salmo trutta Lin.) 1. Fish feeding naturally. Hydrobiologia XX:241-247.

Swift, D. R. 1964. Activity cycles in the brown trout (Salmo trutta Lin.) 2. Fish artificially fed. J. Fish. Res. Bd. Canada 21:133-138.

Waters, T. F. 1968. Diurnal periodicity in the drift of a day-active stream invertebrate. Ecology 49:152-153.

Waters, T. F. 1969a. Invertebrate drift--ecology and significance to stream fishes, p. 121-134. In T. G. Northcote (ed.) Salmon and trout in streams. H. R. MacMillan Lectures in Fisheries, Univ. of British Columbia, Vancouver, B.C.

Waters, T. F. 1969b. Diel patterns of aquatic invertebrate drift in streams of northern Utah. Utah Acad. Proc., 46:109-130.

Zippen, C. 1958. The removal method of population estimation. J. Wildl. Mgmt. 22:82-90.

APPENDIX

Table 5. Summary of estimated fish remaining in section at beginning of each day, Temple Fork, 1972

	Run 1	Run 2	Run 3	Run 4	Run 5
Day	Fish remaining	Fish remaining	Fish remaining	Fish remaining	Fish remaining
1	398	536	613	662	721
2	371	514	538	652	700
3	339	474	506	592	675
4	302	427	474	539	671
5	275	380	394	496	644
6	264	345	367	430	615
7	245	310	351	394	590
8	216	300	335	367	571
9	205	290	330	366	540
10	200	273	314	363	539
11	195	266	313	353	529
12	187	264	308	350	519
13	182	247	307	343	515
14	177	227	291	333	509

Table 6. Summary of diurnal fish movements, Temple Fork, 1972

Time interval	Run 1 Day 1-7	Run 1 Day 8-14	Run 2 Day 1-6	Run 2 Day 7-14	Run 3 Day 1-5	Run 3 Day 6-14	Run 4 Day 1-7	Run 4 Day 8-14	Run 5 Day 1-8	Run 5 Day 9-14	Total	Early Phase	Late Phase
						Observed movement							
1300-1400	3	1	6	5	1	2	12	2	16	3	51	38	13
1500-1600	2	5	8	4	3	1	15	2	8	2	50	36	14
1700-1800	4	3	8	5	3	3	10	1	8	0	45	33	12
1900-2000	3	0	4	6	3	4	9	2	6	1	38	25	13
2100-2200	9	1	7	2	4	1	7	0	14	0	45	41	4
2300-2400	13	0	23	2	10	0	5	0	13	2	68	64	4
0100-0200	2	1	7	2	4	0	3	0	4	0	23	20	3
0300-0400	8	3	6	1	2	1	8	0	1	1	31	25	6
0500-0600	8	1	4	0	4	2	1	0	7	2	29	24	5
0700-0800	10	1	10	6	7	2	8	3	6	0	53	41	12
0900-1000	3	1	3	1	2	1	3	1	6	3	24	17	7
1100-1200	3	4	5	2	3	0	8	1	5	1	32	24	8
						Adjusted movement							
1300-1400	8	3	15	12	5	11	40	7	31	6	138	99	39
1500-1600	5	13	20	10	16	5	50	7	15	4	145	106	39
1700-1800	11	8	20	12	16	16	33	3	15	0	134	95	39
1900-2000	8	0	10	15	16	21	30	7	12	2	121	76	49
2100-2200	24	3	17	5	21	5	23	0	27	0	125	112	13
2300-2400	34	0	57	5	54	0	17	0	25	4	196	187	9
0100-0200	5	3	17	5	21	0	10	0	8	0	69	61	8
0300-0400	21	8	15	2	11	5	27	0	2	2	93	76	17
0500-0600	21	3	10	0	21	11	3	0	14	4	87	69	18
0700-0800	27	3	25	15	37	11	27	10	12	0	167	128	39
0900-1000	8	3	7	2	11	5	10	3	12	6	67	48	19
1100-1200	8	11	12	5	16	0	27	3	10	2	94	73	21

Table 7. Abbreviated regression analysis of factors affecting fish movement, all days combined, Temple Fork, 1972

Source of variation	Degrees of freedom	Mean square
Total	69	325.005
Maximum temperature	1	96.345
Minimum temperature	1	110.811
Mean temperature	1	24.509
Water velocity	1	613.870
Water depth	1	757.701*
Discharge	1	629.739
Daylength	1	2218.586*
Average length	1	280.782
Average weight	1	333.418
Average K factor	1	353.138
Fish remaining	1	7370.683*
Model	11	1113.055
Error	58	175.548

*Significant at the 0.05 level.

Table 8. Abbreviated regression analysis of factors affecting fish movement, Early Phase alone, Temple Fork, 1972

Source of variation	Degrees of freedom	Mean square
Total	32	299.127
Maximum temperature	1	71.027
Minimum temperature	1	219.294
Mean temperature	1	93.314
Water velocity	1	1158.945*
Water depth	1	1163.231*
Discharge	1	1032.403
Daylength	1	1005.155
Average length	1	432.534
Average weight	1	486.546
Average K factor	1	583.339
Fish remaining	1	244.063
Model	11	411.898
Error	21	240.056

*Significant at the 0.05 level.

Table 9. Abbreviated regression analysis of factors affecting fish movement, Late Phase alone, Temple Fork, 1972

Source of variation	Degrees of freedom	Mean square
Total	36	31.559
Maximum temperature	1	0.291
Minimum temperature	1	4.490
Mean temperature	1	0.065
Water velocity	1	11.101
Water depth	1	13.541
Discharge	1	16.937
Daylength	1	19.703
Average length	1	17.926
Average weight	1	21.744
Average K factor	1	36.232
Fish remaining	1	0.739
Model	11	29.571
Error	25	32.433

VITA

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Master of Science

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Major Field: Fishery Biology

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