DISPERSION PATTERNS OF HATCHERY-REARED RAINBOW TROUT STOCKED IN A VIRGINIA MOUNTAIN STREAM

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Abstract: Dispersion patterns of 578 tagged rainbow trout stocked into pool and riffle habitats of Big Stony Creek, Giles County, Virginia, were determined from voluntary tag returns and a creel census of fishermen during the 1979-80 trout fishing season. Twenty-two percent of the trout remained within the original 30 m stocking location; 45 percent of the trout moved downstream while 33 percent moved upstream. The median dispersion distance and direction for all trout that moved beyond the initial release sites was 30 m downstream. The majority (75%) of the marked fish were caught within 400 m of the stocking location. There was no significant difference ($P > 0.136$) between the median distance moved of trout stocked into pools and those stocked into riffles.

Three major physical factors (residence time, water temperatures, and stream flow rates) were found to strongly influence stocked trout dispersion. The distance trout moved was directly correlated ($R = 0.50$, $P < 0.001$) with the amount of time in the stream. During stream conditions of low water temperatures and high flow rates, trout dispersion increased. Movement of spring stocked rainbow trout was primarily downstream, while movement of fall stocked trout was upstream. Summer stocked rainbow trout showed little movement.

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Trout stocking constitutes a significant portion of the freshwater fisheries management programs in the United States. Nationwide, about 23 percent of state fishery-management budgets are reserved for fish-cultural programs, with salmonid hatcheries accounting for 82 percent of the total fish-rearing expenditures (Everhart et al. 1975). Most of these trout are assigned to catchable-sized, put-and-take fishery programs. In Virginia, approximately 77 percent of the fish stocked in the state are allocated to such a program (Wollitz 1978). Over 1,000,000 trout weighing nearly 410,000 pounds are stocked annually into approximately 185 streams in 40 counties of western Virginia.

Put-and-take fishing, when developed to its ultimate, involves no consideration of overwinter survival, carrying capacity, or food availability (Wood 1953). The essential management element is the anticipated fishing pressure over a given time period. An adequate number of fish are then allocated to meet the estimated take. An immediate and substantial return of fish to the fishermen is the desired objective of catchable trout programs.

Rainbow trout *(Salmo gairdneri)* is the predominant species used in catchable trout programs. Rainbow trout have intermediate catchability, being considered easier to catch than brown trout *(S. trutta)*, although not as easily caught as brook trout *(Salvelinus fontinalis)* (Cooper 1959). Rainbow trout, however, are more migratory than the other 2 species (Shetter and Hazzard 1940, Trembley 1943, Shetter 1944). Since trout that move out of authorized public fishing waters represent a substantial recreational and economic loss, the expected dispersion patterns of stocked fish and those factors that influence movement are important management considerations. A general knowledge of dispersal behavior of hatchery-reared trout and the primary mechanisms that regulate movement could enhance catchable trout programs by developing methods to increase holdover and, thereby maximize angler yield and satisfaction.

Although the movement of hatchery-reared rainbow trout has been described by a number of researchers (Trembley 1943, Shetter 1944, Stefanich 1951, Cooper 1952, Ratledge and Cornell 1953, Newell 1957, Bjornn and Mallet 1964, Klein 1974), most of these studies were conducted on relatively wide, slowly flowing rivers. Comparatively little is known about the dispersion of rainbow trout stocked in the relatively narrow, swift mountain streams typical of Virginia's catchable trout waters.

This study was initiated to describe the dispersion patterns of hatchery-reared rainbow trout stocked in Big Stony Creek, a mountain stream in Giles County, Virginia. The specific objectives were: (1) to determine the direction and amount of movement following stocking, (2) to compare the dispersion patterns of trout stocked in pools with those planted in riffle habitats, (3) to describe and compare seasonal dispersal patterns of trout stocked at 6 different times throughout the year, and, (4) to examine the influence of temperature, flow, and residence time on the movement of stocked rainbow trout.

METHODS

Big Stony Creek, a tributary of the New River, is located in Giles County near Pembroke, Virginia. The stream lies within the Ridge and Valley physiographic province of southwestern Virginia (Hoffman 1969). Big Stony Creek is typical of Virginia's mountain streams and is characterized by steep gradient, coarse substrate, and abundant riparian vegetation. The stream is second order, being fed by 2 permanent and several intermittent tributaries, drains an area of 125.9 km^2, and is approximately 23.0 km in length with an average fall of 21.4 m/km.

Approximately 13.7 km of Big Stony Creek lies within the Jefferson National Forest interspaced with private land ownership. The stream is easily accessible as it parallels State Route 635. The stream is heavily stocked and is intensively fished because of its easy access and large amount of public ownership. An upper 5.5 km section of Big Stony Creek was selected as the study site. The study area is bounded downstream by the Forest Service's Interior Park and upstream by private land 0.9 km above Forest Service Road 942.

The stream substrate consists primarily of gravel and boulders. Stream flows range from greater than 6.5 m^3/sec in March and October to a low of 0.41 m^3/sec in August. Stream temperatures ranged from a low of 4° C in March to a high of 18° C in July. Dissolved oxygen levels were characteristically high (95 percent of saturation) and the pH was slightly alkaline (7.4). Resident fishes observed in Big Stony Creek were: creek chub *(Semotilus atromaculatus)*, blacknose dace *(Rhinichthys atratulus)*, longnose dace *(R. cataractae)*, mountain redbelly dace *(Phoxinus oreas)*, rosyside dace *(Clinostomus funduloides)*, northern hogsucker *(Hypentelium nigricans)*, white sucker *(Catostomus commersoni)*, mottled sculpin *(Cottus bairdi)*, and fantail darter *(Etheostoma flabellare)*.

The study area was divided into 183 individual 30 m sections sequentially numbered as one proceeds upstream. Each section was prominently marked with plastic flagging. Three pools and 3 riffle habitats, as uniform as possible, were selected to examine the influence of habitat on dispersion patterns. Stocking was in accordance with the state of Virginia's 1979 scheduled stockings in March, May, June, July, September and October. The dates, residence times and total numbers of tagged rainbow trout stocked into Big Stony Creek are presented in Table 1. Virginia's trout season was closed from February 15 through April 6, and also from May 7 through 11 for restocking. This opening and re-opening of the trout season permitted a comparison of the effects of residence time on trout dispersion. The data of February 26 and March 1, March 19 and March 22, and May 7, 10, and 11, were pooled and are subsequently referred to as the March 1, March 19 and May 10 stockings, respectively.

Each of the 3 pool and riffle habitats were stocked with 40 individually marked rainbow trout, except on October 9, when 35 fish per site were stocked. All trout were obtained

Table 1. Stocking schedule, effective residence time and numbers of tagged rainbow trout stocked into Big Stony Creek, 1979.

Date	Residence Time (Days)[1]	Number of Fish
February 26	40	142
March 1	37	147
March 19	19	150
March 22	16	150
May 7	5	221
May 10	2	245
May 11	1	246
June 11	0	297
July 2	0	310
September 24	0	310
October 9	0	210
Total		2428

[1]Length of time trout were in the stream before fishing was permitted.

from Coursey Springs State Fish Rearing Station. The trout were individually marked with Floy internal anchor tags (Dell 1968) and held in pens at the hatchery 3-5 days before stocking to ascertain any tagging mortality. No mortality was observed during the holding periods. Lengths and weights for a sub-sample of 20 randomly chosen trout per stocking date were recorded. Mean total length ranged from 26 to 29 cm and mean wet weight ranged from 193 to 286 grams.

Data on trout movement and harvest from Big Stony Creek were collected primarily through creel censusing of fishermen. Creel censusing has been shown to be an effective method for obtaining returns on the movements of fish (Stefanich 1951). Creel clerks interviewed all fishermen encountered utilizing pre-printed creel forms. Items of primary interest included: numbers of fish caught, number of tagged fish caught, where caught and numbers of hours fished. Creel censusing was conducted daily for the first week after each stocking date. In addition, random periodic creel censusing was conducted throughout the fishing season until November 30, at which time fishing pressure was minimal. Additional information was obtained through voluntary returns of fish tags by fishermen, telephone responses and through the local game checking station. Non-parametric statistical procedures were applied to the various data sets. The individual tests employed for the various comparisons are given in the results.

RESULTS AND DISCUSSION

From 2428 tagged rainbow trout, 688 tags, representing a return rate of 28 percent, were recovered from anglers during the study. Of these returns, anglers could supply information to adequately identify individual capture sites (within a 30 m section) for 578 trout. Capture site information for the remaining 16 percent (110 trout) of the returns was insufficient to evaluate movement. Recovery rates of tagged rainbow trout in other published studies have ranged from 3-25 percent (Moring 1980), 5-17 percent (Bjornn and Mallet 1964), 22-41 percent (Ratledge and Cornell 1953), and 1-38 percent (Shetter 1944).

In comparison, our recovery rate was moderately high and, we feel, quite representative of the stocked population.

Movement After Stocking

Dispersion patterns, as a function of percent recovery, distance, and direction, for 578 hatchery-reared rainbow trout stocked in Big Stony Creek during 1979 are presented in Fig. 1. Most of the trout did not move far from the release sites. The majority (75%) of the trout were recovered within 400 m of the stocking sites; 22 percent of the marked population remained within the 30 m sections into which they were introduced. In terms of direction, 45 percent of the fish were recovered downstream while 33 percent were recaptured upstream of the release sites. The median dispersal distance and direction for all trout that moved beyond the initial release sites was 30 m downstream.

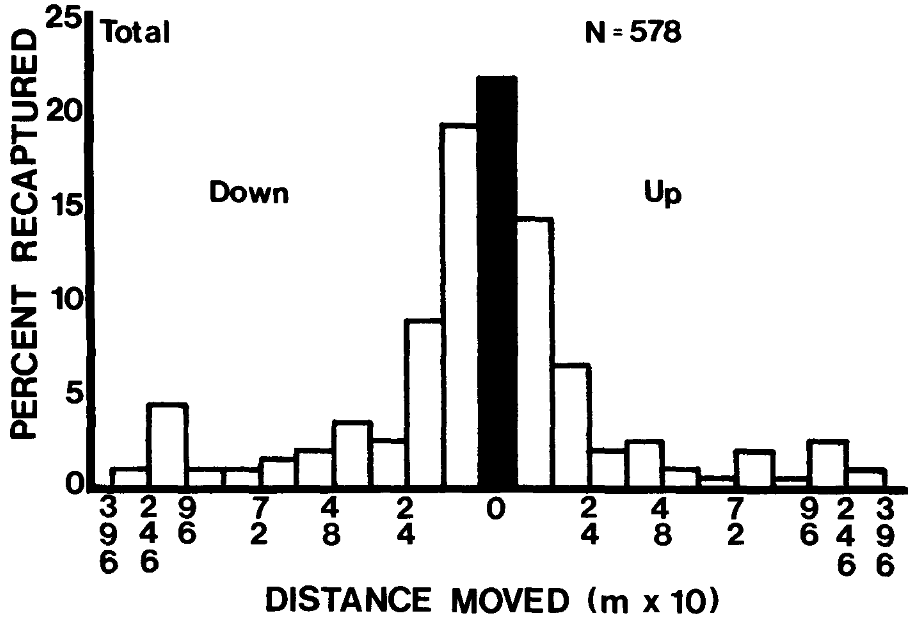

Fig. 1. Percent recovery, distance and direction moved of 578 hatchery-reared rainbow trout stocked into Big Stony Creek, 1979.

These data clearly show that the movement of tagged, hatchery-reared rainbow trout stocked in Big Stony Creek was restricted to a relatively short distance from the release site. Although the majority of the trout did move beyond the immediate stocking site, the observed median recovery distance was only 30 m. A number of other researchers have also concluded that hatchery-reared, rainbow trout are largely sedentary and exhibit little or no movement after stocking (Trembley 1943, Shetter 1944, Stefanich 1951, Cooper 1952, Ratledge and Cornell 1953, Newell 1957, Bjorn and Mallet 1964, Klein 1974).

Comparative studies relating genetic differences in various trout stocks to movement have produced conflicting results (Carbine 1953, Ratledge and Cornell 1953, Moring and Buchanan 1978). While it is recognized that any rainbow trout stock may have latent migratory tendencies (Carbine 1953), the movement of hatchery-reared rainbow trout does not appear to be an inherent migratory tendency such as that exhibited by salmon or sea-run races of trout, but rather a localized movement initiated by specific conditions of the environment at the time of stocking (Cooper 1959). Although a few marked trout were recovered beyond our study area (in excess of 3 km), evidence of any lengthy upstream or downstream migratory tendency was not observed. Our results indicated that stocked rainbow trout moved downstream more frequently than upstream. Other studies have similarly reported a greater tendency for hatchery-reared rainbow trout to move in a downstream direction (Newell 1957, Ratledge and Cornell 1953).

Effects of Habitat

A comparison of the dispersion patterns between rainbow trout stocked into pools with those stocked into riffle habitats is shown in Fig. 2. Regardless of the habitat, most trout were recovered near the release site. Of the 283 rainbow trout stocked into pools and the 295 trout stocked into riffles, 22 and 21 percent, respectively, remained within the 30 m release site. No distinct directional movement was evident for those fish stocked into pool habitats. Thirty-eight percent of the trout released into pools moved downstream while 40 percent moved upstream. In contrast, rainbow trout stocked into riffle habitats exhibited a marked tendency to move downstream. Fifty-one percent of the trout stocked into riffles were recovered downstream of the release site while only 28 percent were recaptured upstream. The median dispersion distance for trout stocked into pools and that moved out of the release site, 30 m downstream, was not significantly different from zero (Wilcoxon Signed Rank Test, $P > 0.075$). The median dispersion distance for trout stocked into riffles and that moved from the release site, 60 m downstream, was significantly different from zero (Wilcoxon Signed Rank Test, $P < 0.003$).

The greater percentage of rainbow trout moving downstream from riffle areas than pool areas may be due to the increased water velocity encountered in riffle areas. Clothier (1953) reported a direct correlation between water reduction and rainbow trout movement upstream in an irrigation canal, while Northcote (1958) found that the response of juvenile rainbow trout to water currents were of an individual nature. Kalleberg (1958) reported that Atlantic salmon *(Salmo salar)* fry moved upstream as the water velocity was lowered. In this study differences in velocity between habitats were relatively small (mean annual difference of 4.6 cm/s). A comparative analysis of the median distance moved by all trout stocked into pools versus the median distance moved by all trout stocked into riffles (30 m downstream) showed no significant difference (Wilcoxon Rank Sum Test, $P > 0.136$).

Effects of Season, Water temperature and Flow Rate

Rainbow trout stocked during the spring of the year (March and May) in both habitats exhibited a distinct tendency to move downstream (Table 2). At this time, the median distances moved ranged from 30 to 90 m. Throughout the remainder of the year (June through October), trout stocked in pools moved upstream. The median upstream distance for trout stocked in pools was 30 meters in June, 60 meters in July and 90 m in October. In late September, most of the pool stocked trout remained within the release area. After May, rainbow trout released into riffle areas remained within the stocking site; in October, the trout showed a slight tendency to move upstream. The only statistically significant difference in dispersion distances between trout stocked in pools and those trout stocked in riffles occurred in July and October. During these months, trout stocked in pools moved significantly further (n - ranking method, $P < 0.006$ and $P < 0.001$ respectively) than trout stocked into riffles.

The observed interrelationships between water temperatures, flow rates and trout movements are illustrated in Fig. 3. The directional movement of rainbow trout followed a clear seasonal pattern of downstream movement in the spring and upstream movement in the fall; no appreciable directional movement occurred during the summer months. These distinct downstream-upstream movements were associated with relatively low water temperatures ($< 12°C$) and high flow rates (3.3 m^3/s), characteristic of the spring and fall periods. During the summer "warm water-low flow" conditions (temperatures of 12°C to 18°C, flows of 0.4 to 2 m^3/s), most trout remained in the immediate vicinity of the

Table 2. Seasonal dispersion of rainbow trout stocked into pools and riffles, Big Stony Creek, 1979.

	Pool			Riffle			Total		
Dates	M[1]	Range	n	M	Range	n	M	Range	n
Mar 1	-30	-2700 1560	19	-30	-2280 1710	11	-30	-2700 1710	30
Mar 19	-30	-3140 1620	32	-90	-2940 1890	34	-45	-3140 1890	66
May 10	-90	- 810 900	39	-60	-2810 1110	29	-60	-2810 1110	68
Jun 11	30	- 390 540	21	0	-1170 1260	36	0	-1170 1260	57
Jul 2	60	- 360 60	24	0	- 990 150	32	0	- 990 150	56
Sep 24	0	-1170 2910	41	0	-2010 2280	50	0	-2010 2910	91
Oct 9	90	- 60 2520	5	15	0 150	6	30	- 60 2520	11

[1]Median distance moved (m); Negative values indicate downstream movement

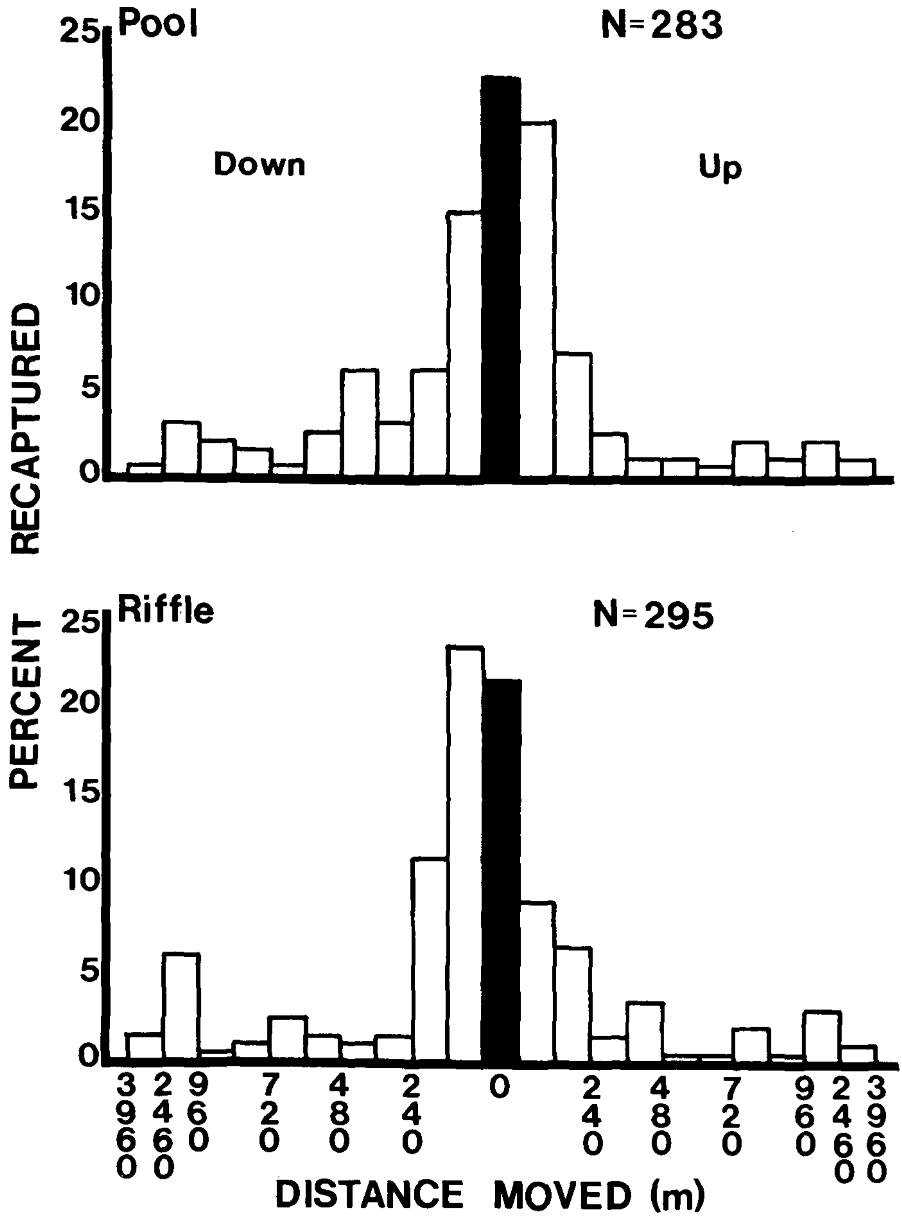

Fig. 2. Percent recovery, distance and direction moved of 283 rainbow trout stocked into pool and 295 rainbow trout stocked into riffle habitats, Big Stony Creek, 1979.

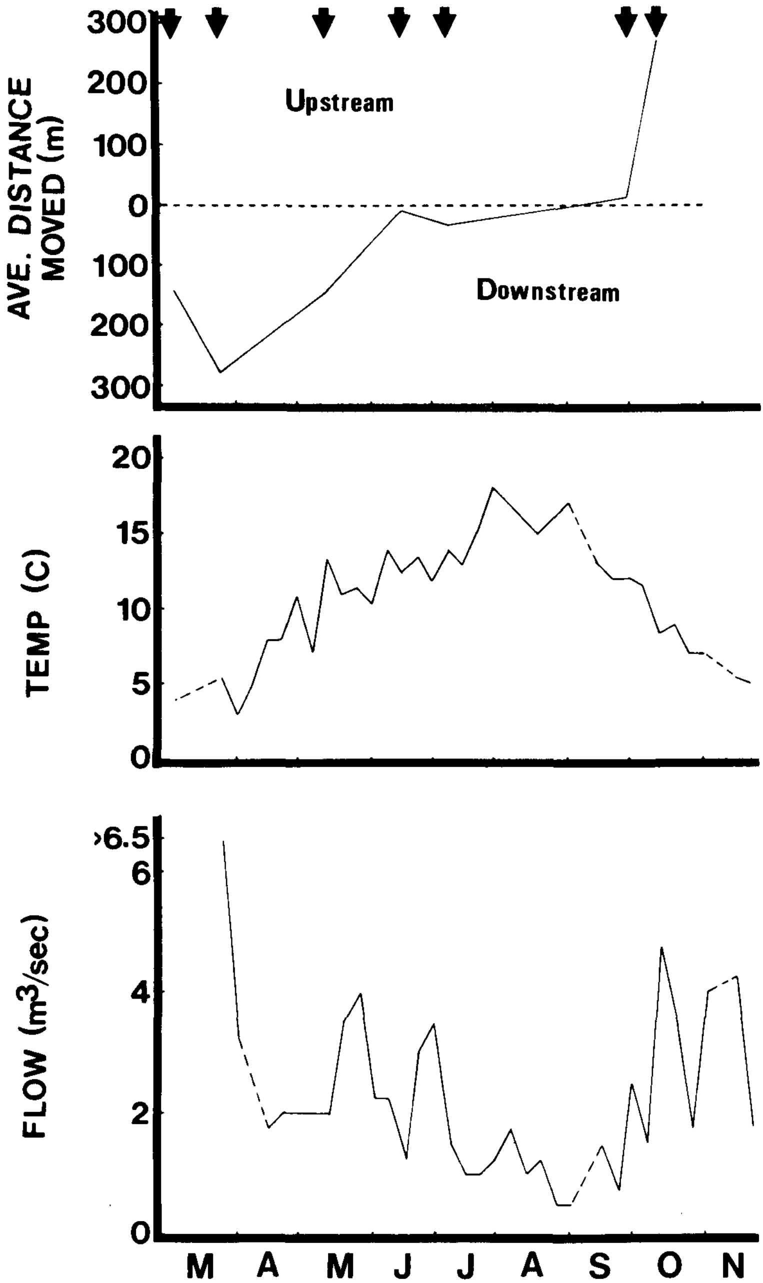

Fig. 3. A comparison of mean weekly water temperatures and flow rates and average distance moved by rainbow trout stocked into Big Stony Creek, 1979. Arrows indicate stocking dates.

release site. The strong downstream movement exhibited by spring stocked rainbow trout appeared to be related to high flow rates and low but increasing water temperatures. In contrast, the strong upstream movement demonstrated by fall stocked rainbow trout was associated with high flow rates and low but decreasing water temperatures.

These results suggest that stream water temperatures and flow rates are interactive physical factors that strongly influence the movements of stocked rainbow trout. Moreover, the data indicates that the direction of movement of trout may be more related to water temperatures, particularly rising or lowering water temperature alterations, than flow rates. The few published studies addressing flow rates and dispersal patterns of stocked trout have produced conflicting results. Newell (1957) concluded that flow had no effect on the movement of rainbow trout, while Clothier (1953) observed increased upstream movement of rainbow trout with reduced flows. Neither of these views could be substantiated by our findings. Although we could not separate the effects of flow from those of temperature on the movement of trout, our data clearly demonstrate that high flows ($> 3m^3/s$) were directly related to increased movements, whereas low flows were strongly associated with decreased mobility.

The influence of water temperature on the directional movements of trout has been more closely examined than that of stream flow. Cooper (1952) found that brook and rainbow trout stocked in the Pigeon River in Michigan, when water temperatures were less than 10°C, exhibited an immediate downstream movement, while trout planted at higher temperatures showed very little movement. Newell (1957) working with rainbow trout in the Swift River in New Hampshire reported similar results. These 2 studies investigated water temperature and dispersal direction of spring and summer stocked trout. Our results, in part, are in close agreement with these findings. We noted a similar downstream movement for spring stocked rainbow trout planted at water temperatures below 12°C and similarly little movement for summer stocked trout at water temperatures from 12° to 18°C. However, we found fall stocked rainbow trout planted in October at a water temperature of 10°C moved upstream rather than downstream as predicted by Cooper and Newell. Brynildson (1967) and Butler and Borgeson (1965) also reported a tendency for fall stocked rainbows, planted at temperatures near or below 10°C, to either move upstream or remain at the release site. Thus, while trout movement increases in cooler waters (near 10°C), it appears that rising or falling temperature regimes, or other unexamined seasonal attributes such as increasing or decreasing light intensities, may be implicated in the direction of dispersal of stocked rainbow trout.

Effect of Residence Time

Residence time, the amount of time the trout were in the stream before capture, was examined as a potential factor influencing the distance moved. Residence times for the trout stocked in Big Stony Creek ranged from 0 to 125 days; movement distances ranged from 0 to 3140 m (Fig. 4). Most of the trout (85%), were recovered within the first 20 days of stocking. The longer the fish were in the stream prior to capture, the greater distance from the stocking location they moved. Movement distance was significantly correlated with residence time (Spearman Rank Correlation, $R = 0.50$, $P < 0.001$). These results are analogous to those of Moring and Buchanan (1978), who reported a greater percentage of rainbow trout stocked 12 days before the season had moved the length of their study section (13.3 km) than trout stocked 2 days before opening day. Although other factors may influence the distance moved by stocked trout, residence time is clearly an important attribute of dispersal.

Management Implications

A number of management implications applicable to catchable trout stocking programs are suggested by the preceding results. First, we found that the dispersion of hatchery-reared rainbow trout was relatively symmetrical and generally restricted to within 400 m of the release site. Moreover, we detected no significant difference in the movement

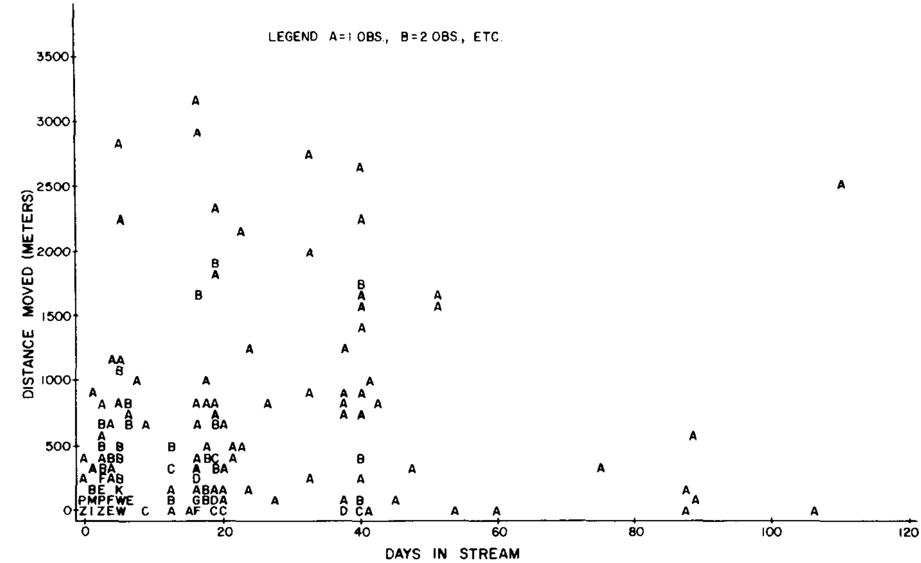

Fig. 4. Relationship between residence time in the stream and distance moved of rainbow trout stocked into Big Stony Creek, 1979.

patterns or the catchability of rainbows stocked into pools and riffle habitats. Therefore, *stocking at approximately 300 meter intervals, into either pools or riffles, and at highly* accessible points along the stream would facilitate a uniform distribution of the fish and a high return to the anglers.

Second, the data clearly shows very distinct seasonal movement patterns of stocked rainbow trout. Apparently, *stream water temperatures and flow regimes strongly influence* both the distance and direction of movement. Rainbow trout stocked into cool ($<$ 12°C) waters with corresponding high flows ($>$ 3 m^3/s) exhibited considerable movement from the release site, while trout stocked into relatively warm ($>$ 12°C) waters during periods of low flow ($<$ 2 m^3/s) remained in the immediate vicinity of the release site. Spring stocked trout planted at low but increasing temperatures moved downstream and fall stocked trout planted at low but decreasing temperatures moved upstream. Therefore, scatter stocking of summer planted fish would insure a better distribution of trout than liberating large numbers of fish at 1 or a few spots along the stream (spot stocking). *Spot stocking of trout in the upstream reaches of public waters during the* spring and in the downstream sections during the fall would accommodate for the directional tendencies exhibited and facilitate a more equitable distribution of the trout in the stream.

Finally, we observed that residence time strongly influenced the dispersion distance of rainbow trout. Residence time was significantly correlated with movement distance; the longer the trout were free in the stream, the greater the distance they moved. Managers, therefore, could directly influence the distribution of trout in a stream and, indirectly, the anglers along the stream bank by manipulating residence time. For example, our results showed that increasing residence time to greater than 20 days before the season opened would increase trout dispersion. This strategy, however, may reduce angler catch as a result of natural mortality or emigration from the area. Conversely, decreasing residence time to a few days prior to opening day would limit dispersion and, consequently, may improve catch rates. Clearly, more research on the influence of abiotic and biotic factors on the movement of stocked trout should be conducted.

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