Movements of the cutthroat trout (Salmo clarki Richardson) in Yellowstone Lake
by Lawrence Allan Jahn

A thesis submitted to the graduate faculty in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE in Zoology
Montana State University
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Abstract:
A study was made of cutthroat trout movement in Yellowstone Lake displaced from their spawning streams during June, July, and August, 1964 and 1965. Three release points were used. Fish were tracked after attachment, of styrofoam floats and their positions recorded. Movement was generally shoreward (eastward) from two near-shore release points. Of 120 fish tracked when the sun was visible, 68.3% went to shore, 19.2% went away from shore, 4.2% showed random movement, and 8.3% were lost. Of 20 fish released when the sun was obscured, 30.0% went to shore, 30.0% went away from shore, 30.0% showed random movement, and 10.0% were lost. Fish liberated at the mid-lake release point traveled generally northward. No directional preference was shown with respect to surface currents. Use of specific landmarks for orientation is doubtful, but the sun may have been used as a reference point since the fish traveled farther and showed a stronger shoreward tendency on sunny days.

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Zoology

Approved:

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Head, Major Department

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Abstract

A study was made of cutthroat trout movement in Yellowstone Lake displaced from their spawning streams during June, July, and August, 1964 and 1965. Three release points were used. Fish were tracked after attachment of styrofoam floats and their positions recorded. Movement was generally shoreward (eastward) from two near-shore release points. Of 120 fish tracked when the sun was visible, 68.3% went to shore, 19.2% went away from shore, 4.2% showed random movement, and 8.3% were lost. Of 20 fish released when the sun was obscured, 30.0% went to shore, 30.0% went away from shore, 30.0% showed random movement, and 10.0% were lost. Fish liberated at the mid-lake release point traveled generally northward. No directional preference was shown with respect to surface currents. Use of specific landmarks for orientation is doubtful, but the sun may have been used as a reference point since the fish traveled farther and showed a stronger shoreward tendency on sunny days.

INTRODUCTION

There are many organisms which exhibit oriented movement, such as birds during seasonal migrations, homing pigeons during races, bats seeking their prey, and sea turtles returning to their natal breeding grounds. Fish also show oriented movements with those of salmonids being perhaps the best known. Lindsey et al. (1959) found that adult rainbow trout (Salmo gairdneri) returned to their homestreams with very little straying, and Shapovalov and Taft (1954) reported similar results for the steelhead trout (Salmo gairdneri gairdneri) and silver salmon (Oncorhynchus kisutch). Johnson and Groot (1963) discovered well-oriented movement of sockeye salmon (Oncorhynchus nerka) through a complex lake system. Stuart (1957) has shown repeat homing, i.e., year after year, and homing following displacement for brown trout (Salmo trutta). Platts (1959) found that artificially spawned cutthroat trout (Salmo clarki) returned to their homestreams after displacement to a Utah reservoir. Ball (1955) showed that most adult cutthroat trout in Yellowstone Lake return to their natal streams, and Cope (1956) reported diurnal variation in their stream movements.

Studies on vision and olfaction have shown these senses to be important for oriented movements of fishes. Investigations concerned with visual cues include Hasler et al. (1958), Henderson (1963), Hasler and Wisby (1958), Schwassmann and Braemer (1961), and Schwassmann and Hasler (1964). Those concerned with olfactory cues include Hasler and Wisby

(1951), Wisby and Hasler (1954), Hasler (1960), Idler et al. (1961), Brett and Groot (1963), and Fagerlund et al. (1963).

The present study was concerned with "open-water" movements of the cutthroat trout to see if movement patterns existed in fish displaced from streams into Yellowstone Lake. "Open-water" is defined here as that part of the lake where depths are sufficiently great to eliminate use of bottom cues for orientation. Research concerned with such movements has recently been undertaken on the white bass (Roccus chrysops) by Hasler et al. (1958) and Henderson (1963), but no work has been done on the "open-water" movements of cutthroat trout.

Yellowstone Lake offers excellent conditions for this study because it is large (362 sq. km.), deep (97 meters maximum), certain basic homing studies have been done, contains an endemic cutthroat trout population not contaminated with trout from other sources, and has permanent fish traps constructed near the mouths of Clear, Cub and Pelican Creeks (Figure 1) where fish are readily available for experimental purposes.

METHODS AND MATERIALS

Field experiments were carried out during June, July and August of 1964 and 1965. The cutthroat trout used were taken from the Clear Creek and Cub Creek traps. These were all sexually mature and moving upstream to spawn. They were netted from the traps and immediately put into a covered tank containing 20-25 liters of creek water. This tank was transported to the boat and then to one of the three selected release points in the lake (Figure 1). It took 6-8 minutes to get to Release Points 1 and

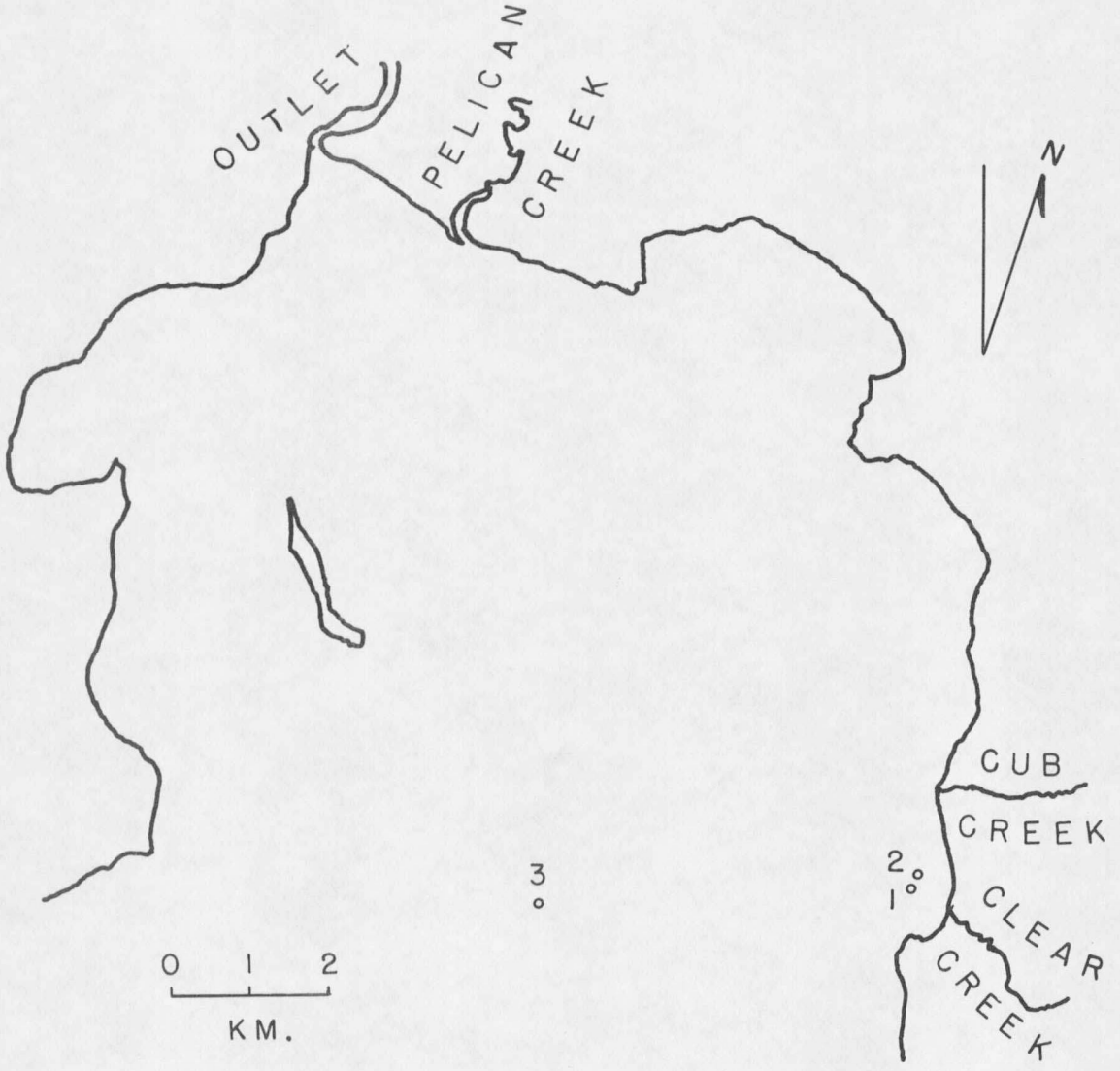

Figure 1. Map of Yellowstone Lake showing the location of release points and creeks where experimental fish were secured.

2 and 14-18 minutes to Release Point 3. The release points were located with reference to the mouth of Clear Creek. Release Point 1 was 0.56 kilometers northwest and Release Point 2 was 0.50 kilometers west-northwest (water depth of 29 meters). Release Point 3 was 5 kilometers directly west (water depth of 89 meters). Release Point 1 was used in 1964 and Release Points 2 and 3 were used in 1965.

At a release point a tracking device was attached at the posterior margin of the dorsal fin of each experimental fish. These fish were then released as quickly as possible and with a minimum of disturbance. Two trout at Release Points 1 and 2 and five trout at Release Point 3 were liberated for each experiment.

Three types of tracking devices were used. The most successful was of the "bobber" type modified from that of Hasler and Wisby (1958). The float consisted of a styrofoam cube, about 5 cm. on a side covered with aluminum foil. This was fastened to one end of a 2 meter nylon line which had an alligator clip tied at the other end.

The device was usually pulled underwater immediately after release of the fish. This condition persisted no longer than 90 seconds, and then the float usually remained at the surface for the rest of the experiment. The float having bright reflective surfaces was clearly visible for a distance of about 0.5 kilometers in calm water. During 1964, the location of experimental fish was determined by sighting on landmarks with the unaided eye. During 1965, a sextant was used which made observations more accurate. The locations of experimental fish were recorded at approxi-

mately ½-hour intervals after release. In order not to disturb the fish, it was necessary to remain at least 20 meters away when recording locations. In final analyses, proper corrections were made in plotting these locations on maps. Plastic floats 6.35 cm. in diameter used by sports fishermen, were tried as floats on this tracking device, but these were less satisfactory than the styrofoam floats.

Experiments originating at Release Points 1 and 2 were usually terminated after 2 hours. It was found early in this study that if fish were not close to shore by that time, their movements were either random or directed away from shore. Experiments were ended sooner than 2 hours if the experimental fish reached water shallow enough so that a silver-colored disk (about 20 cm. in diameter) could be seen on the lake bottom. This indicated that the fish was possibly getting orientational cues from the bottom and was no longer in "open-water". Positions of experimental fish liberated at Release Points 1 and 2 were plotted for 0.5 hours, 1.0 hours, 1.5 hours, and 2.0 hours after release. Locations of some experimental fish were not obtained at the designated time because these fish were temporarily "lost". From these plots, the direction of fish from either release point was determined and the mean direction for each time interval calculated, according to the method described by Batschelet (1965).

Experiments originating at Release Point 3 were terminated after 1 hour, and the fish were picked up as quickly as possible. One sighting was taken on each experimental fish released at this Point, and this was taken at the termination of each experiment. This procedure gave infor-

mation on direction of "take-off". In 1965, 69 fish were recovered and their lengths and sex determined. No length or sex data were taken in 1964.

A drift drogue suspended from a yellow float by a heavy cord at 1 meter was used to detect currents at the approximate depth at which the fish moved. This device was made of 2 aluminum sheets 50 cm. x 41 cm. x 0.15 cm. fitted together at right angles by means of a lengthwise slit halfway through each piece. Sightings on the drift drogue were made at the same intervals as those on experimental fish.

Another device for securing information on direction of "take-off" was described by Horrall (1961). This consisted of a timing mechanism which triggered the inflation of a balloon and dragged the fish to the surface where its position could be determined after any desired period of time. This device had the advantage of not restricting the fish to the upper 2-meter zone of the lake as did the "bobber" type. An attempt to use this device in Yellowstone Lake was unsuccessful probably because of cold water and pressure affecting its operation.

A third device consisted of a tracking table and a calibrated monofilament line attached to the experimental fish with an alligator clip. When the fish pulled out the line, this showed the distance traveled and also the number of degrees from north at any given time. This device proved to be unsatisfactory because of its size and wind interference which caused bowing of the line.

RESULTS

Forty-two fish taken in Clear Creek were tracked from Point 1, June 13 to July 30, 1964. Sixty-five fish from Clear Creek and 33 fish taken in Cub Creek were tracked from Point 2, June 21 to July 19, 1965. Twenty-five Clear Creek fish and 18 Cub Creek fish were released at Point 3 during the period July 23 to August 5, 1965, for experiments to test the direction of "take-off". Fish of similar length were used in all experiments, but males were somewhat smaller (Table I).

Table I. Length and sex of experimental fish, 1965. (Number of fish in parentheses)

Creek of Origin	Release Point	Number and Sex	Length (mm) Range	Average
Clear	2	16 females	340 - 400	366(10)
		10 males		372(1)
Cub	2	21 females	320 - 390	362(21)
		9 males	320 - 360	347(9)
Clear	3	10 females	330 - 360	343(10)
		3 males	290 - 360	333(3)
Cub	3	10 females	340 - 390	366(9)
		6 males	350 - 370	362(6)

The mean directions in degrees from true north (Figure 2) and average straight-line distances traveled (Table II) at given time intervals for fish liberated at Point 1 were: 0.5 hours - 22.0° (north-northeast), 313 meters; 1.0 hours - 55.9° (east-northeast), 448 meters; 1.5 hours - 129.2° (southeast), 502 meters; 2.0 hours - 124.0° (southeast), 535 meters. The mean direction of termination points for all fish was 97.4° (east), or

Table II. Average straight-line distances traveled (in meters) from Release Points 1, 2, and 3 at ½-hour intervals. (Number of experimental fish in parentheses)

Release Point	Creek of Origin	Time After Release (hrs.)	Sunny Weather Distance Range	Sunny Weather Distance Average	Cloudy Weather Distance Range	Cloudy Weather Distance Average	Total Average
1	Clear	0.5	15 - 1003	316 (35)		173 (1)	313
		1.0	130 - 1195	455 (32)	210 - 495	352 (2)	448
		1.5	99 - 1003	545 (16)	142 - 557	350 (2)	502
		2.0	68 - 1109	566 (17)		25 (1)	535
2	Clear	0.5	44 - 804	337 (43)	87 - 538	215 (11)	311
		1.0	99 - 1046	557 (34)	49 - 792	367 (13)	505
		1.5	118 - 1442	619 (16)	185 - 743	359 (8)	532
		2.0	160 - 1430	751 (21)	198 - 725	389 (9)	643
2	Cub	0.5	117 - 792	382 (29)		328 (1)	380
		1.0	106 - 861	446 (21)	155 - 409	282 (2)	432
		1.5	217 - 984	574 (10)		861 (1)	601
		2.0	180 - 954	414 (6)		594 (1)	439
3	Clear	1.0	226 - 1843	731 (14)	150 -1655	555 (8)	667
3	Cub	1.0	75 - 1279	638 (17)			638

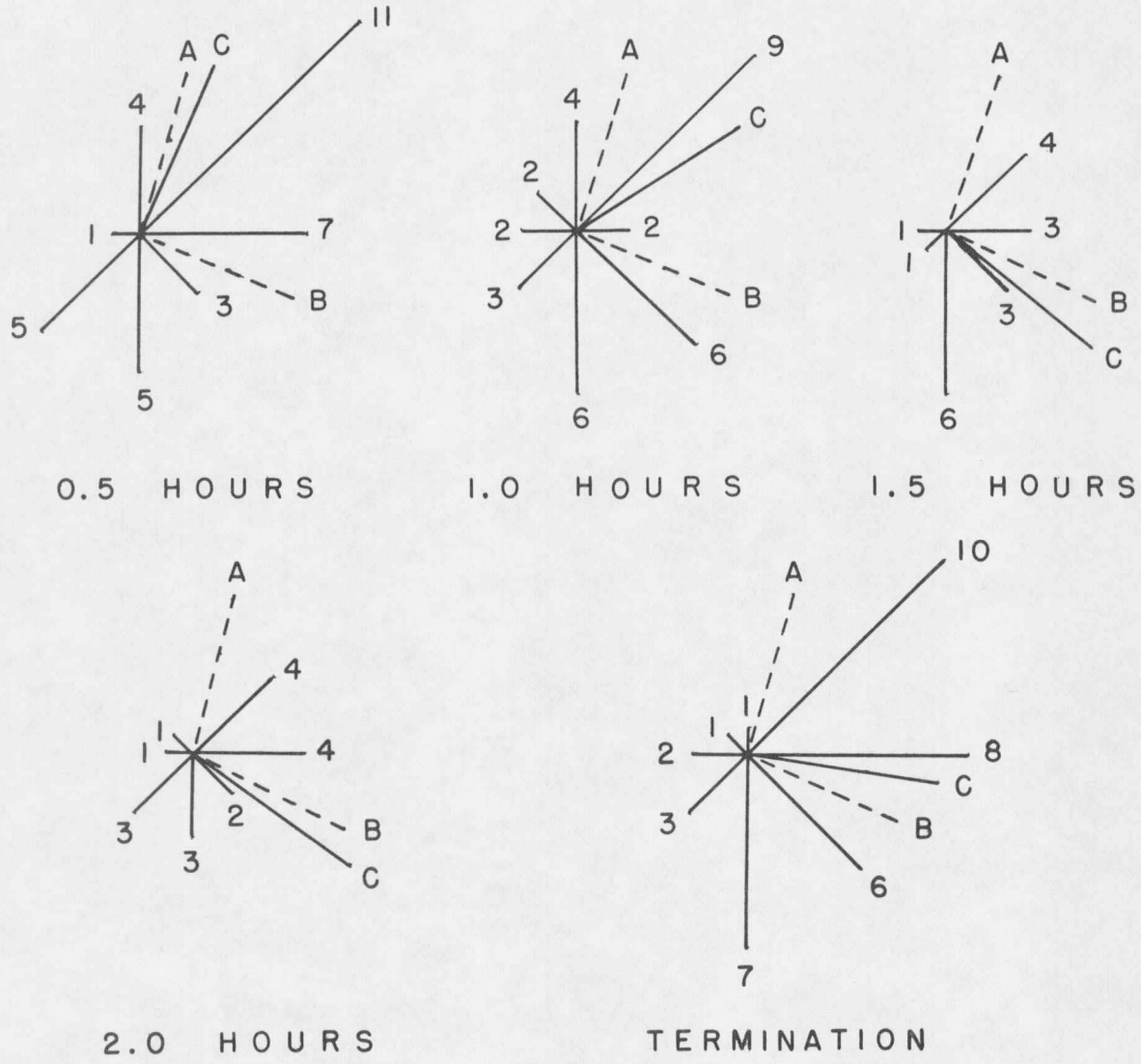

Figure 2. Direction of movement (north, northeast, east, etc.) and number of Clear Creek fish released at Point 1 for each time interval and at termination. A - direction of Cub Creek. B - direction of Clear Creek. C - mean direction for all fish at each time interval.

Time Interval	No. Terminated	No. Temporarily "Lost"	No. Lost
0.5 Hours	3	6	0
1.0 "	9	4	1
1.5 "	8	8	3
2.0 "	18	0	0

16.6° north of the mouth of Clear Creek.

The mean directions and average straight-line distance (Table II) from Point 2 for Clear Creek fish (Figure 3) were: 0.5 hours - 86.0° (east), 311 meters; 1.0 hours - 124.2° (southeast), 505 meters; 1.5 hours - 59.6° (east-northeast), 532 meters; 2.0 hours - 3.3° (north), 643 meters. The mean direction of termination points was 87.4° (east), or 51.6° north of the mouth of Clear Creek. For Cub Creek fish (Figure 4), the mean directions and average straight-line distances (Table II) were as follows: 0.5 hours - 123.6° (east-southeast), 380 meters; 1.0 hours - 134.2° (southeast), 432 meters; 1.5 hours - 132.3° (southeast), 601 meters; 2.0 hours - 265.0° (west), 439 meters. The mean direction of termination points was 113.4° (east-southeast), or 25.6° north of the mouth of Clear Creek.

The direction of "take-off" (Figure 5) and straight-line distance after 1.0 hours was determined for all fish liberated at Point 3. Clear Creek fish showed a mean direction of 54.6° (northeast) and an average distance of 667 meters, while Cub Creek fish had a mean direction of 13.8° (north-northeast) and an average distance of 638 meters.

Comparison of movement was made for periods when the sun was visible as contrasted to those when the sun was obscured. Thirty-nine fish were released from Point 1 when the sun was visible and 3 when the sun was obscured. Of those released when the sun was visible, 27 went to shore (i.e., were no longer in "open-water"), 5 went away from shore, 3 showed random movement near the release point, and 4 were lost. Of those re-

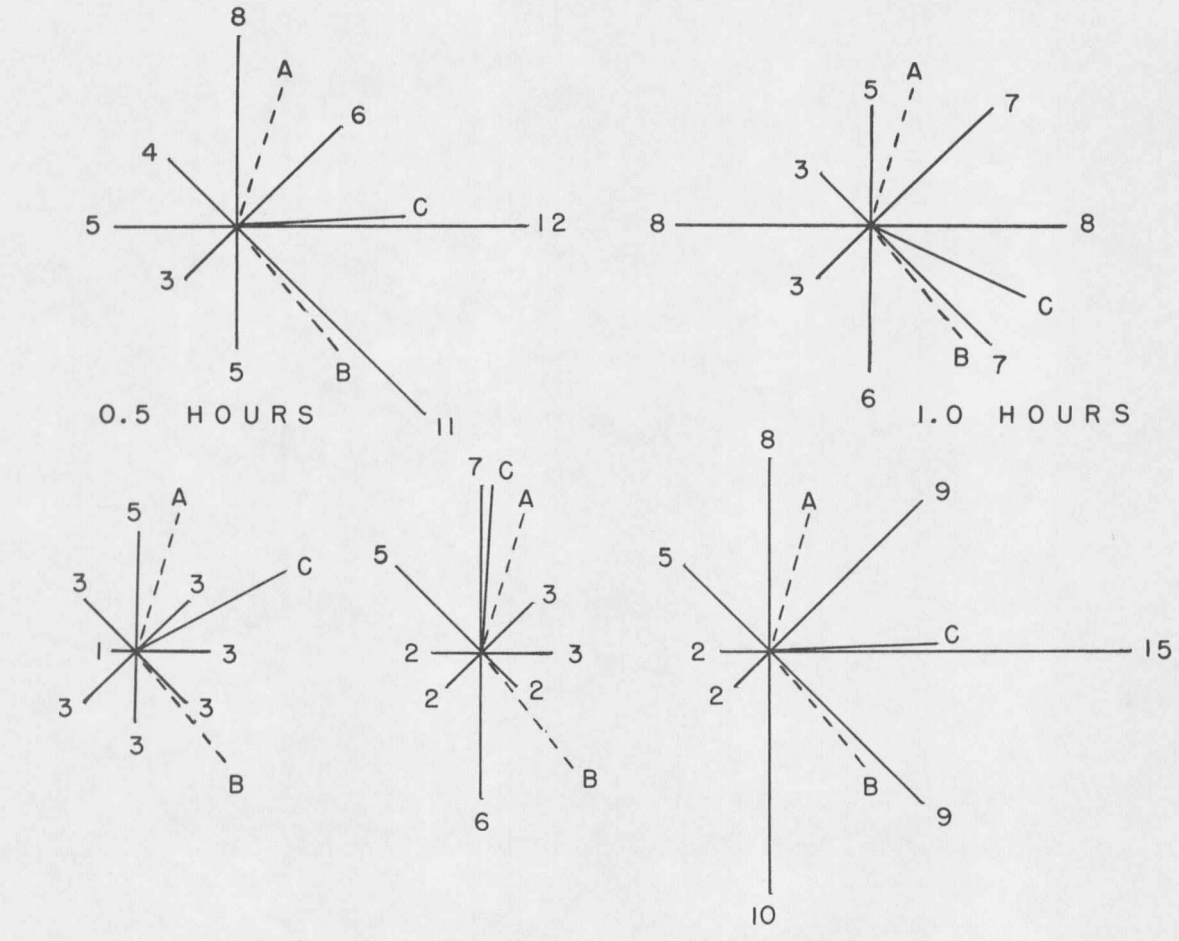

Figure 3. Direction of movement (north, northeast, east, etc.) and number of Clear Creek fish released at Point 2 for each time interval and at termination. A - direction of Cub Creek. B - direction of Clear Creek. C - mean direction for all fish at each time interval.

Time Interval	No. Terminated	No. Temporarily "Lost"	No. Lost
0.5 Hours	10	10	0
1.0 "	15	6	1
1.5 "	5	11	3
2.0 "	30	0	0

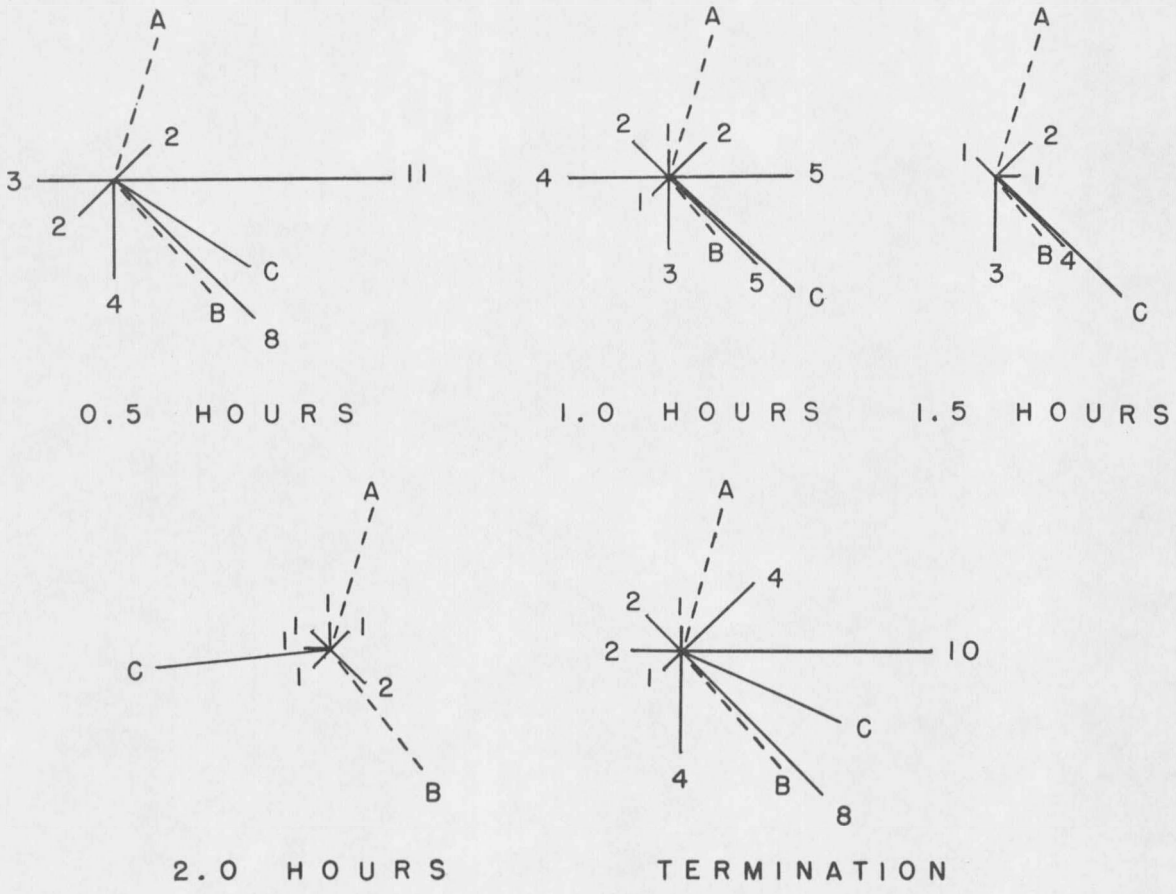

Figure 4. Direction of movement (north, northeast, east, etc.) and number of Cub Creek fish released at Point 2 for each time interval and at termination. A - direction of Cub Creek. B - direction of Clear Creek. C - mean direction for all fish at each time interval.

Time Interval	No. Terminated	No. Temporarily "Lost"	No. Lost
0.5 Hours	8	4	0
1.0 "	8	2	1
1.5 "	9	6	0
2.0 "	7	1	0

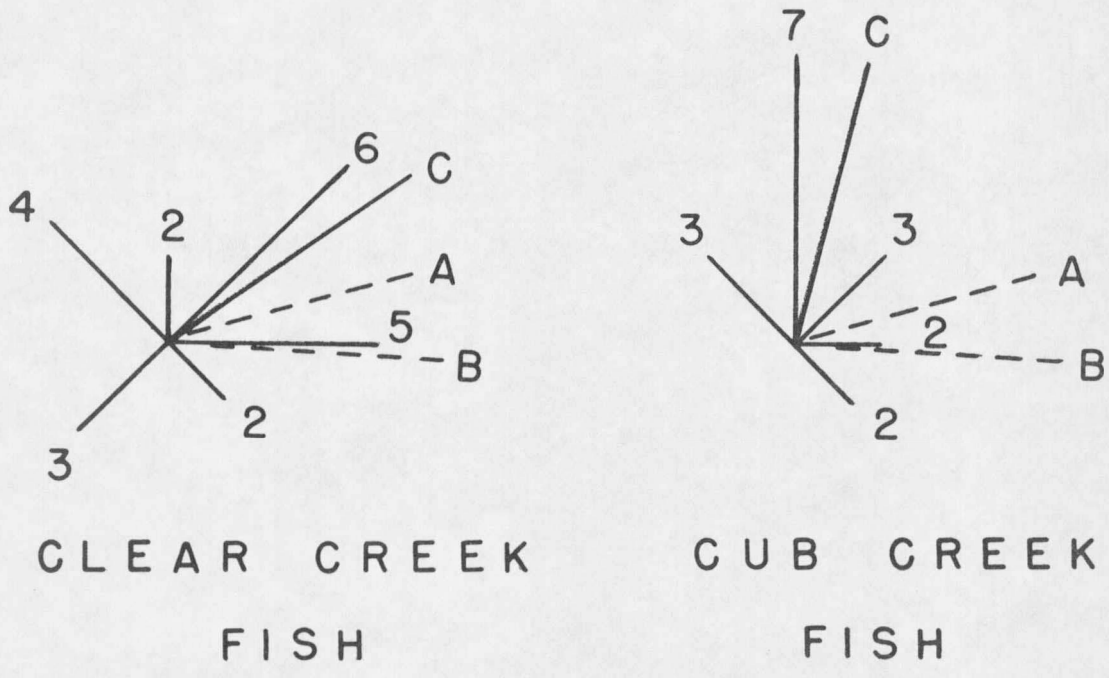

Figure 5. Direction of "take-off (north, northeast, east, etc.) and number of experimental fish released at Point 3 after 1.0 hours. A - direction of Cub Creek. B - direction of Clear Creek. C - mean direction for all fish from each creek. Three fish from Clear Creek and 1 from Cub Creek were lost during the experiments.

leased when the sun was obscured, 1 went to shore, 1 showed directed movement away from shore, and 1 moved randomly near the release point. Fifty fish from Clear Creek and 31 fish from Cub Creek were released from Point 2 when the sun was visible while 15 fish from Clear Creek and 2 fish from Cub Creek were released when the sun was obscured. When the sun was visible, 55 fish went to shore, 18 headed away from shore, 2 showed random movement near the release point, and 6 were lost. When the sun was obscured, 5 fish went to shore, 5 went away from shore, 5 showed random movement near the release point, and 2 were lost. Combining all fish, the results were as follows: of the 120 fish released when the sun was visible, 68.3% went to shore, 19.2% went away from shore, 4.2% showed random movements near the release points, and 8.3% were lost; of the 20 fish released when the sun was obscured, 30.0% went to shore, 30.0% went away from shore, 30.0% showed random movement near the release point, and 10.0% were lost.

Fish from all three release points were combined for each time interval for analysis of straight-line distance traveled from the release points (Table II). Those released when the sun was visible traveled 122 meters farther at 0.5 hours, 138 meters at 1.0 hours, 177 meters at 1.5 hours, and 258 meters at 2.0 hours than when the sun was obscured.

Females taken in Clear Creek traveled an average of 256 meters farther from Release Point 2 than did males. The average time involved for those reaching shore was 57 minutes (range 26 to 122 minutes) for females and 59 minutes (range 33 to 141 minutes) for males. Females taken

in Cub Creek traveled an average of 111 meters farther than males. The average time involved for those reaching shore was 75 minutes (range 41 to 102 minutes) for females and 59 minutes (range 27 to 102 minutes) for males. Females from both Clear Creek and Cub Creek released at Point 3 traveled an average of 81 meters farther from the release point than did males.

Fish movements were analysed with respect to the direction of the current. The current drogue drifted at an average speed of 151 meters per hour in predominantly a southerly direction from Points 1 and 2 while it drifted at an average speed of 209 meters per hour northward from Point 3. Fish liberated at all release points showed no directional preference in relation to the drogue.

DISCUSSION

The mean directions of fish released at Points 1 and 2 showed a general movement shoreward (easterly). The mouths of the creeks from which the fish were taken were also in this general direction. It is likely that experimental fish were attracted to the streams in order to complete spawning or were simply attracted to the shoreline itself. Platts (1959) gives evidence for the first of these suppositions, but no previous work was found which supports the second. Fish released at Point 3 were about equally distant from east and west shorelines (5 kilometers) and also from the north and south shorelines (8 kilometers). In spite of this, Clear Creek fish released at Point 3 traveled northeast and showed a mean direction of 38.4° north of the mouth of Clear Creek, while Cub Creek fish

traveled north and showed a mean direction of 59.2° north of the mouth of Cub Creek. It may be that these fish had less "desire" to return to their streams to spawn, since they were taken late in the spawning season. The surface current may have influenced the direction of movement in that it flowed at a faster speed and more consistently northward from Point 3.

The use of specific landmarks by the fish for orientation immediately after release is doubtful. Knowledge of the "fish window" (Walls, 1942) and angles of light incidence (Slater and Frank, 1933) show that the amount of light coming from the atmosphere into the "fish window" is not great. Light coming from the highest landmark on the eastern shoreline as seen from Release Points 1 and 2 had an angle of incidence of 85° 17' and from the lowest prominent landmark (rise immediately above the beach) 88° 18'. Thus 60.05% and 84.02%, respectively, of incident light never enters the water at Release Points 1 and 2. Similarly at Release Point 3, 71.24% and 89.29%, respectively, of the incident light never enters the water.

Everything seen in the atmosphere is compressed into the "fish window", and therefore all objects become reduced in size. There is a small amount of light from these objects which enters the water. With absorption and dispersion occurring before the light enters the eye of a fish, the possibility of the fish seeing distinct objects on shore is doubtful. However, the shoreline may appear as a thin band on one side of the "fish window" to which the fish might orient. The possibility of distinguishing the shoreline probably becomes even less when surface waves exist.

The use of celestial phenomena (e.g., the sun) in orientation has been established for fish. Hasler et al. (1958) showed that the pumpkinseed (Lepomis gibbosus) and immature bluegill (Lepomis macrochirus) could be trained to the sun's position. Johnson and Groot (1963) showed a positive relationship between mean hours of sunshine for days immediately following release of sockeye salmon and rate of travel to a lake outlet. The tendency of cutthroat trout to go shoreward and distances traveled when the sun was visible were greater than when the sun was obscured.

Surface currents may not be important in orientation of cutthroat trout unless they carry characteristic stream odors. However, no one has shown that cutthroat trout use odor as an orientational cue.

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