STUDIES ON THE BEHAVIOR AND LIFE HISTORY OF THE MOUNTAIN WHITEFISH *(PROSOPIUM WILLIAMSONI* GIRARD)

by

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of

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in

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VITA

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ABSTRACT

In-season homing of displaced adult mountain whitefish from Mission Creek was demonstrated by the return of 31 fish (10.2%) in 1968, and 367 fish (31.4%) in 1969, from release sites. In 1969, there was a significant difference in homing time between sexes. More fish homed from release sites in the Yellowstone River downstream than upstream from the mouth of Mission Creek and a greater percentage of males homed than females from all release sites in 1969. Repeat homing in 1969 was evidenced by the return of eight fish marked in 1968. Mountain whitefish fry ranging in age from newly hatched to seven weeks exhibited strong positive phototaxis to illumination ranging from 40-200 ft-c and also responded strongly to a decrease in light intensity. Fry were more attracted to red, yellow and white rectangles and showed greater avoidance to black and blue rectangles in a trough than in a tank under approximately equal light intensities. They showed a greater preference for red than any other of the colors used. Adult mountain whitefish spawned under artificial conditions in the laboratory and in an outdoor raceway. Fry of this species were reared on commercial trout food for approximately seven weeks subsequent to hatching. Analyses of digestive tract contents of mountain whitefish ranging in total length from 12.5-31.0 mm collected from the Yellowstone River showed Tendepedidae larvae to be the most important food organism both in numbers and frequency occurrence.

INTRODUCTION

Mountain whitefish *(Prosopium williamsoni* Girard*)* are often abundant and provide an extensive and increasingly important sport fishery. They have rarely been artificially propagated or planted. The natural range of this species extends from northern British Columbia eastward to the Peace River, Alberta (Lindsey, 1955) and southward throughout much of the northern intermountain region of the United States. In Montana, it is native in all larger streams on both sides of the Continental Divide and extends from the western boundary to the central part of the state (Brown, 1970).

The objectives of my study were to investigate: the in-season homing behavior of adult mountain whitefish in a river (fluvial) system; the early fry behavior; the spawning of adults and rearing of fry under artificial conditions; the food from fry which were collected in a river. Studies began in October, 1968, and continued through June, 1970.

Previous studies on mountain whitefish cover a broad spectrum of subjects including food habits, (McHugh, 1940, Laakso, 1951); life history, (Sigler, 1951); spawning habits and early development, (Brown, 1952); and hematology, (McKnight, 1966).

While the Coregoninae have received little attention with respect to homing behavior, many of the Salmoninae and other fishes have been rather intensively investigated. The majority of homing investigations of freshwater fishes have dealt with those living in lake (adfluvial) environments which either spawn there or migrate to tributaries to spawn. Some important studies include: brook trout *(Salvelinus fontinalis)* Vladykov, 1942; lake trout *(S. namaycush)* Loftus, 1957; cutthroat trout *(Salmo clarki)* Platts, 1959; sockeye salmon *(Oncorhynchus nerka)* Hartman and Raleigh, 1964; white bass *(Roccus chrysops)* Horrall, 1961, and others, but these have all been studied in adfluvial situations. Investigations where a tributary choice was involved in a fluvial system include: brown trout *(S. trutta)* Stuart, 1957; charr *(Salvelinus willughbii)* Frost, 1963; cutthroat trout *(Salmo clarki)* LaBar, 1970, and others, but again, these fish were all from adfluvial systems.

Propagation of Coregonines in North America has been more or less restricted to the commercially important lake whitefish *(Coregonus clupeaformis)*, but at least two instances of mountain whitefish propagation are known (Simon, 1951; Montana Fish and Game Communication). No previous studies of the behavior of whitefish fry or of mountain whitefish food habits (fry less than 31.0 mm) have been found.

DESCRIPTION OF STUDY AREA

The homing behavior investigation of adult mountain whitefish was restricted to the following areas (Fig. 1): Mission Creek (lower 2.1 km); Yellowstone River (8.5 km upstream and 16.1 km downstream from the mouth of Mission Creek); Shields River (lower 0.6 km); side-channel extending from the Yellowstone River and tributary to Mission Creek (0.7 km). Mission Creek, the side-channel, and Shields River are the only tributaries to the Yellowstone River in the study area.

Mission Creek has an annual spawning run of several thousand mountain whitefish which enter it from the Yellowstone River. This creek is small, accessible, on private property, and little influenced by fishermen. It is approximately 20.9 km long and has an average gradient of about 65.1 m/km and enters the Yellowstone River from the south. The maximum flow occurs during spring run-off, and the minimum flow, which would normally be in winter, takes place during mid-summer and early fall due to irrigation diversion. The stream bed in the study area is mainly composed of rubble, gravel, sand, and silt, with boulders predominating in the upper reaches. Bank cover is primarily composed of willows, with some red dogwood and cottonwood.

MATERIALS AND METHODS

In 1968, most mature mountain whitefish were captured in a fyke net (1.0 m dia.) set about 1.8 km from the mouth in Mission Creek (Fig. 1). Common sense netting (6.4 mm mesh) was used to block the creek and divert fish into the fyke net. Some fish were taken by electrofishing during the day or with a dip net at night. In 1969, adult fish were captured exclusively with two traps made of hardware cloth (1.27 cm mesh) attached to wooden frames (1.54 x 1.54 x 0.63 m). These were set about 200 m up the creek from the mouth (Fig. 2) and another trap was placed in the side channel about 27 m from its confluence with Mission Creek, but this failed to take any fish. These traps were secured to the stream bed by metal posts. Either wooden or metal grates, with bars spaced about 1.5 cm apart, were used to block the streams and divert fish into the traps. In both years, fish were dipnetted from the traps into live cars. The majority of fish were held less than one hour but a few were kept as long as 18 hours before being used in experiments.

Mountain whitefish fry were taken from the Yellowstone River during low water periods by means of either a drift net or an aquatic dip net (both 20 cm mesh) for the food study. The drift net was anchored to the river bottom so it would catch suspended organisms and other materials. The aquatic dip net was rapidly swept over the river bottom near shore. When water levels were high, a seine

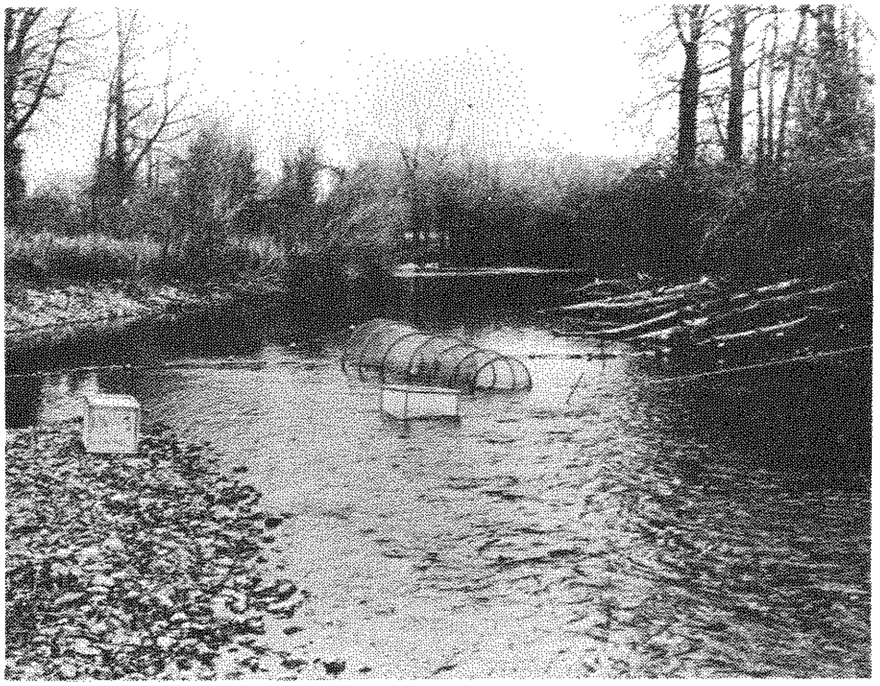

Fig. 1. Fyke net used to capture mountain whitefish in Mission Creek during 1968 viewed from upstream.

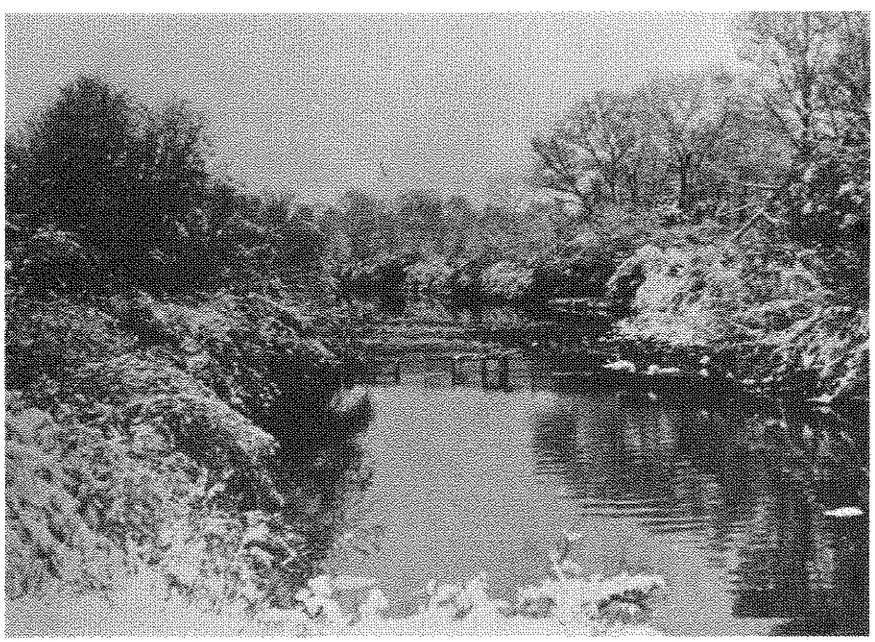

Fig. 2. Traps used to capture mountain whitefish in Mission Creek during 1969 viewed from downstream.

(3.2 mm mesh) was effective in capturing fry along the river-edge. Fry were preserved in 10% formalin within three minutes after capture and then stored for later examination. Mountain whitefish fry used in the food study were measured (total length) and the contents of the digestive tract removed and then examined with the aid of a binocular microscope.

All adult mountain whitefish used in homing experiments were sexed and tagged and a sample was measured for total length. The right pelvic fin was removed from about half of those taken in 1968. Sex was usually determined by the plumpness of females or by the large numbers of well developed pearl organs on males, but when doubt occurred, a gentle stroke along the sides of the fish resulted in the extrusion of either milt or ova. Almost half of all adults taken in both years were tagged on the posterior base of the dorsal fin using Mueller #30 alligator clips (McCleave, *et al.*, 1967). Vinyl tubing (about 10 cm length) coded with colored bands was attached to the clips. These tags provided individual recognition of fish at a distance up to about 10 m when binoculars were used. Other adult fish were tagged using a Floy Tagging Gun, Model FDM-68, and white, numbered anchor tags (Floy Tag and Manufacturing, Inc.). These were placed on either side of the back, below the middle of the dorsal fin. About one-third of the fish tagged in this manner were dipped from live cars, 4-7 at a time, and placed in a used galvanized tub containing about 10 liters of M.S. 222 (1:5000) solution. After the anesthetic took effect, fish were tagged and returned to a live car by dipnet, and allowed to recover for a minimum of one hour.

Adults used in 1968 experiments were dipnetted from a live car after tagging and either released at the tagging site or placed in plastic garbage containers (45-90 liter capacity) filled with fresh creek-water and then transported by vehicle 1.7 km downstream over rough road. They were then either carried directly to a displacement site and released, or dipped into washtubs filled with creek-water and transported by boat to release sites. In 1969, all fish were tagged at the traps near the mouth of Mission Creek and then either released immediately below the traps or dipnetted into a tub containing creek-water. The tub was then carried about 13.6 m and emptied into a covered stock tank containing creek-water (depth about 30-40 cm). Fish in this tank were transported distances ranging from 2.3-22.5 km (the first 2.0 km over rough road), dipnetted into a tub containing water from stock tank and then carried to the release site. The maximum time from tagging to release in 1968 did not exceed 2.0 hours and in 1969, 3.5 hours.

The behavior of mountain whitefish fry was investigated at the Montana State University laboratory. The fry used for experiments were hatched in this laboratory and ranged in age from those newly hatched to seven weeks old. Light and color experiments were performed in a fiberglass tank, 122 cm dia. x 73 cm deep (Fig. 3) and a fiberglass trough, 364 x 35 x 20 cm. Overhead fluorescent lights, a microscope lamp (American Optical Model 359) and a two-celled flashlight (D batteries) were employed in light experiments. Light intensities were measured with a Weston Photronic Foot-Candle Meter (Model 614). Galvanized and aluminum rectangles (23.5 x 28 cm, 13.0 x 15.0 cm, in tank and trough respectively) were divided into four equal rectangles (Fig. 4). The two rectangles diagonal to each other were painted the same color (Coast-to-Coast spray paints; white enamel GP-221, black enamel GP-222, Swift red GP-214, yellow GP-206, Royal blue GP-207). Two colors were placed on each plate. Those used with black were white, red, yellow, and blue. Those used with red were white, yellow, and blue. In each experiment one plate was placed on the bottom of the tank or trough and then all lights were turned off to allow random distribution of the fry. The laboratory was almost completely dark at this time. After 15 minutes, room lights were turned on and the fry counted on each of the four sections within 5-15 seconds. Subsequent counts were made at five minute intervals for 30 minutes and then at 45 and 60 minutes, after which time the experiment was terminated. The observer peered over the edge of the tank and trough during counts but otherwise remained hidden from the fry. No alarm reaction by the fry was observed during counts.

Mountain whitefish spawning, early life history, and propagation under artificial conditions were investigated. An artificial spawning

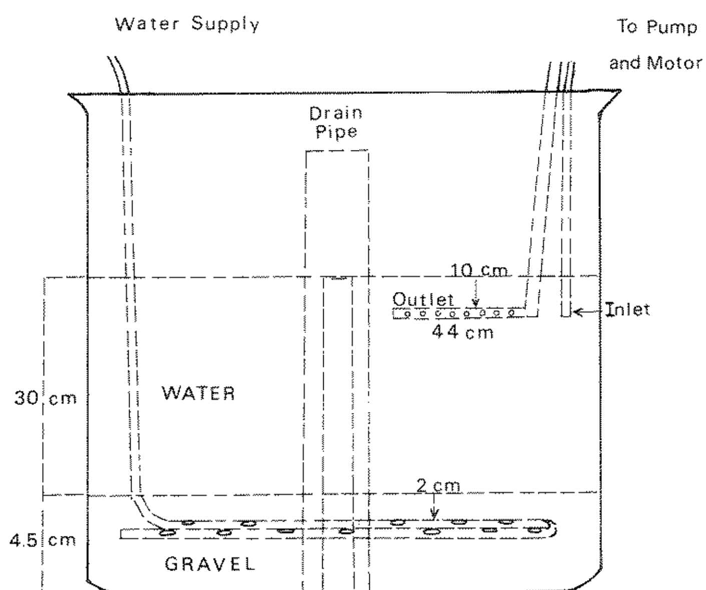

Fig. 3. Fiberglass laboratory tank used in propagation and fry behavior experiments of mountain whitefish.

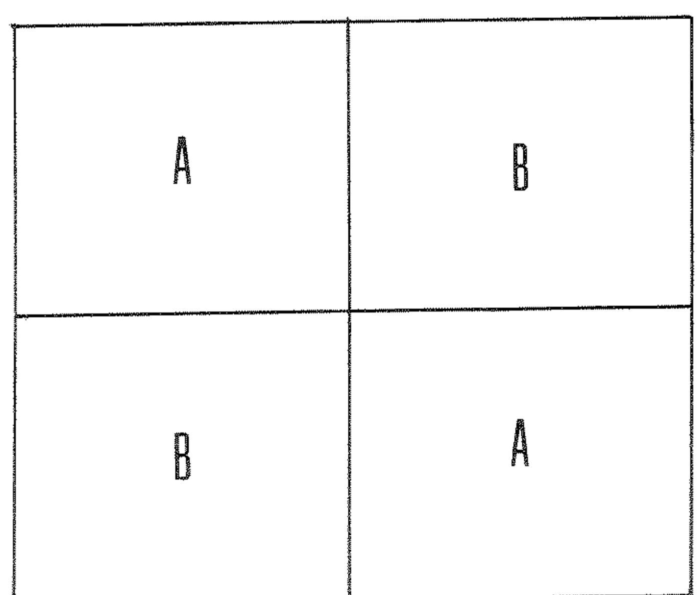

Fig. 4. Test plate used to determine mountain whitefish fry response to colors. Two colors were used on each plate with two diagonal rectangles, A-A or B-B, painted the same color.

area was created in a section of outdoor raceway (4.95 x 1.82 x 1.40 m) at the Fish Cultural Development Center near Bozeman, Montana in 1969 (Fig. 5). Rubble and gravel (depth 5-10 cm) were placed in the bottom of the raceway and water was pumped in from Bridger Creek over a head-gate (62 cm high) to form a riffle-like area (depth 30-40 cm) in the raceway. Another experimental spawning situation was created by placing gravel in a fiberglass tank (Fig. 3) in the laboratory. Dechlorinated city water was continuously supplied through a perforated hose (holes about 9 cm apart), buried in the gravel around the middle of the tank in order to provide percolation. Additional circulation was provided by a pump.

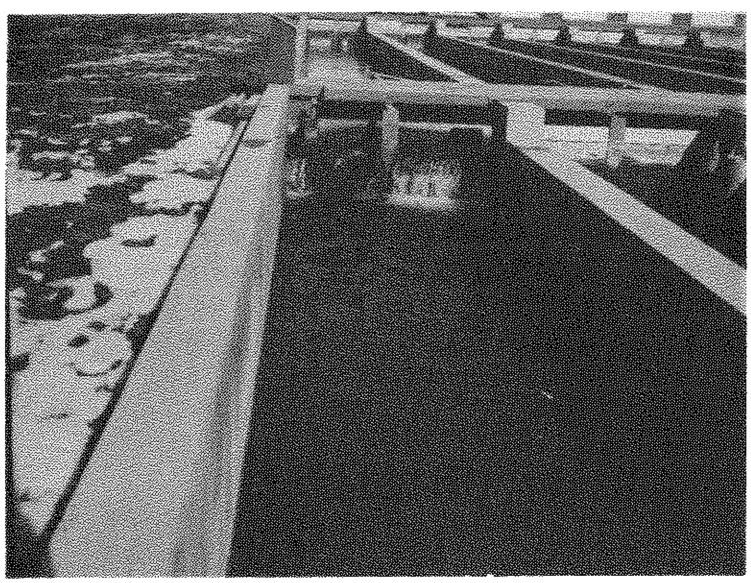

Fig. 5. Section of outdoor raceway used in propagation experiments of mountain whitefish in 1969.

Ripe fish were transported from Mission Creek and released into the raceway and tank. Fish in the raceway received no additional treatment. Those in the tank were kept under lighted conditions for approximately 10-12 hours, corresponding to daylight periods. This was repeated each day for 10 days. Spawning fish were then removed. In 1968, several ripe males and females from Mission Creek were stripped of sex products at the site of capture. Fertilization was accomplished by mixing the sex products in a small amount of water in a plastic container. The eggs were then transported to the laboratory (about 45 minute trip) and transferred into Downing jars (13.5 cm dia. x 51 cm high). The jars were placed in a trough and supplied with dechlorinated water. The overflow water from these jars passed into the trough where the water was maintained at a depth of about 13.5 cm. In 1969, three ripe males and three females were brought into the laboratory and held for several days before stripping of sex products. Treatment of these products was the same as described for 1968. Fry were reared in the trough and in the tank in 1969.

The 1969 data concerning homing times of mountain whitefish were analyzed with the aid of a computer. These data were transformed by taking the square root of counts in order to obtain a more homogeneous variance. An analysis of variance employing the method of unweighted means (Snedecor and Cochran, 1967) was used as an approximate analysis due to the unequal sample sizes. Data concerning mountain whitefish fry responses to colors were also analyzed with the aid of a computer. A single multiple regression run was computed each for the trough and tank data.

RESULTS

Homing Behavior

Gerking (1959), proposed a general definition of homing as applied to fishes since there was no single explanation for this phenomenon. He defines homing as a "... choice that a fish makes between returning to a place formerly occupied instead of going to other equally probable places". At least three types of homing are recognized in relation to spawning migrations of fishes: (1) natal homing is the return of spawning adults to the area of their birth (Clemens *et al.*, 1939; Ball, 1955; Donaldson and Allen, 1957); (2) repeat homing is the return of adults in following spawning seasons to the place of initial spawning (Cope, 1957; Stuart, 1957; Lindsey *et al.*, 1959; Frost, 1963); (3) in-season homing is the return of adults within the same spawning season to the site of original capture after displacement (Platts, 1959; Hartman and Raleigh, 1964; Helle, 1966; McCleave, 1967; Jahn, 1968; LaBar, 1970).

My study was concerned with the in-season homing behavior of adult mountain whitefish. Fish that were captured in the traps, displaced, and returned to the traps, or those that were captured in or upstream from the fyke net, displaced, and recaptured in or upstream from the fyke net are considered to have demonstrated in-season homing.

The spawning run of mountain whitefish began in the second week of October and ended during the second week of November during both years.

The average total length of males both years, based on 238 fish, was 33.0 cm (range 24.4-46.3). The average total length of females both years, based on 178 fish, was 34.8 cm (range 25.6-52.0). Fish entering Mission Creek early in the spawning season (October 14-23, 1969) were predominately males (61%) and as the spawning run progressed (October 23 to November 6), females (62%) were most numerous. Fish entering the creek remained near the mouth in groups (usually of several hundred) during the daytime and then at dusk ascended the creek in mass. As they progressed upstream they stayed in pools during the day and at dusk continued upstream in smaller groups moving through shallow riffles from one pool to the next. The majority of mountain whitefish remained in that portion of Mission Creek between 1.1-2.1 km from the mouth but a few were observed upstream as far as 2.4 km. Brown (1952), reported spawning whitefish were seen only in the lower 270-450 m (approximate) of the streams investigated (including Mission Creek).

In late August 1969, the lower 1.1 km of Mission Creek was sampled to determine if adult mountain whitefish were present and about 25 were found. These were all in one pool which had a depth of approximately 1.5 m. Young-of-the-year and those in their second year were taken only in the riffle areas. There was also a small number of brown trout, rainbow trout, and cutthroat trout present in both pools and riffles. No adult mountain whitefish were found upstream beyond 1.1 km, where extremely low water conditions and lack of pools prevailed. The side channel from the Yellowstone River also contained a few adult mountain whitefish and trout at that time.

The release sites used in 1968 (Fig. 6) to test in-season homing behavior were located as follows (distances from the mouth of Mission Creek): Mission Creek, 1.6 km (200 m downstream from fyke net, E); mouth of Mission Creek (D); mid-point of Yellowstone River, 100 m downstream (A); mid-point of Yellowstone River, 175 m upstream (C); across Yellowstone River, 50 m (B). The release sites used in 1969 (Fig. 6) were located as follows (distances from the mouth of Mission Creek):

Mission Creek

200 m upstream, immediately below traps (S)

Mouth (T)

Yellowstone River, downstream

2.3 km, south side (U)

4.3 km, north side (V)

16.1 km, south side (W)

Yellowstone River, upstream

3.5 km, north side (X)

8.5 km, south side (Y)

Shields River, upstream

8.2 km, north side (0.6 km from mouth of Shields River, Z)

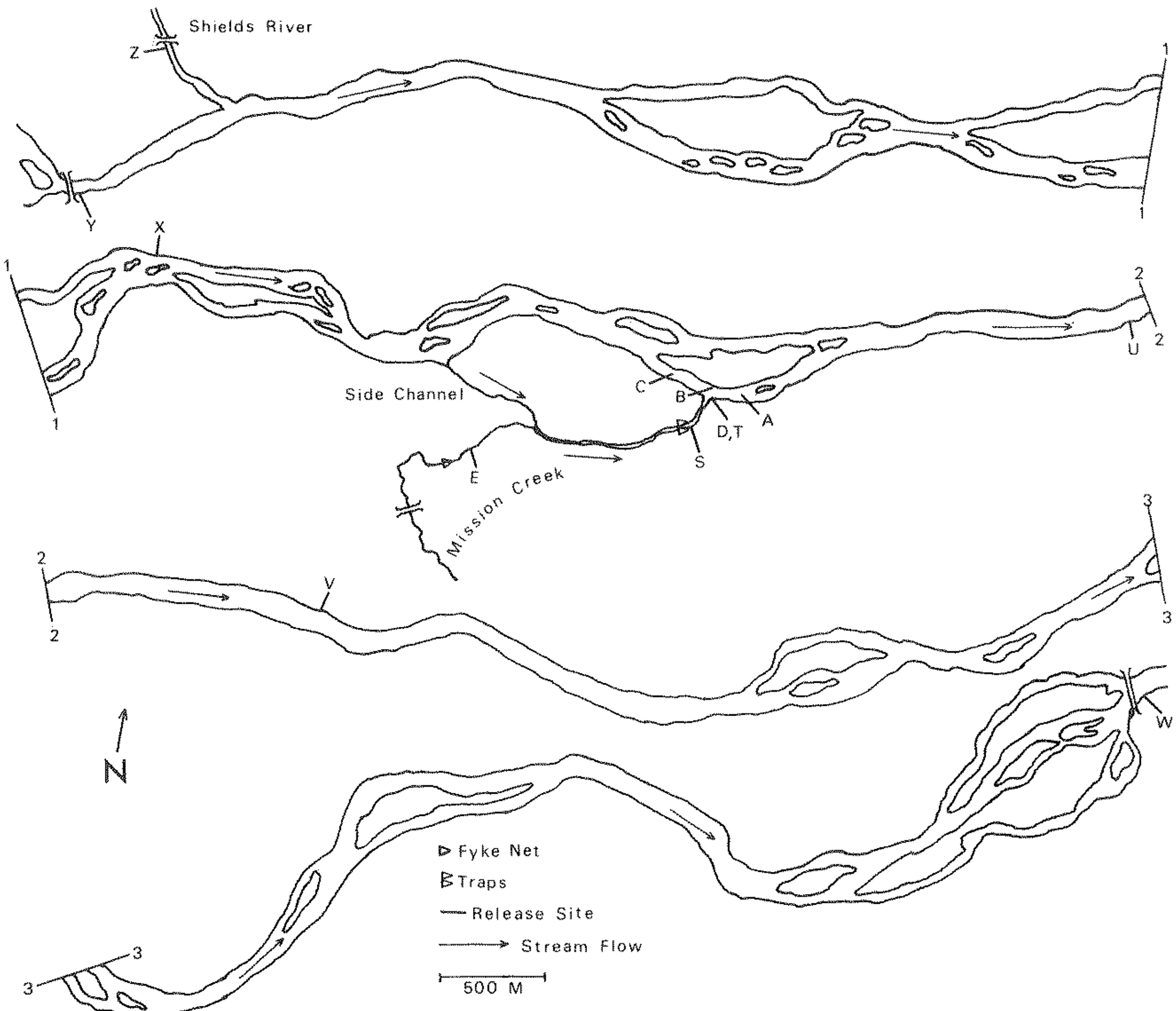

Fig. 6. Study area of Yellowstone River and Mission Creek showing locations of release sites, fyke net, traps, tributaries, side channel, and direction of stream flow.

In-Season Homing 1969 Of 1180 fish displaced at all release sites, 367 (31.4%) homed (Table I). The mean homing time for all returns (Table III) was 6.9 days (range 1-33). Although approximately equal numbers of males and females were released, about twice as many males homed as females. The mean homing time for males was 7.3 days (range 1-26) and for females 5.9 days (range 1-33). This difference is significant but a comparison of male and female homing times from each release site was not significant and there also was no significant difference in homing times when individual release sites were compared (Table IV).

Analysis of all fish in relation to the distance displaced from the traps showed the highest probability of return for those released nearest the traps and decreased as distances increased (Fig. 7). A Z-test to determine the significance of this tendency was highly significant for both males and females.

The total of all fish (Table II) displaced immediately below the traps (S) and at the mouth of Mission Creek (T), showed a greater number of homing fish than either those displaced in the Yellowstone and Shields Rivers (X,Y,Z) above, or in the Yellowstone River (U,V,W) below, the mouth of Mission Creek. Of 94 males and 27 females released at combined sites S and T, about 64% of the males and 37% of the females homed. Approximately equal numbers of males and females were released below the mouth of Mission Creek (U,V,W) but almost 30% more males than

Table I. Number of mountain whitefish displaced and number homing in 1969.

Release Site	Males No. Released	Males No. Homing No.	Males No. Homing %	Females No. Released	Females No. Homing No.	Females No. Homing %	Total No. Released	Total No. Homing No.	Total No. Homing %
S	52	36	69.2	18	6	33.3	70	42	60.0
T	42	24	57.1	9	4	44.4	51	28	54.9
U	138	98	71.0	61	27	44.3	199	125	62.8
V	29	12	41.3	39	12	30.7	68	24	35.2
W	83	18	21.7	145	18	12.4	228	36	15.8
X	80	42	52.5	69	26	37.7	149	68	45.6
Y	86	11	12.8	121	11	9.1	207	22	10.6
Z	85	11	12.9	123	11	8.9	208	22	10.6
Totals	595	252	42.4	585	115	19.7	1180	367	31.4

Table II. Combined number of mountain whitefish displaced and number homing in 1969.

Combined Release Sites	Males No. Released	Males No. Homing No.	Males No. Homing %	Females No. Released	Females No. Homing No.	Females No. Homing %	Total No. Released	Total No. Homing No.	Total No. Homing %
Below traps and at mouth (ST)	94	60	63.8	27	10	37.0	121	70	57.9
Below mouth (UVW)	250	128	51.2	245	57	23.3	495	185	37.4
Above mouth (XYZ)	251	64	25.5	313	48	15.3	564	112	19.9

Table III. Mean homing time (days) of mountain whitefish displaced in 1969 (M = Mission Creek; Y = Yellowstone River, B = below mouth of Mission Creek, A = above mouth of Mission Creek; S = Shields River).

Release Site		Males			Females			Totals		
		No. Homing	Mean	Range	No. Homing	Mean	Range	No. Homing	Mean	Range
M	S	36	7.4	2-26	6	9.1	1-33	42	7.6	1-33
	T	24	6.6	2-14	4	4.5	2- 6	28	6.3	2-14
Total		60	7.1	2-26	10	7.3	1-33	70	7.1	1-33
	U	98	6.3	1-19	27	7.7	1-28	125	6.6	1-28
Y-B	V	12	6.9	4-11	12	4.6	1- 8	24	5.7	1-11
	W	18	9.6	4-17	18	4.8	3- 8	36	7.2	3-17
Total		128	6.8	1-19	57	6.1	1-28	185	6.6	1-28
Y-A	X	42	7.9	1-16	26	4.8	1-24	68	6.7	1-24
	Y	11	8.4	3-21	11	6.3	3-11	22	7.3	3-21
S-A	Z	11	10.7	1-17	11	5.5	1-11	22	8.1	1-17
Total		64	8.5	1-21	48	5.3	1-24	112	6.9	1-24
Grand Total		252	7.3	1-26	115	5.9	1-33	367	6.9	1-33

Table IV. Analysis of variance of homing time of mountain whitefish displaced in 1969.

Source of variation	df	F
Sex	1	19.25*
Sex by release site interaction	7	1.27
Release sites (S, T, U, V, W, X, Y, Z)	7	1.06
Subdivision on release sites (S,T) (U,V,W) (X,Y,Z)	2	0.79

* Significant at $P < 0.0005$

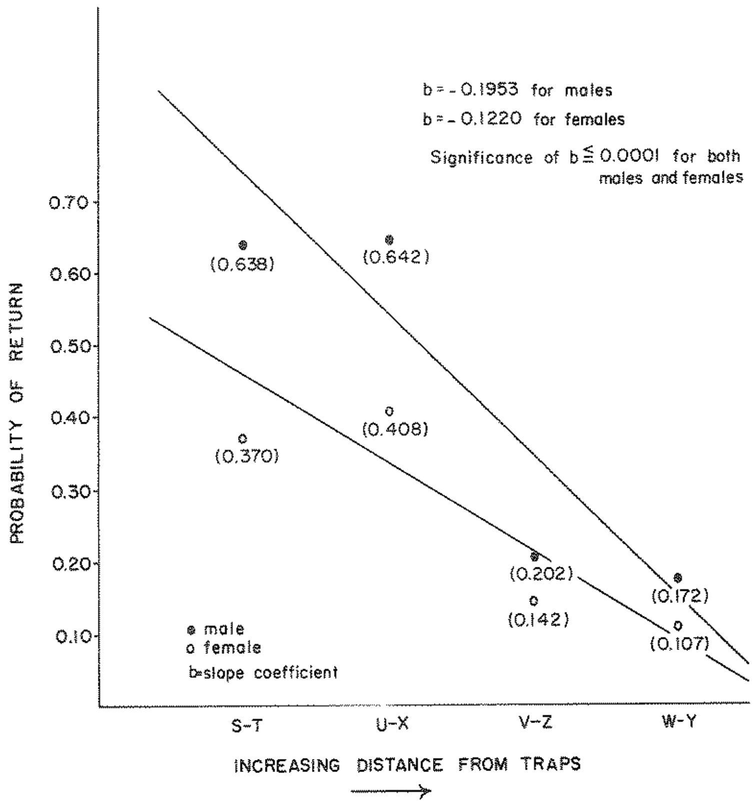

Fig. 7. Analysis of return probability of displaced mountain whitefish versus increasing distances from traps in 1969.

females homed. A total of 313 females and 251 males were released above the mouth of Mission Creek (X,Y,Z) but 10.2% more males than females homed. There was a significant difference between the number of homing males and females from the three combined release groups (Chi-square = 55.65 with 2 df, males; Chi-square = 14.01 with 2 df, females). There was no significant difference in homing time among these three groups (Table IV).

Of 199 fish displaced at release site U, 62.8% homed. This constituted the greatest number of homing fish for any release site. The mean homing time for these fish was 6.6 days (range 1-28). More males (71.0%) homed from this release site than for any other.

Repeat homing was evidenced by the capture in the traps of three females and five males marked in 1968. These fish were again tagged and displaced in 1969 but none were recaptured.

Seven tags from displaced fish in 1969 were returned by fishermen during the period January through April, 1970. All fish (6 females, 1 male) were caught in the Yellowstone River within the study area.

<u>In-Season Homing</u> - <u>1968</u> Of 305 fish displaced at all release sites, 31 (10.2%) homed to or above the fyke net (Tables V and VI). Twenty-two of these (71.0%) were recaptured in the fyke net and five (16.1%) were taken by dipnetting in an area extending from immediately above the fyke net to about 470 m upstream. The remaining four (12.9%) were identified by their tags within the stream in an area extending from

Table V. Number, sex, and homing time of mountain whitefish displaced in 1968 (percent homing per release date in parentheses).

Release		No. Released		Return	No. Homing	
Site	Date	Male	Female	Date	Male	Female
A	10/19	1	3			
	10/27	24	7	10/29		1 (14.3)
				11/15		1 (14.3)
				11/11	1 (4.2)	
D	10/26	27	9	10/29	1 (3.7)	
				10/30	1 (3.7)	
				11/3	1 (3.7)	1 (11.1)
				11/5	1 (3.7)	
				11/6	1 (3.7)	
				11/13	1 (3.7)	
				11/19	1 (3.7)	
	10/27	34	12	10/29	1 (2.9)	
				10/31	1 (2.9)	
				11/2	1 (2.9)	1 (8.3)
				11/5	1 (2.9)	
				11/11	2 (6.0)	
				11/14	1 (2.9)	
	10/30	3	3			
	11/2	36	13	11/6	1 (2.8)	
				11/9	1 (2.8)	
C	11/2	15	10	11/6		1 (10.0)
				11/7	1 (6.7)	
	11/3	13	12	11/6		1 (8.3)
B	11/3	14	11	11/6		1 (9.1)
	11/7	12	12	11/10		1 (8.3)
				11/11		1 (8.3)
				11/13		1 (8.3)
E	11/9	5	12	11/11		2 (16.7)
	11/15	7	13	11/19		1 (7.7)
	11/19	2	2			
	11/21	1	0			

Table VI. Number of mountain whitefish displaced and number homing in 1968 (Y = Yellowstone River, M = Mission Creek).

Release Site		Males			Females			Total		
		No. Released	No. Homing No.	%	No. Released	No. Homing No.	%	No. Released	No. Homing No.	%
	A	25	1	4.0	10	2	20.0	35	3	8.5
Y	B	26	0	0.0	23	4	17.3	49	4	8.1
	C	28	1	3.5	22	2	9.0	50	3	6.0
Total		79	2	2.5	55	8	14.6	134	10	13.4
M	D	92	16	17.4	37	2	5.5	129	18	14.0
	E	15	0	0.0	27	3	11.1	42	3	7.1
Total		107	16	15.0	64	5	7.8	171	21	12.3
Grand Total		186	18	9.7	119	13	10.9	305	31	10.2

Table VII. Mean homing time (days) of mountain whitefish displaced in 1968.

Release Site		Males			Females			Total		
		No. Homing	Mean	Range	No. Homing	Mean	Range	No. Homing	Mean	Range
	A	1	15.0		2	5.5	2-9	3	8.6	2-15
Y	B	0	-	-	4	4.0	3-6	4	4.0	3- 6
	C	1	5.0		2	3.5	3-4	3	4.0	3- 5
Total		2	1.0	5-15	8	4.3	2-9	10	5.4	2-15
M	D	16	9.2	2-24	2	7.0	6-8	18	8.9	2-24
	E	0	-	-	3	2.6	2-4	3	2.6	2- 4
Total		16	9.2	2-24	5	4.4	2-8	21	8.0	2-24
Grand Total		18	9.9	2-24	13	4.3	2-7	31	7.5	2-24

immediately above the fyke net to 200 m upstream. Twenty-three fish (74.0%) homed within nine days after release and eight (26.0%, all males) took 10-24 days. The mean homing time for all fish (Table VII) was 7.5 days (range 2-24).

Ten (13.4%) of 134 fish displaced in the Yellowstone River (sites A,B,C) homed. The mean homing time was 5.4 days (range 2-15). Eight (14.6%) of 55 females and only two (2.5%) of 79 males displaced at these sites homed. The mean homing time of these females was 4.3 days (range 2-9). One male homed from site A in 15 days, the other from site C in five days. Of the females, two (20.0%) homed from site A in a mean time of 5.5 days (range 2-9), four (17.3%) homed from site B in a mean time of 4.0 days (range 3-6), and two (9.0%) homed from site C in a mean time of 3.5 days (range 3-4).

Of 171 fish displaced at or upstream from the mouth of Mission Creek, 21 (12.3%) homed. The mean homing time was 8.0 days (range 2-24). Eighteen (14.0%) of 129 fish that homed from site D, constituted the greatest total return of fish displaced for any release site. The mean homing time for this group was 8.9 days (range 2-24). Sixteen (16.4%), of the 92 males displaced at site D, homed. Their mean homing time was 9.2 days (range 2-24). The two remaining fish (both females) homed in 7.0 days (range 6-8). Three females (11.1%) and no males, displaced at site E, homed. The mean homing time was 2.6 days (range 2-4).

Some marked fish escaped over or under the fyke net as evidenced by the nine returns (29.0%) which homed without being taken in the fyke net. The seine blocking the creek was pulled below the surface on several occasions due to accumulation of leaves.

Fry Behavior

Laboratory experiments were conducted using 500 to 700 mountain whitefish in the tank and 200 to 300 in the trough (newly hatched to seven weeks old) to determine response to light and color. Eggs and fry were kept in a tank under light intensities ranging from 50 to 58 ft-c (at water's surface). Eggs in Downing jars were kept under a light intensity of 36 ft-c (at water's surface). Fry in a trough were kept under light intensities ranging from 20 to 60 ft-c (at water's surface). Light intensities were constant at all times.

Light Experiments

Experiment 1. An experiment was conducted to test light response of fry, less than one hour old, that were hatched in a Downing jar. About 25 fry were swimming or resting near the bottom of the jar (40-50 cm from the water's surface). All room lights were turned off and with the laboratory in almost complete darkness, a two-celled flashlight (D batteries) was turned on and held about 2 cm above the overflow spout of the jar (150 ft-c). Fry swam to the surface area of strongest light intensity within one or two seconds. Within a few seconds, all were carried over the overflow spout into the trough. This test was repeated a few days later with 29 fry of the same age and the results were the same as described above. When the flashlight beam was moved down along the sides or near the bottom of the jar it did not appear to alter their normal movements. The fry did not swim to the surface but continued to either rest near the bottom or swim about, usually in the lower half of the jar.

Experiment 2. An experiment was conducted in a tank and a trough to observe the response of fry (newly hatched to seven weeks old) to strong light intensities using a flashlight and microscope lamp. Within a few minutes after all lights were turned off and the laboratory was in almost complete darkness, a flashlight was held approximately 4 cm above the water's surface (120 ft-c) in the trough for about five minutes. This gave a field of light about 40 cm wide at the bottom of the trough. Fry vigorously swam to the surface in the lighted area within a second or two after the light was shone on the water and remained swimming there at an angle ranging between 20° and 60° with their heads almost always pointed towards the surface. This response lasted from five to 60 seconds before they passively sank or swam to the bottom in the lighted area. Fry continuously swam at the surface during the course of the experiment. Other fry moved into the lighted area and either swam around or rested on the bottom. This experiment was repeated with another lot of fry in the tank and the results were similar.

A microscope lamp was placed at the edge of the trough for 0.5 hours. This gave a lighted field of 12 cm at the water's surface (200 ft-c) and 15 cm at the bottom. Fry response was the same as described when the flashlight was used. The microscope lamp was subsequently placed at the center of the tank 58 cm above the water's surface for 11 hours. This gave a light field of approximately 22 cm at the surface (40 ft-c) and 25 cm at the bottom. Again, fry response was similar to that described in previous tests. Only a few fry were observed in the dark area of the tank at termination of this experiment, all other fry were in the field or periphery of light.

Experiment 3. An experiment was conducted to determine if fry in a trough would "follow" a light field. A 150 cm section of the trough was blocked off which contained fry ranging in age from newly hatched to five weeks. When fry were randomly distributed, a microscope lamp at one end of the blocked-off section was turned on. The field of light and intensity were the same as described in Experiment 2. All room lights were turned off for the remainder of the experiment. Fry near the area of light responded as described in Experiment 2. About 2.5 hours later, a large number of fry were in the lighted area but others were present throughout the rest of the section. Six hours later, only about 10 fry remained outside the light field. The microscope lamp was then moved 100 cm towards the other end of the section where no fry were present. Fry from the previously lighted area almost at once moved towards the newly lighted portion. Within two hours, most of the fry were in the field or periphery of light. The experiment was terminated 12.5 hours later and about 20 fry remained at the end of the trough away from the light, all other fry were in the lighted area.

Experiment 4. An experiment was conducted to observe the response of fry (newly hatched to seven weeks old) to a change in light intensity from 20-60 ft-c to 2-4 ft-c over the trough. The majority of fry in the trough vigorously swam to the surface within one or two seconds after a decrease occurred, just as they had responded in previously described experiments to a light field in a dark room. Within 60 seconds almost all of these had returned to the bottom and within five minutes there were none at the surface. When the light intensity was returned within a few seconds to the higher level, fry ceased their vigorous swimming at the surface within a second or two and either passively sank or swam to the bottom. This change in light levels was repeated several times in rapid succession over a two to three minute period. With each succeeding change from higher to lower levels, fewer and fewer fry swam to the surface until there was almost no response.

Color Experiments

Color combinations of either black and red, black and white, black and yellow, or red and white were used in both the tank and trough. A black and blue combination was used only in the tank and combinations of red and blue and red and yellow were confined to the trough. Data were graphed and a second degree regression curve calculated for each color in each experiment (Fig. 8a-k). Red, yellow, and white colors are referred to as A; black and blue colors are referred to as B.

Fry exhibited a strong preference in the trough for A colors, especially red, over B colors (Fig. 8b,f,j) but showed little difference in response to A-B combinations in the tank (Fig. 8c,e) except for red vs. black (Fig. 8a). There was little difference in fry response to A-A combinations in both the tank and trough (Fig. 8g-i) and also to a B-B combination in the tank (Fig. 8k). In tank experiments, there was generally an increase in fry numbers through the first 30 minutes and then relative stability for the remaining portion of the experiment. The accumulation of fry on both colors was about the same as shown by the curves. This was also true in trough experiments but only for A-A combinations.

In all experiments using A-B combinations (except Fig. 8b), there were more fry present on A colors than on B colors at time 0. Tests on intercepts for both tank and trough were significant (Table VIII). This indicates that fry were either somehow attracted more to A colors than B colors during the dark period or that a random distribution of fry was not realized at the beginning of the counts. The hypothesis that fry were not merely responding to light(A)-dark(B) combinations rather than to specific colors in both the tank and trough was sustained (Table VIII). The hypothesis that a single regression curve could be fitted

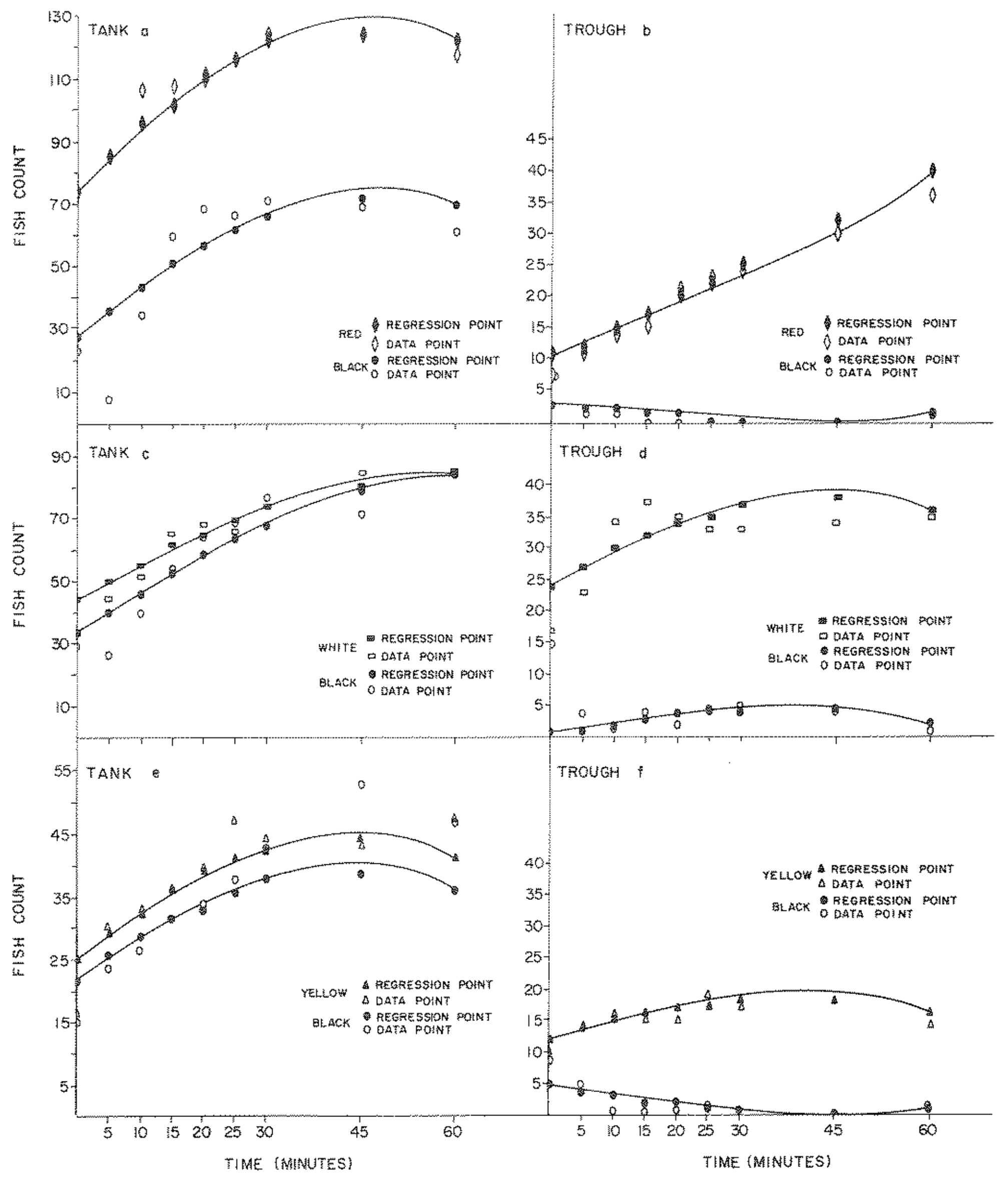

Fig. 8a-f. Fish count versus time (minutes) in tank and trough color experiments.

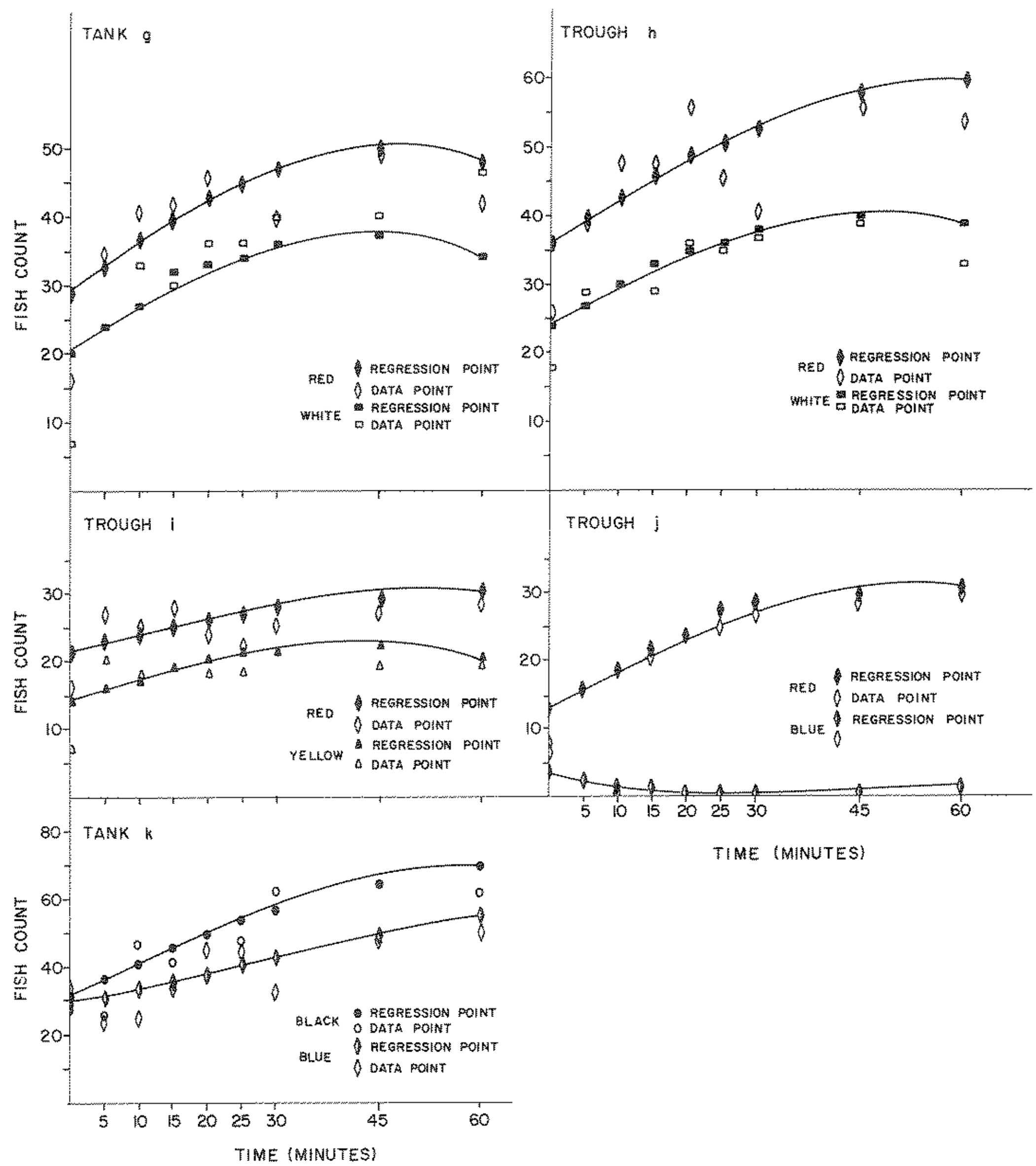

Fig 8g-k. Fish count versus time (minutes) in tank and trough color experiments.

Table VIII. Mountain whitefish fry response to color.

Source of variation	df	F
Intercept	4	6.63* (1)
	4	3.80** (2)
Use of only light (A) colors vs. dark (B) colors	6	1.79 (1)
	6	1.15 (2)
Similarity of curves	4	6.02* (1)
	3	19.77* (2)

* Significant at $P < 0.005$

** Significant at $P < 0.010$

(A) Red, yellow, white

(B) Black, blue

(1) Tank

(2) Trough

for all data from both tank and trough was rejected which further indicates the fry exhibited a preference for certain colors (Table VIII).

Propagation of Mountain Whitefish

Experiments were conducted to determine if adult mountain whitefish would spawn under artificial conditions. These were undertaken in an outdoor raceway at the Fish Cultural Development Center and in a laboratory tank. Observations were also made on the hatching and rearing of fry. Fertilized eggs were hatched in Downing jars at the laboratory during both years.

Twenty-four males and 24 females in spawning condition were taken from Mission Creek during late October, 1969 and released in a section of outdoor raceway containing gravel and rubble taken from a nearby stream (Fig. 5). All but three of these fish jumped over the headgate of the raceway but at least some spawning occurred previous to this time since about 300 eggs were found in the gravel. These eggs were generally distributed near the head of the raceway where water turbulence was greatest. They were checked periodically throughout their development to near the hatching stage (March 20, 1970), but after that time no viable eggs or fry were found. The fry probably escaped by drifting or swimming through perforated grates at the lower end of the raceway.

Three males and three females in spawning condition from Mission Creek were placed in a tank at the laboratory (Nov. 3, 1969) and were not disturbed for the next 40 hours (Fig. 3). After 24 hours several thousand eggs were found throughout the gravel. Approximately 10 days later a fungus infection was evident and the eggs were treated with a 1:500 solution of formaldehyde once each day for 15 minutes until hatching began. The tank was rapidly drained and refilled after each treatment. Nevertheless, a large number of eggs died. Many dead eggs in clumps of two to 10 were in the first two centimeters of gravel. Most of these were removed. The infection was arrested after about three weeks of treatment. Hatching began about January 21, 1970 with the majority hatching during the first week in February.

In both years, fertilized eggs placed in Downing jars soon became infected with fungus. A commercial fungicide was used to treat eggs in 1968 but the majority of eggs were destroyed in spite of this treatment. Only about 10 eggs hatched. Eggs were treated with formaldehyde in 1969 and the fungus was controlled. Dead eggs were removed periodically until all eggs hatched. Hatching began January 14 and ended during the third week in February, 1970. The majority of eggs hatched during the first week of February. Water temperature in the laboratory averaged 5.8°C (± 1.5) from late October through March.

The hatching process was observed several times in a Downing jar. Embryos were seen to move violently for several seconds within the egg membranes until the posterior portion of the fry popped out. Fry remained quiescent for some time after this occurred. Many partially hatched fry were observed swimming or resting with the egg membrane still covering the anterior portion of their bodies. The average diameter of 10 eggs was 4.1 mm (range 3.9-4.3) when measured just prior to hatching. Eggs examined just before hatching and egg membranes of partially hatched fry had 2-4 holes. Other empty egg membranes examined had these holes also, in addition to an obvious split which had ragged edges, through which the fry escaped. The total length of 10 newly hatched fry averaged 13.8 mm (range 13.5-14.0).

All fry were fed 4-6 times each day with "No. 1 trout starter" (Silver Cup) which had been finely ground. Fry in the tank attempted to ingest particles of food within a few days after hatching. Many would seize a particle and then almost immediately reject it. Others appeared to swallow the food. The majority of fry ingested food near the bottom of the tank as the particles were sinking but a few came to the surface and took food as it was introduced. Dissection of a few fry five days after the onset of feeding confirmed the presence of food material in the alimentary tract. Only a few fry in the trough had food material in their digestive tracts.

Severe mortality of fry occurred in both the tank and trough after about seven weeks subsequent to hatching. Gas bubbles were found in the abdominal region. These bubbles were easily seen through the translucent body wall in all affected fry. These individuals lived for 3-5 days after becoming afflicted. During the initial stages of gas accumulation, they were observed to constantly swim with their heads pointed towards the bottom at various angles. As the gas bubbles became larger, these fry remained at the surface either swimming or motionless. Bubble formation was less pronounced in the tank when the water level was decreased to about 10 cm and the pump was used to spray the water's surface, thus providing increased agitation.

Food Analysis of Digestive Tract of Fry

A preliminary investigation was conducted to determine the frequency and average number of food organisms found in mountain whitefish ranging in total length from 12.5-31.0 m. Ninety-one fry were taken from the Yellowstone River for examination during the period of March 19 to May 20, 1970.

Diptera was the predominate food organism, comprising 97.6% of the total food items found (Table IX). Midge larvae composed 80.7% of all dipterans with 82 of the 91 fry containing midge larvae (Average 6.1). Fry taken on April 19 had the highest average number of midge larvae (9.9). Midge pupae were the next most numerous food item with an average of 2.4 in 29 fry. Only 15 (16.5%) other organisms were found in the fry examined. These included Plecoptera, Copepoda, Ephemeroptera, Annelida, and Amphipoda in order of decreasing numerical abundance.

Thirteen of the fry contained yolk material. Seven of these (12.5-15.0 mm total length) were taken in the earliest collection (March 19). The smallest fry collected (12.5 mm total length), contained one midge larvae in addition to yolk material which almost filled its entire body

Table IX. Digestive tract contents of mountain whitefish (12.5-31.0 mm). FO = frequency occurrence.

Organism	19 Mar.70		28 Mar.70		11 Apr.70		19 Apr.70		2 May 70		20 May 70		Total	
	% FO	Mean No.	% FO	Mean No.	% FO	Mean No.	% FO	Mean No.	% FO	Mean No.	% FO	Mean No.	% FO	Mean No.
Simulidae larvae	25	1.0	-	-	6	1.0	-	-	-	-	-	-	3	1.0
Tendepedidae larvae	25	1.0	100	3.7	100	5.5	100	9.9	100	7.8	50	2.6	90	6.1
Tendepedidae pupae	-	-	-	-	6	1.0	33	1.1	35	2.0	78	3.3	32	2.4
Blepharoceridae pupae	-	-	-	-	-	-	-	-	-	-	6	1.0	1	1.0
Immature larvae	-	-	-	-	-	-	-	-	-	-	72	3.1	15	3.1
Total Diptera	63	1.0	100	3.7	100	6.3	100	10.3	100	8.2	100	6.4	97	7.0
Plecoptera	-	-	-	-	-	-	-	-	4	1.0	17	1.0	4	1.0
Copepoda	-	-	-	-	6	1.0	-	-	12	1.0	-	-	4	1.0
Ephemeroptera	13	1.0	-	-	-	-	-	-	-	-	6	1.0	2	1.0
Annelida	-	-	-	-	-	-	7	1.0	-	-	6	1.0	2	1.0
Amphipoda	-	-	-	-	6	1.0	-	-	-	-	-	-	1	1.0
Unidentified	-	-	-	-	-	-	-	-	4	1.0	6	1.0	2	1.0
No. of Fry	8		8		16		15		26		18		91	
No. Empty	3 (37.5%)		0		0		0		0		0		3 (33%)	

cavity. Only one fry (14.5 mm total length) collected on April 19 and none taken after this date contained yolk material. Also all fry over 15.0 mm were devoid of yolk.

DISCUSSION

Displaced mountain whitefish from Mission Creek demonstrated in-season homing. The difference between numbers of males and females homing may have resulted from the fact that males are ripe for a longer period than females and were not affected as much by the delay due to displacement in their return to Mission Creek. The interruption of spawning behavior of ripe females induced by displacement may have caused them to spawn before returning to Mission Creek, thereby negating their desire to home. Handling and the trip over rough road to displacement sites may also have been a factor in causing fewer females to home than males. The greater number of fish homing from release sites below the mouth of Mission Creek was probably due to olfactory cues from Mission Creek. These cues would not be present in the river above the mouth. Homing from above the mouth may have been the result of random movement downstream until olfactory cues from Mission Creek were encountered. Visual cues may have aided in homing from either above or below the mouth of Mission Creek. McCleave (1967) and LaBar (1970) found no significant sex difference in numbers of homing cutthroat trout in their studies at Yellowstone Lake.

The striking positive phototaxis of mountain whitefish fry to artificial light appears to be quite different from most other salmonids studied. Stuart (1953) found brown trout *(Salmo trutta)* alevins exhibited strong negative phototaxis when exposed to artificial illumination. Hoar *et al.*, (1957), investigated fry of *Oncorhynchus* spp. and found *O. kisutch* were indifferent to light of moderately high intensities, *O. nerka* were photonegative, and schools of *O. keta* and *O. gorbuscha* showed a marked preference for light. The reaction of newly emerged *O. gorbuscha* to a decrease in light intensity is apparently similar to that of mountain whitefish fry. Kwain and McCrimmon (1969), reported rainbow trout yolk sac fry *(S. gairdneri)* of various ages were indifferent or photonegative to illumination. The positive phototaxis shown by mountain whitefish fry coupled with weak swimming ability may be an important factor in their habitat selection. Fry of this species occupy the shallow stream margins and back waters for a period of about three months subsequent to hatching (Brown, 1952). These regions contain an abundant source of food and normally remain free from larger predatory fish and also the greatest light intensities are usually in these areas.

The reason for differences in mountain whitefish fry responses to A-B (A = red, yellow, or white; B = black or blue) color combinations between a tank and trough is not clear. There was an avoidance of B colors by the fry in the trough over a 60 minute period but the opposite was true in the tank. The differences in physical characteristics, depth of water, or numbers of fry between the tank and trough may have been partly or wholly responsible. Further investigation is needed to ascertain why differences in fry numbers occurred at time 0 and why the trough data indicate color preference between all A-B combinations while the tank data do not.

The influence of light and color on the behavior of mountain whitefish fry is obviously complex. Further laboratory experimentation supplemented by field observations are needed to gain a better understanding of the relationships between fry behavior and light and color.

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