THE 1969 FULTON RIVER SOCKEYE FRY QUALITY AND ECOLOGY PROGRAM

SUMMARY OF RESULTS

Technical Report 1970 - 14

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INTRODUCTION

The Department of Fisheries of Canada embarked, in 1965, on a major program of spawning channel construction at Babine Lake, B. C., in an attempt to augment the spawning capacity of the natural streams tributary to the lake. The first channel was completed in October 1965 on the Fulton River.

The success of such a program will depend considerably on the extent to which the quality of the artificially produced fry resembles that of their naturally produced counterparts. A high quality, or fitness, will ensure that large numbers of the fry return as adults to be harvested by the fishery or to spawn and replenish the stock.

Consequently an attempt was made in 1968 to measure and compare various indices of the quality of naturally and artificially produced fry at Fulton River. Some differences between the populations were found but it quickly became evident that the significance of these differences could not be ascertained without a more complete knowledge of the species' ecological relationships with predators, food, and environmental conditions. A preliminary attempt to elucidate some of these relationships was made in 1968 (Dill, 1969).

The present study, conducted in 1969, is primarily an attempt at further elucidation of a few of these relationships (particularly predator-prey interactions). In addition, some quality indices were remeasured for the two fry populations in order to determine the generality of the conclusions reached in the earlier study.

LENGTH, WEIGHT AND DEVELOPMENT STAGE OF RIVER AND CHANNEL FRY

Random samples of 50 river and 50 channel fry were taken from the fan traps at 0100 hours daily. Each fry was weighed to the nearest mg, measured to the nearest mm, and recorded as being in one of the five standard development stages previously described (Dill, 1969).

The mean daily weights, lengths and development stages are shown for the two fry populations in Figs. 1, 2 and 3 respectively. The daily percentage of stage 5 fry in the samples is presented in Fig. 4.

A stratified analysis of the length and weight data revealed that channel fry were both heavier and longer than river fry (Table I). The differences, although small, were significant at the .001 level. Channel fry were also in a later stage of development at the time of emergence than were river fry.

Table I. Mean weights and lengths of Fulton River and channel sockeye fry, 1969

Measure	Population	$\bar{x}$	s^2	t
Weight (mg)	River	174.3	.3958	81.33*
	Channel	176.3	.5727	
Length (mm)	River	29.8	.0017	226.55*
	Channel	30.1	.0017	

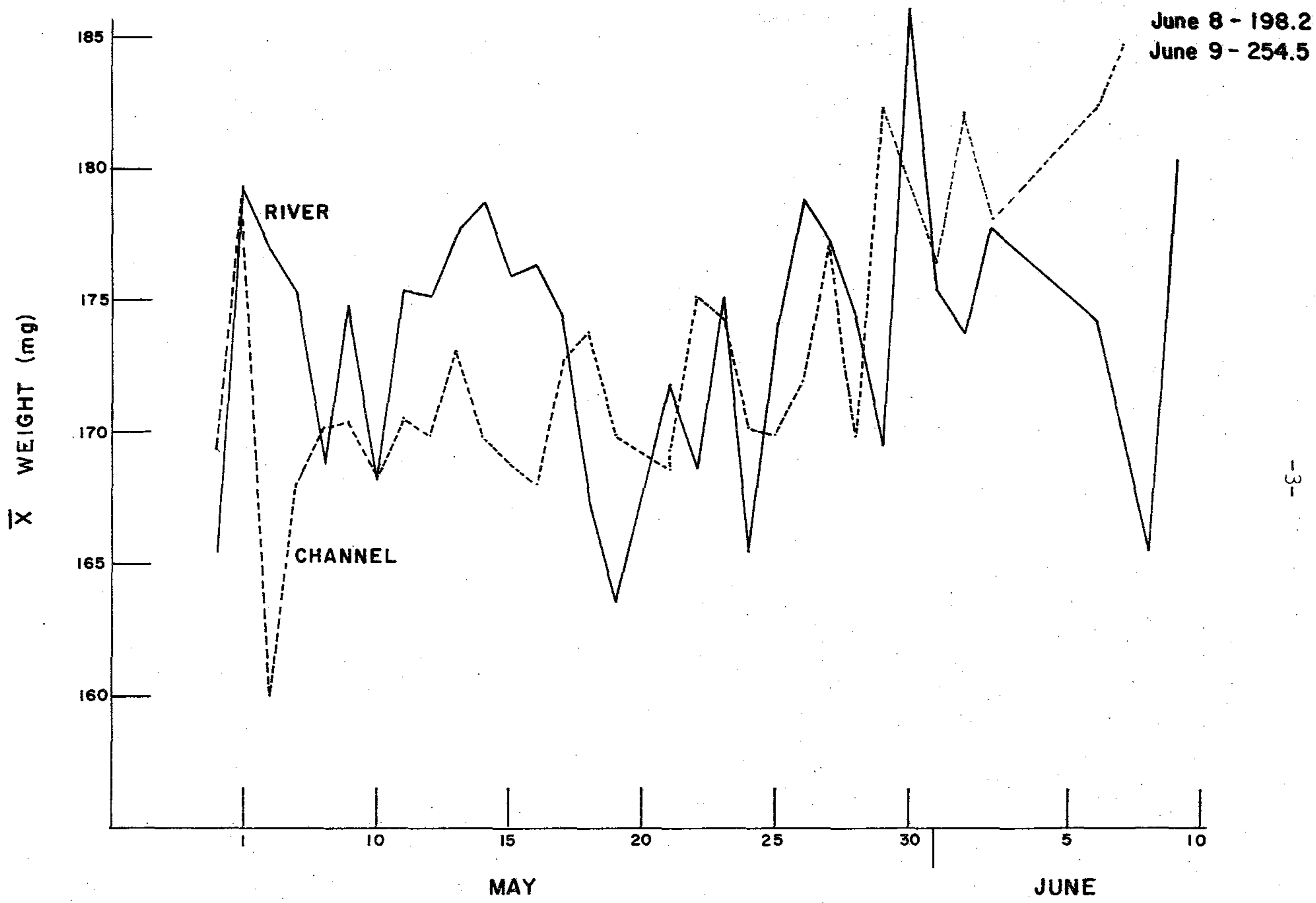

Figure 1. Weights of Fulton River and channel sockeye fry, 1969.

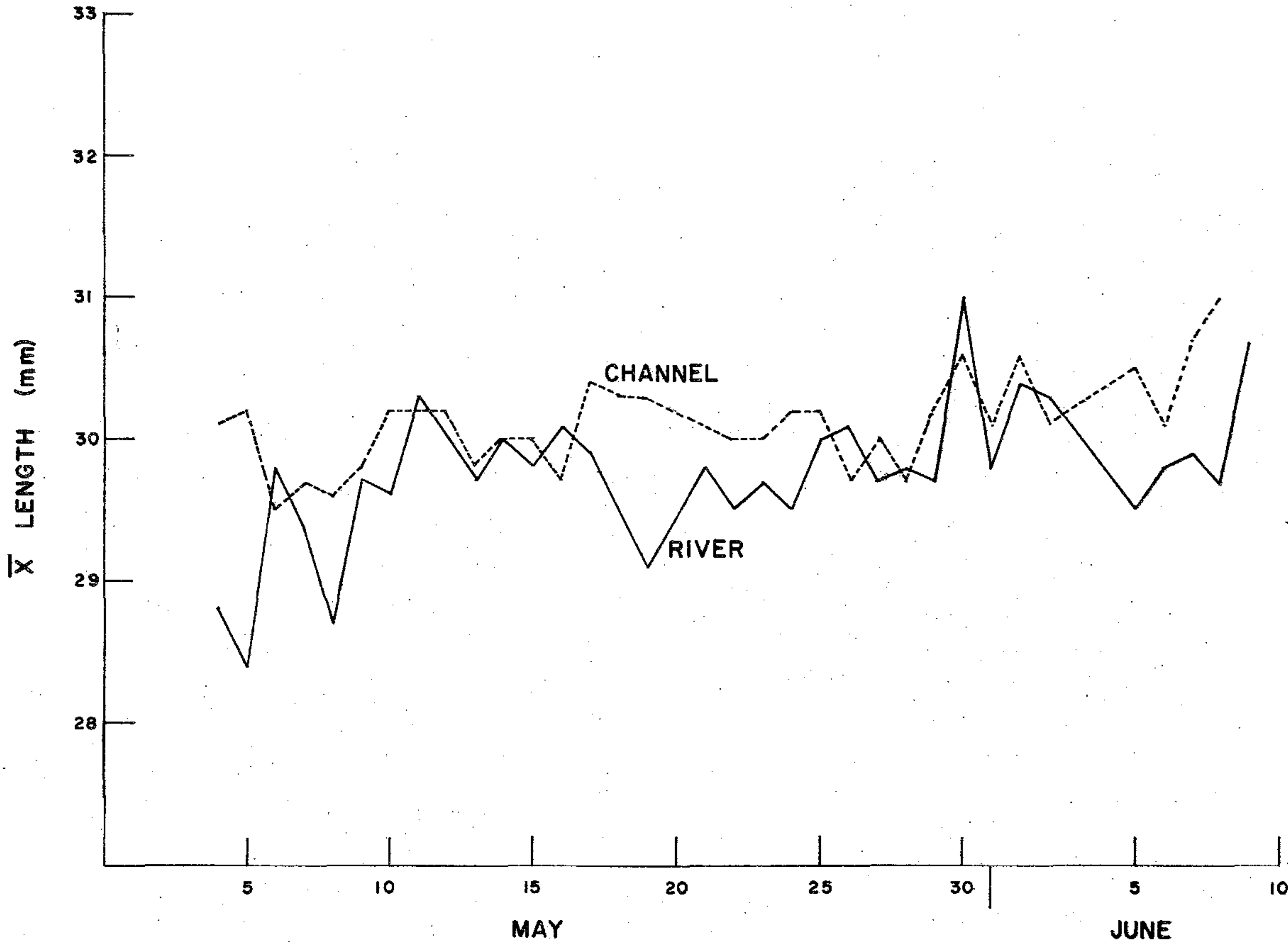

Figure 2. Lengths of Fulton River and channel sockeye fry, 1969.

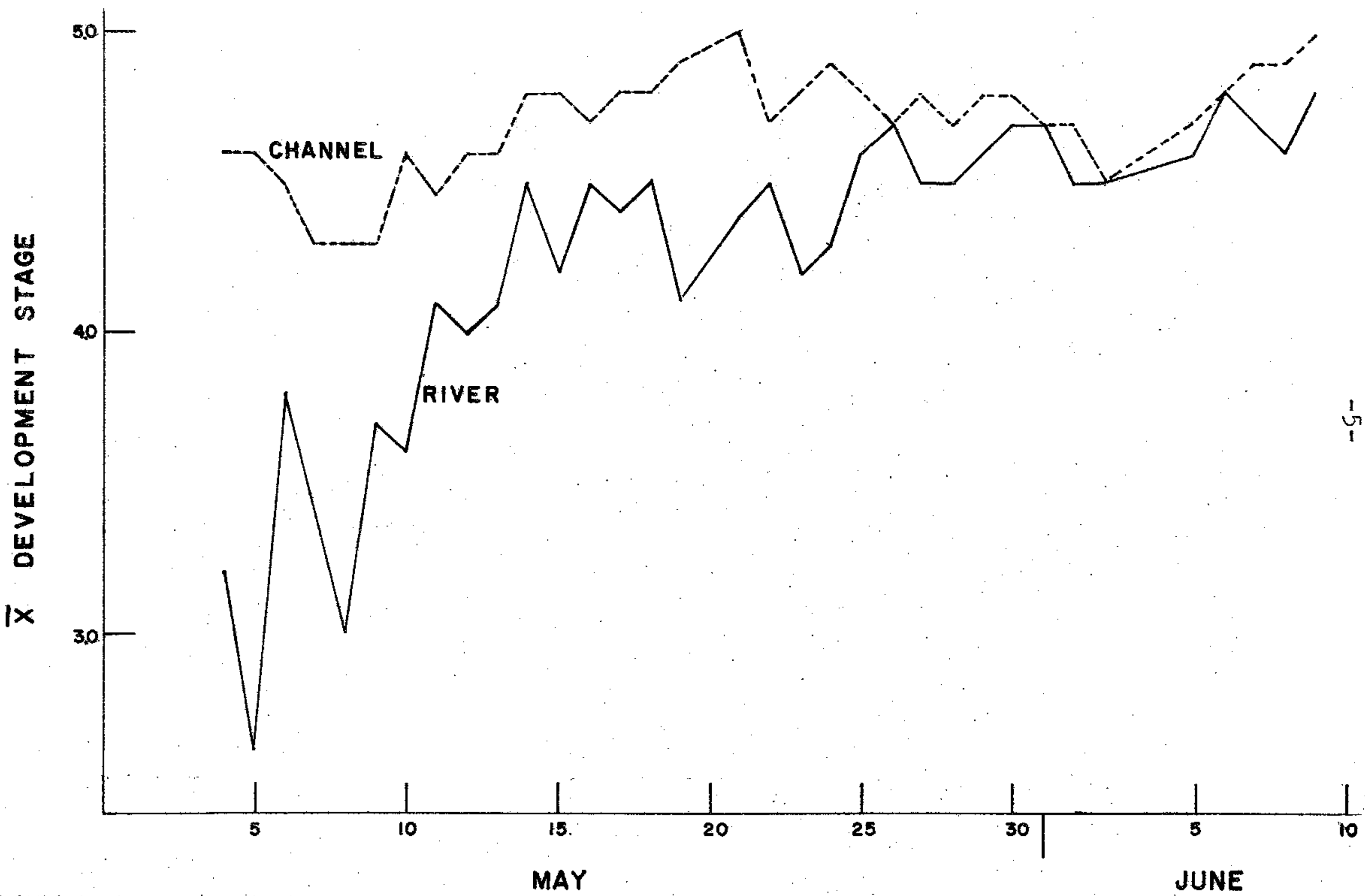

Figure 3. Development stage of Fulton River and channel sockeye fry, 1969

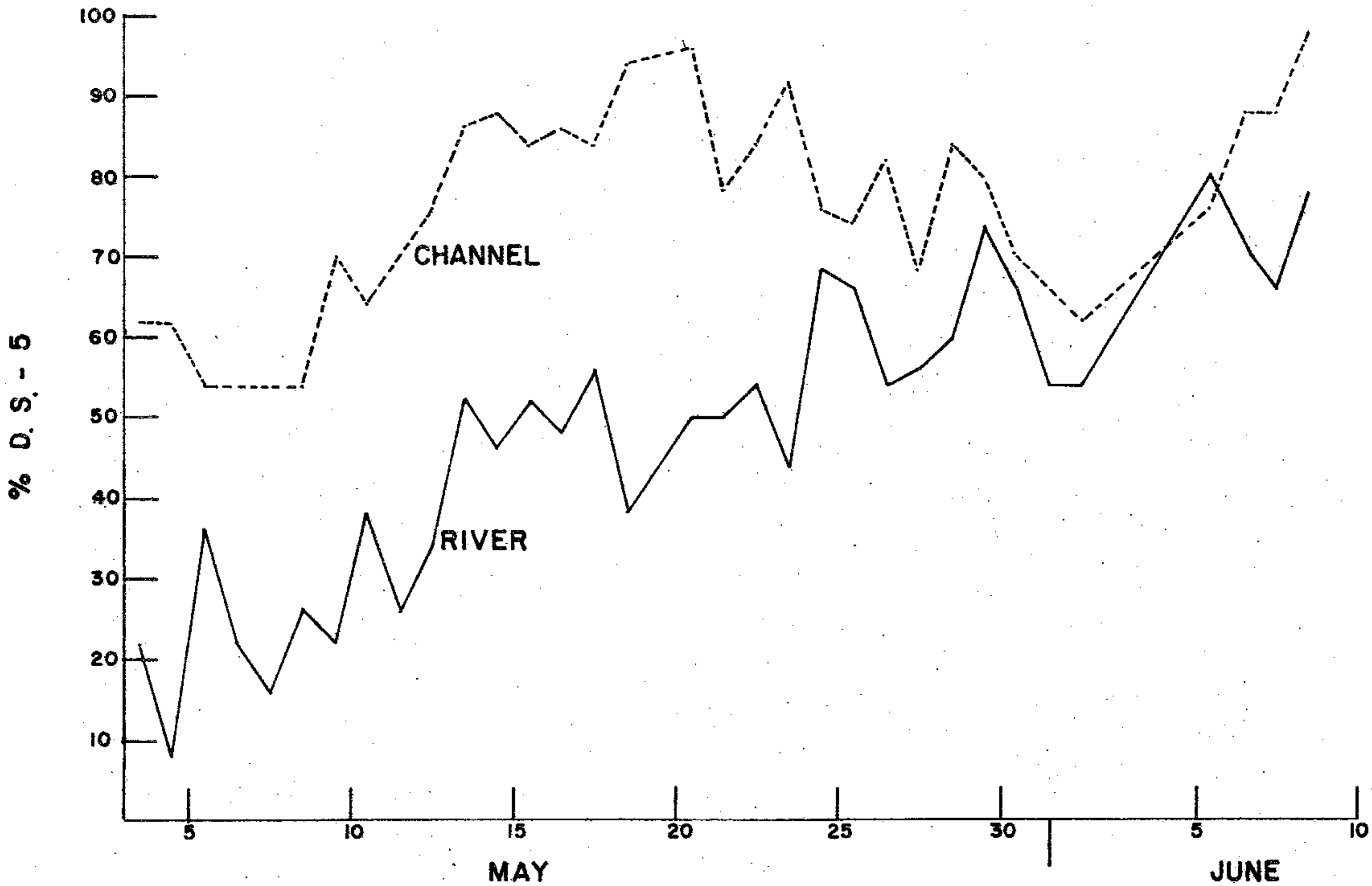

Figure 4. ~~Percent stage~~ 5 development of channel and river sockeye fry, 1969.

The situation with regard to weight was the reverse of that recorded in 1968, when the river fry were heavier than the channel fry (Dill, 1969). Fry from both populations were heavier (approx. 30 mg) than in 1968. The channel fry were longer in both years, although fry from both populations were longer (approx. 0.5 mm) in 1969 than in 1968. Both river and channel fry were more mature at the time of migration than they were in 1968, as well as being more similar to each other.

The data suggest that channel fry were at least equivalent in "quality" to river fry in 1969. Both groups were of higher "quality" than in 1968. These differences appear to be related to changes in the relative migration timings of the two populations. The 50 percent point of the river migration preceded that of the channel by only two days in 1969 (cf 13 days in 1968). The fact that the river discharge in 1969 (but not the channel discharge) was much lower than in 1968 supports the hypothesis that timing of emergence and quality of the fry largely associated with discharge.

QUANTIFICATION OF DEVELOPMENT STAGE

Owing to the subjectivity of the present method of staging fry, an attempt was made to find a more quantitative procedure. Carotenoids were extracted from the yolk with benzene. This was done by macerating a fry sample with the benzene in a Waring blender and centrifuging the homogenate. The supernatant solution was read with a Spectronic-20 colorimeter sensitized to the red area of the spectrum by means of an IR filter and tube. The percent transmittance of river and channel fry samples was to be compared. Unfortunately, reproducible readings were not obtained owing to a malfunction in the colorimeter. Preliminary results suggest, however, that the method is feasible if the blending and centrifuging times are sufficiently long (≈ 15 min).

EFFECTS OF LENGTH AND DEVELOPMENT STAGE ON THE SWIMMING ENDURANCE OF SOCKEYE FRY

In 1968, the swimming endurance of channel fry was greater than that of river fry (Dill, 1969). Two hypotheses were advanced to account for this result: (1) longer fry have greater endurance than shorter fry; and/or (2) more mature fry have greater endurance than less mature fry, since the former are more hydrodynamically efficient. The present study was designed to test these hypotheses. The results were submitted by Mr. John Mathers in partial fulfillment of the requirements for the BSc (Honours) degree at the University of Victoria.

Effect of Length

Three discrete groups of channel fry were tested between May 20 and June 8: (1) 28-29 mm fork length; (2) 29-30 mm f.l.; (3) 30-31 mm f.l. All fry tested were in development stage 4. The method of testing and the apparatus were similar to those used in 1968, except that acclimation time was reduced to ten hours (cf 12 hours in 1968), velocity was increased more slowly and maximum velocity was increased to .92 ft/sec (cf .59 ft/sec in 1968).

The results indicate that swimming endurance is a function of length, at least early in the season (Fig. 5). Seasonal (possibly temperature) differences, however, contribute a great deal of variability to the results and make interpretation difficult.

Effect of Development Stage

Four discrete groups of river fry were tested between May 20 and June 7: DS 2, DS 3, DS 4, and DS 5. All fry tested were 28-29 mm long. The testing method was identical to that described for "Effect of Length" above.

The results (Fig. 6) indicate that there is an effect of development stage on swimming endurance, but the exact nature of the relationship is unclear. First, as above, seasonal variation confounds the effect of development stage. Second, moderately mature fry (DS 3 and 4) may have greater endurance than either less (DS 2) or more mature (DS 5) fry.

The data on the effects of both length and development stage are discussed more completely by Mathers (1970).

EXPERIMENTAL STUDIES OF PREDATION ON SOCKEYE FRY

It was concluded in the earlier report (Dill, 1969) that inferences concerning rates of predation on river and channel fry could not be drawn until the relationship between mortality and factors such as prey density, prey distribution,

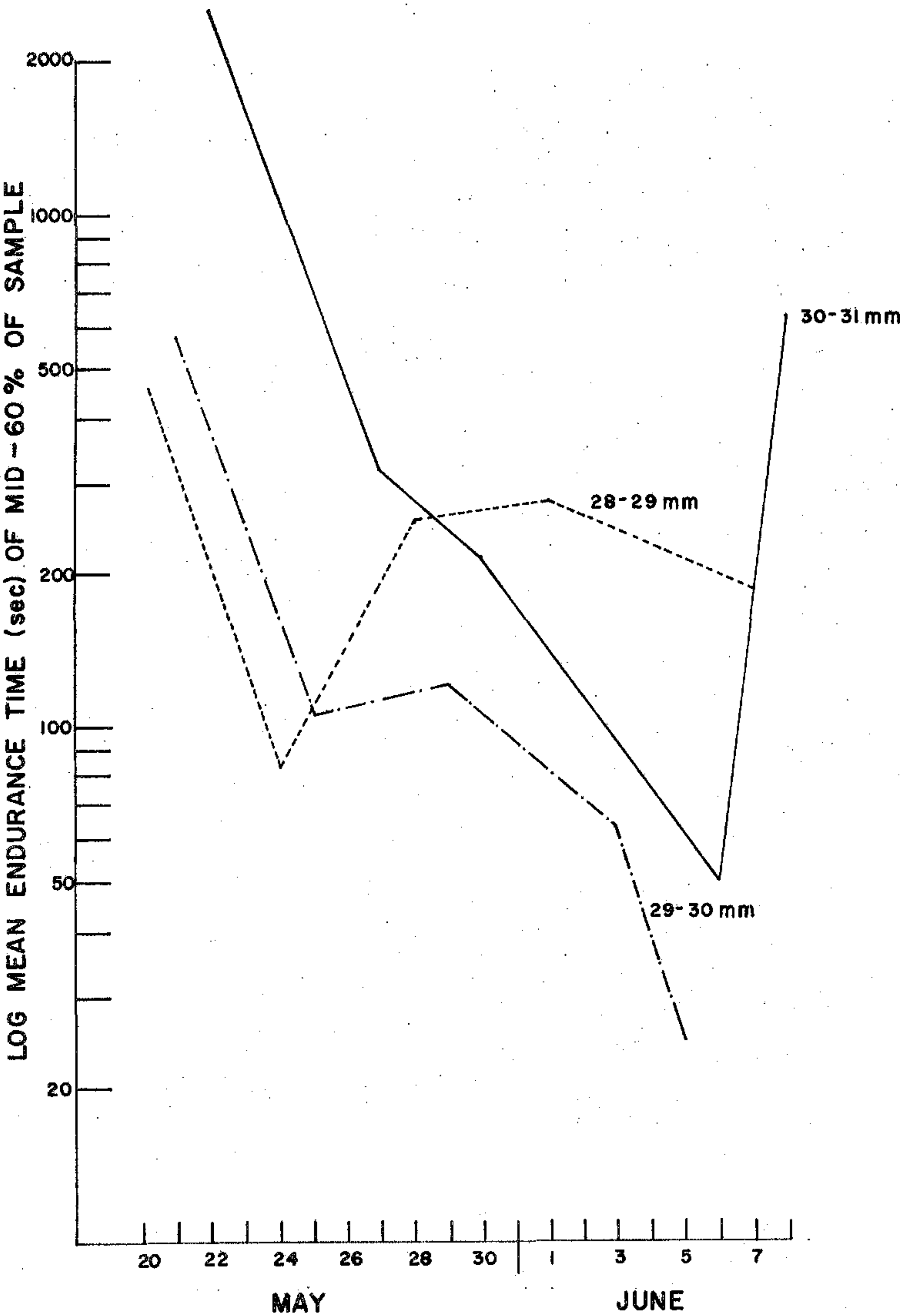

Figure 5. The effect of length on swimming endurance of channel sockeye fry.

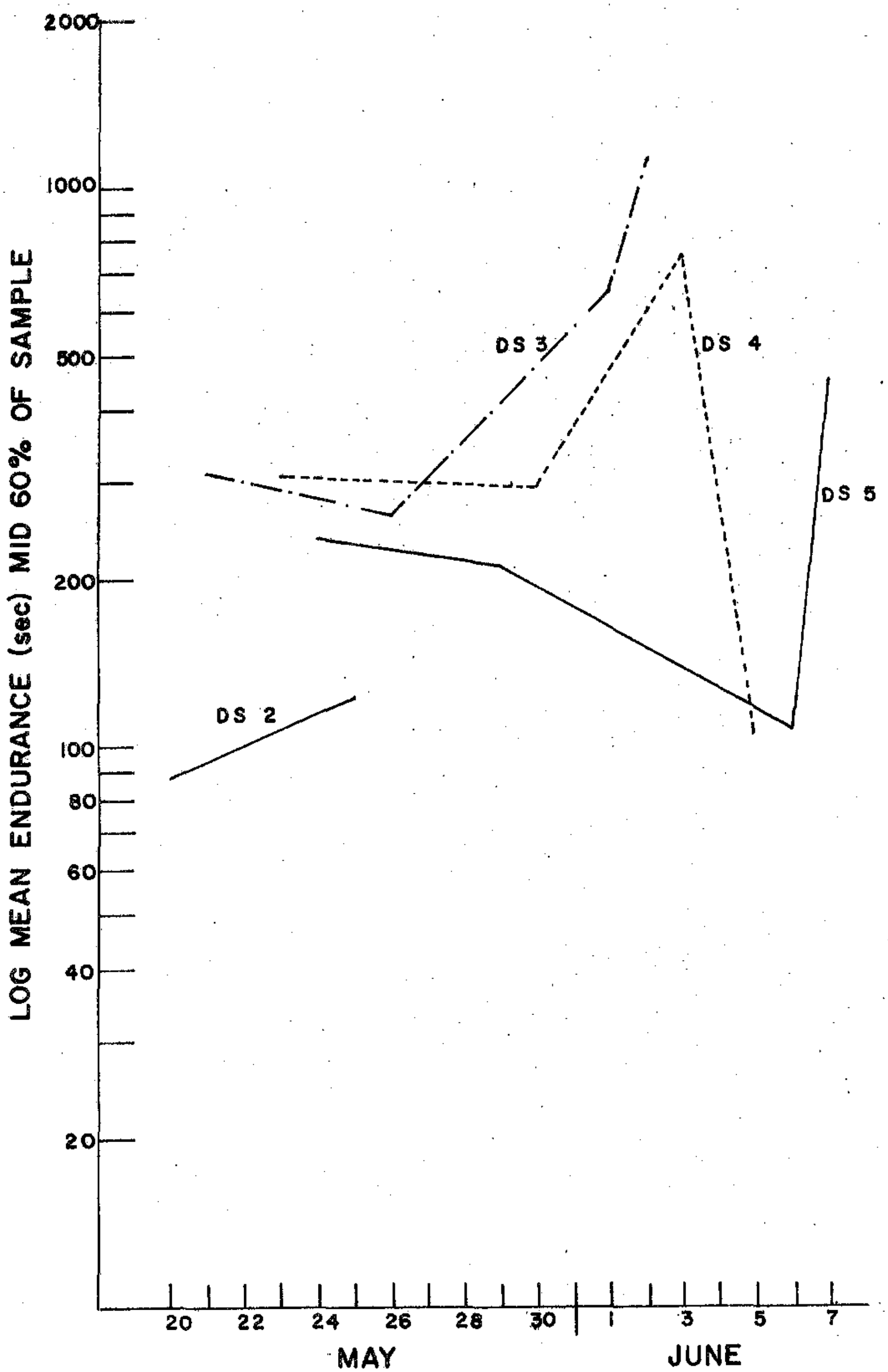

Figure 6. The effect of development stage on swimming endurance of river sockeye fry.

prey size, prey development stage, and the presence of an alternate food organism had been elucidated. This portion of the study represents an attempt at such elucidation. The effects of prey density, distribution and size were studied by Mr. Ron Ginetz and the results submitted in partial fulfillment of the requirements for the BSc (Honours) degree at the University of British Columbia (Ginetz, 1970).

Experiments were conducted in a stream channel (Fig. 7) in which all factors were controlled or accounted for. The stream channel provided two environmental replicates and each replicate was stocked with predators as follows: 7 mountain whitefish; 5 rainbow trout; 2 longnose dace; 3 coho smolts; 3 prickly sculpins; and 2 peamouth chub. These predators were paired by size in the two stream sections. If one member of a pair died the other was removed and both were replaced with new predators if these were available. Tests were conducted in a "relative" rather than an "absolute" manner (see Dill, 1969) so that test-to-test variation in predator populations or environmental conditions would not affect the results. Tests were conducted every day from May 14 to June 13. Fry were introduced at about noon and removed the following morning (except part B).

Effect of Prey Density

The hypothesis tested in this experiment was that as prey density increases, percentage mortality decreases. The control (section B) was always provided with 500 randomly

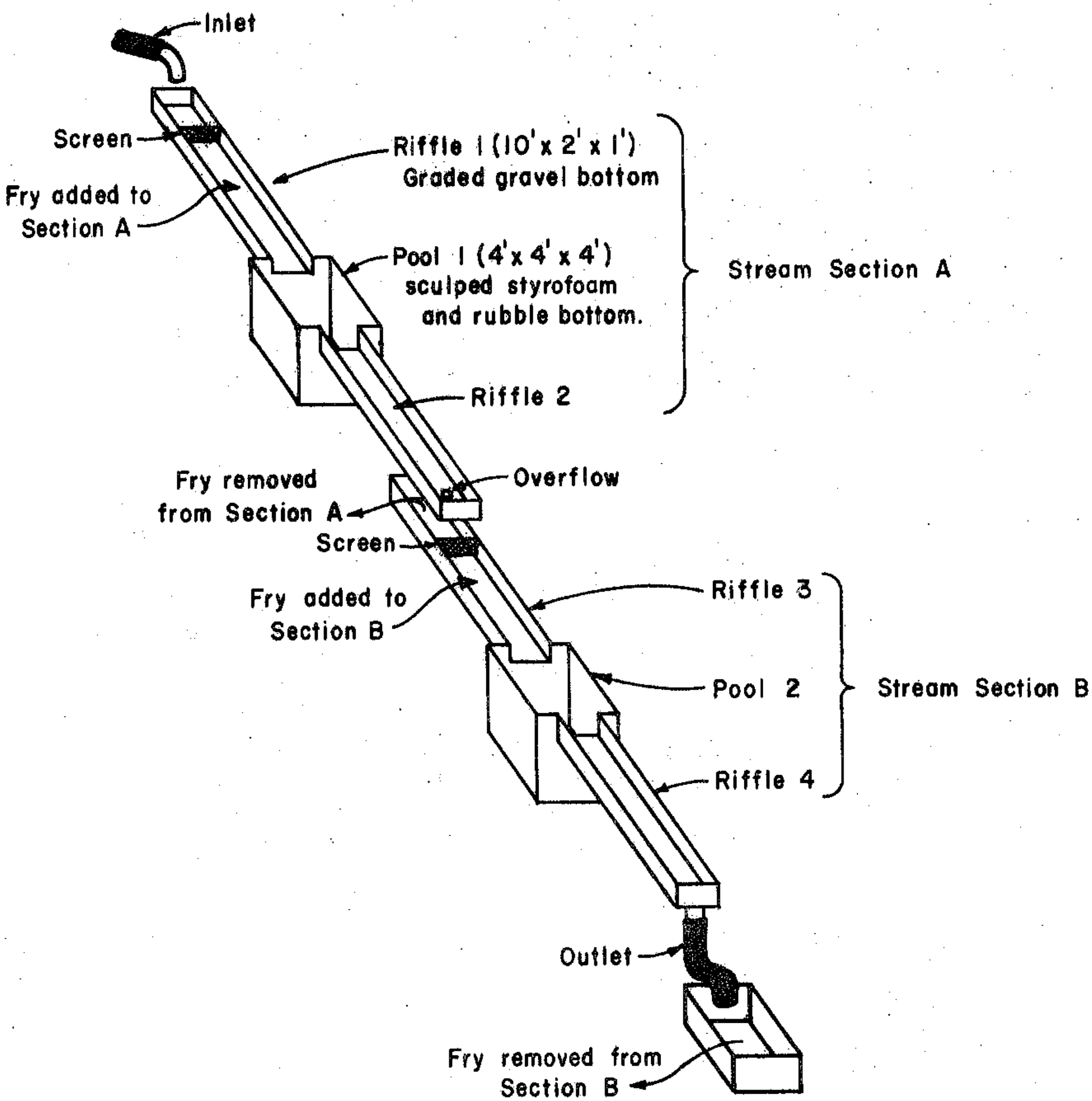

Figure 7. Artificial stream used in the experimental predation studies.

selected fry. The number of fry introduced to section A varied from 100 to 800. Daily results were calculated as a ratio:

$$R = \frac{\%\ \text{mortality experiment}}{\%\ \text{mortality control}}$$

and plotted against the number of prey introduced (Fig. 8). Theoretical results (i.e. those which would be obtained were the hypothesis correct) are also shown.

The results clearly do not support the hypothesis. Prey density has little effect on the percentage of fry eaten, since $R \approx 1$ for all densities. Note however that R for prey numbers 100 to 600 is > 1 but for 700 and 800 is < 1. This suggests a threshold level of prey density at which partial predator satiation occurs, but further work on this relationship is warranted.

Effect of Temporal Distribution of Prey

The hypothesis in this experiment was that a rapid dispersal of fry through a predator gauntlet results in a lower percentage mortality than a slow dispersal of fry through the same situation. Five hundred randomly selected fry were added to each trough between 2400 and 0500 hours each day. In the control stream (section B) all 500 fry were added at 2400 hours. The experimental introductions into section A were as follows:

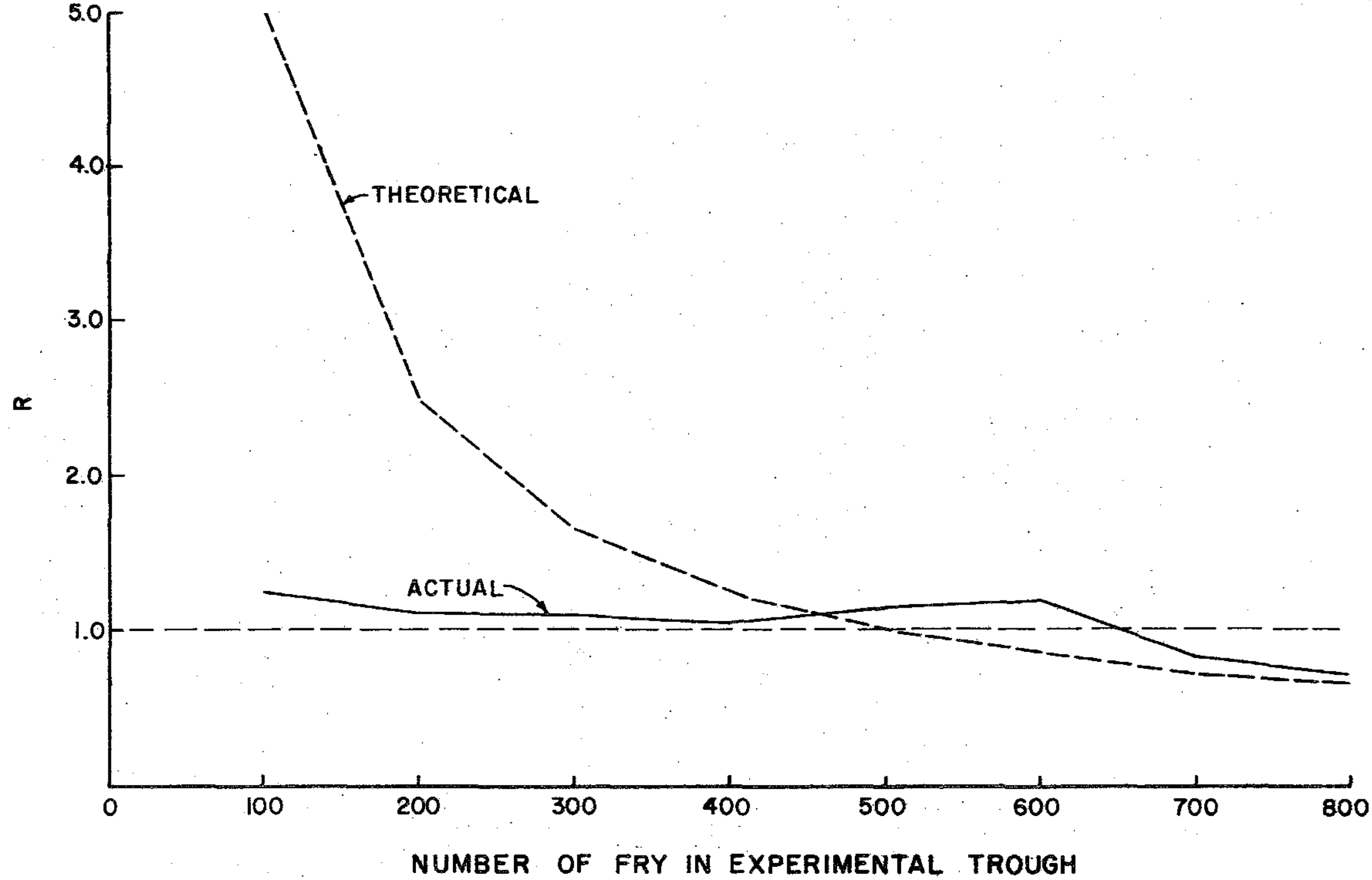

Figure 8. Actual and theoretical results for the prey density experiment. (see text for meaning of R)

Date	1st Introduction	No.	Time to subsequent Introductions	No. of Introductions
May 23	2400 hrs	5	3 min	100
24	"	10	6 "	50
25	"	50	30 "	10
26	"	100	1 hr	5
27	"	250	2.5 hr	2
28	"	500	-	1

The daily results were calculated as in part A above and plotted against the number of introductions (Fig. 9). Theoretical results are also shown. Again, the results obtained refute the original hypothesis. This could be due to: (1) the scattered fry (500) not moving until their density reached a threshold level; (2) the clumped fry (500) moving downstream in small groups; or (3) a combination of these.

Effect of Prey Size

The hypothesis tested in this study was that the rate of predation on small sockeye fry is greater than that on large fry. Eight tests were conducted, four in each stream section. In each test 300 fry, randomly selected with respect to development stage, were used. Each test utilized 100 fry of each of the following lengths: 29-30 mm fork length; 30-31 mm; and 31-32 mm.

The results demonstrate clearly that small sockeye fry are more susceptible to predation than are large fry and that a small size difference may have a profound effect on survival

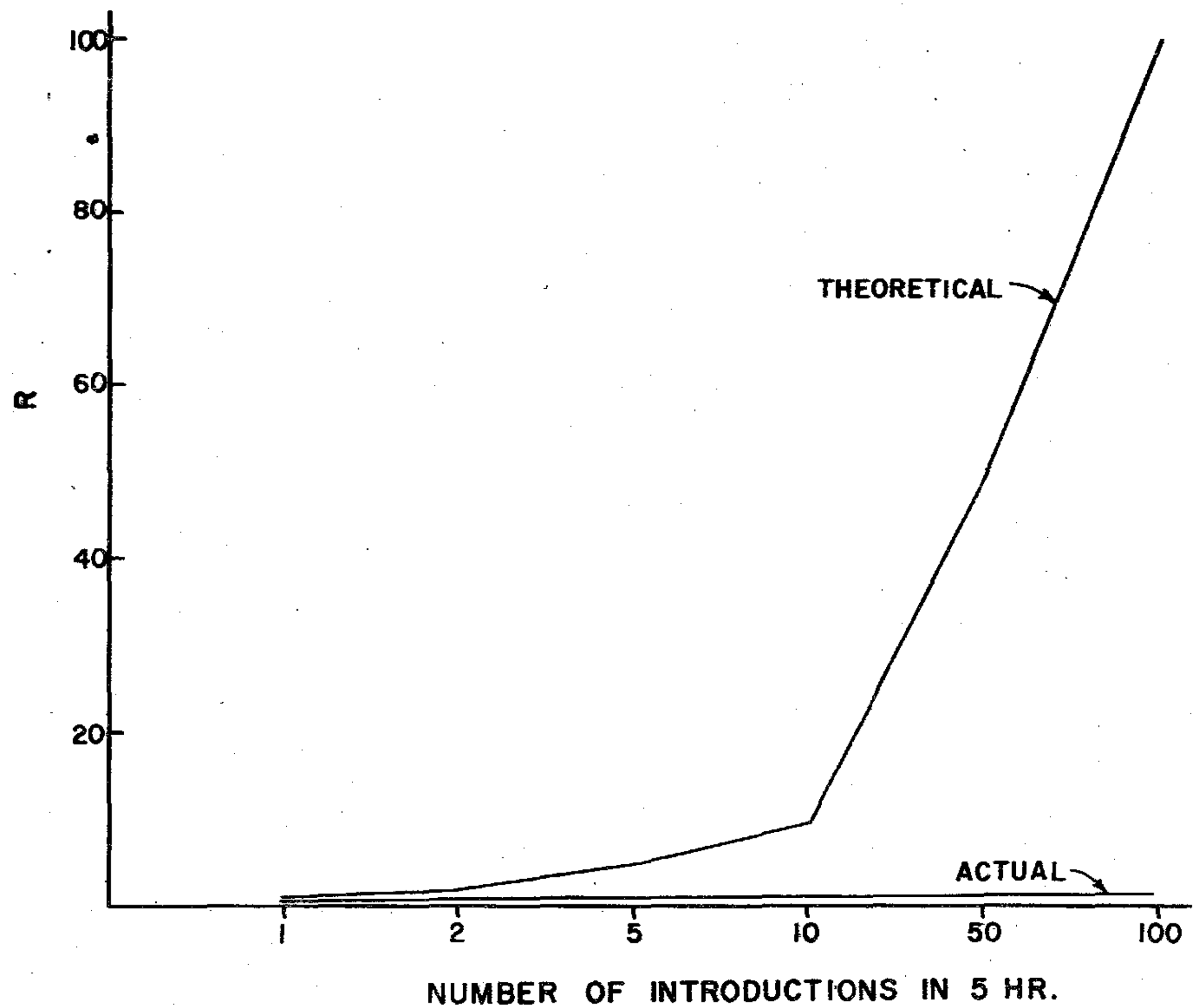

Figure 9. Actual and theoretical results for the migration timing experiment. (see text for meaning of R)

(Table II). Parker (1969) has recorded size selection predation mortality on pink salmon fry.

Table II. Percentage survival by length class in the predation tests

Date	Section	29-30 mm	30-31 mm	31-32 mm
May 29	A	34	54	43
	B	50	55	66
May 30	A	38	62	73
	B	46	60	95
May 31	A	34	49	43
	B	22	30	40
June 1	A	42	49	66
	B	34	35	73
Mean	$\bar{x}$	37.5	49.3	62.4

Effect of Development Stage

The following tests were conducted to determine whether yolk sac fry are more or less susceptible to predation than mature fry. To each stream section 150 DS 4 and 150 DS 5 fry, randomly selected with respect to length, were added and the percent mortality of each group recorded. The test was repeated four times. The results indicate that stage 4 fry are more susceptible to predation than stage 5 fry (Table III). Presumably, less mature fry (DS 2 and 3) would be still more susceptible. It is not known whether the results are due to predators preferentially preying upon stage 4 fry or to stage 4 fry being less able to escape attack.

Table III. Predation upon stage 4 and stage 5 fry

Date	Section	% Mortality DS 4	% Mortality DS 5	DS 4/DS 5	
June 4	A	65.3	31.3	2.086	10.5484*
	B	49.3	22.0	2.241	4.9177*
June 6	A	74.7	38.7	1.930	15.0672*
	B	63.3	18.0	3.517	15.8699*
				$\bar{x}$ = 2.444	

Effect of Alternate Food Supply

It was hypothesized in the earlier report (Dill, 1969) that mortality would be most severe on that fry population migrating when less alternate food was available to the predator. The present experiment was designed to test this hypothesis. Two tests were conducted utilizing 600 fry each. On June 9, 300 fry and 200 insects (mostly the stonefly *Alloperla*) were placed in stream section A and 300 fry alone in section B. The situation was reversed on June 10 when 200 insects (mostly the stoneflies *Isogenus* and *Alloperla*) and 300 fry were placed in section B. The results (Table IV) demonstrate that fry mortality was indeed reduced when an alternate food for the predators was present.

Table IV. Effect of alternate food supply on predation mortality of sockeye fry

Date	% Mortality in Absence of Insects	% Mortality in Presence of Insects	R	X^2
June 9	48.67	31.00	1.57	11.613*
10	46.67	16.33	2.86	4.583*
			$\bar{x}$ = 2.22	

<u>Effect of Relative Abundance of Prey Types</u>

It has been noted by Parker <u>et</u> <u>al</u> (1963) that fin removal increases the risk of pink salmon fry to predation. These authors suggested that removal of a fin caused the fish to swim differently or altered its appearance so that it stood out as an individual and focused the attention of the predator upon it. In all of the tests which Parker conducted the marked fry were present in lower abundance than the unmarked fry. It would be theoretically possible to test the hypothesis by placing the unmarked fry in the minority, i.e. as the unusual fry. If predation were higher on the normal fish then fitness of the prey alone would not be sufficient to predict predation mortality. One would also have to know the relative abundance of each prey type, e.g. large fry might be more vulnerable to predation than small fry if the former were more scarce.

Three tests were conducted to test the foregoing hypothesis. In the first test "abnormal" fry were dyed with Bismarck brown (3/4 hr; 1 gr/10 gal). Section A was stocked with 30 normal and 270 abnormal fry, section B with 30 abnormal and 270 normal fry. The dyed fry were more susceptible to predation in both cases: R = 40.00/26.67 = 1.50 in section A; R = 53.33/28/89 = 1.84 in section B. Mean R = 1.67. The test was repeated with the reverse situation, i.e. - 30 abnormal and 270 normal fry in section A; the opposite in section B. In this case mortality on the less abundant fry was greater, regardless of whether or not they had been dyed

Table V. Effect of relative abundance on predation mortality of sockeye fry

Section	% Dyed	Mort. on 10%	Mort. on 90%	R
A	10	40.00%	10.37%	3.85
B	90	30.00%	12.60%	2.38
				$\bar{x}$ = 3.12

In the third test, both groups of fry were dyed, some with Bismarck brown and the others with neutral red chloride. Section A was stocked with 270 red and 30 brown fry and section B with the opposite. Red fry were preyed upon more than brown fry in both cases. R_A = 46.30/33.33 = 1.39; R_B = 40.00/25.56 = 1.57. The mean R was 1.48. None of the χ^2 for the above three tests, however, were significant because of the 9 - fold (270/30) differences in sample sizes.

The results suggest that vulnerability may be determined in some cases by both fitness and relative abundance and that the relation between them is not a simple one.

PREDATOR TAGGING

Predators were captured in the river proper by gill netting and beach seining. Gill netting was conducted in the fishway exit and beach seining in the Tower Pool and on the left side of the large island below the fence. Predators were also captured in the lake adjacent to the river mouth with a 200 ft purse seine (1 inch mesh). Fish were tagged with numbered Petersen discs and returned to the water in an attempt to determine: (a) population sizes; (b) extent of movement occurring during the period of the fry migration, particularly from the lake into the river.

Rocky Mountain Whitefish (*Prosopium williamsoni*)

The tagging records for this species are shown in Table VI and summarized in Table VII. Only five of the 228 tagged whitefish were recovered. One fish tagged in Tower Pool on April 27 was recovered at the Island the same day, having apparently fallen downstream after tagging. One fish tagged in Tower Pool May 2 was recovered there 24 days later, and another tagged at the Island May 11 was recovered there ten days later. A fourth fish tagged in Tower Pool May 23 was recaptured in Babine Lake near the Fulton mouth on July 18 and a fifth specimen, tagged at the island May 3, was recovered at the mouth of Pinkut Creek on August 12. Systematic recapture attempts were made in the river in June but no whitefish were recovered.

Table VII. Summary of mountain whitefish tagging

Area	No. Tagged	$\bar{x}$ f.l. (cm)
Channel	1	-
Fishway Exit	6	24.6
Tower Pool	85	27.6
Island	127	26.0
River Mouth	9	26.7
Total	228	26.6

Table VI. Tagging records for mountain whitefish

Date		Location	Gear	n	$\bar{x}$ f.l. (cm)
April	27	Tower Pool	BSN	9	---
	27	Island	BSN	15	---
April	28	Tower Pool	BSN	7	---
May	2	Tower Pool	BSN	37	---
May	3	Tower Pool	BSN	22	---
	3	Island	BSN	41	---
May	4	Island	BSN	26	27.2
May	5	Channel	BSN	1	---
May	7	Island	BSN	5	22.4
May	8	Fishway Exit	G/N	6	24.6
May	10	Island	BSN	5	27.3
May	11	River Mouth	PSN	5	24.8
	11	Tower Pool	BSN	3	25.7
	11	Island	BSN	4	23.8
May	13	Island	BSN	9	25.4
May	16	Island	BSN	14	26.2
May	17	River Mouth	PSN	1	26.0
May	21	Tower Pool	BSN	4	26.5
	21	Island	BSN	6	23.5
May	23	Tower Pool	BSN	1	36.0
May	27	River Mouth	PSN	3	30.0
May	28	Tower Pool	BSN	2	33.0
	28	Island	BSN	2	29.3

Rainbow Trout (*Salmo gairdneri*)

The tagging records for rainbow trout are shown in Table VIII and summarized in Table IX by capture location.

Table VIII. Tagging records for rainbow trout

Date	Location	Gear	n	$\bar{x}$ f.l. (cm)
May 12	Tower Pool	BSN	2	-
May 15	River Mouth	PSN	2	47.5
May 17	River Mouth	PSN	8	36.3
May 20	River Mouth	PSN	8	32.4
May 21	Tower Pool	BSN	1	28.0
21	Island	BSN	2	28.5
May 22	River Mouth	PSN	3	23.2
May 23	Tower Pool	BSN	3	30.3
23	Island	BSN	2	25.3
May 27	River Mouth	PSN	1	24.0
May 28	Island	BSN	1	28.5

Table IX. Summary of rainbow trout tagging

Area	No. Tagged	$\bar{x}$ f.l. (cm)
Tower Pool	6	29.7
Island	5	27.2
River Mouth	22	33.6
Total	33	31.9

Rainbow trout captured in the lake (River Mouth) were consistently larger than those captured in the river. Only four tagged trout were recovered, both by sport fishermen. One tagged in Tower Pool May 2 was captured at the nearby highway bridge 28 days later. A second Tower Pool specimen, tagged May 23, was recovered at the counting fence September 16. One tagged in the lake was captured just above the Indian reserve on June 5, 16 days after tagging, providing some evidence of movement into the river. Another trout tagged in the lake May 20 was recovered near Pendleton Bay in the main lake on July 4.

Lake Whitefish (Coregonus clupeaformis)

The tagging data for this species are presented in Table X. All fish were captured in the lake near the river mouth with a purse seine. None have since been recovered. Seining prior to May 11 yielded no whitefish. The species only appeared in the area when the sockeye fry migration began and had apparently disappeared by June 13, as none were captured in several sets on that date.

Table X. Lake whitefish tagging records

Date	n	$\bar{x}$ f.l. (cm)
May 11	13	39.3
15	20	38.7
17	13	35.9
20	5	36.0
22	2	24.0
June 1	1	35.0
Total	54	37.3

PREDATOR STOMACH SAMPLING

Stomach samples were obtained by dissection and stomach pumping of mountain whitefish, lake whitefish, and rainbow trout. The results for the mountain whitefish are summarized in Table XI. The average number of fry per whitefish examined was only 1.3 compared to 11.4 in 1968. Feeding on fry in 1969 was more extensive at the fishway exit than at the Tower Pool, the reverse of the situation observed in 1968. The reason for this change is not known.

The results of the rainbow trout stomach samples are summarized in Table XII. Feeding on fry was most extensive in the lake and least extensive at the fishway exit. The average number of fry per stomach examined was 9.42, much higher than the comparable figure for the mountain whitefish.

The results of the lake whitefish stomach samples are summarized in Table XIII. All fish were captured in Babine Lake adjacent to the mouth of the Fulton. The mean number of fry per stomach examined was 0.97.

Of the three species examined the rainbow trout appears to be the most significant predator. Predation by mountain whitefish on sockeye fry was much less than in 1968. The reason for this seems to lie in the greatly increased dependence by whitefish on salmon eggs as a food item. In 1969, salmon eggs were a diet item in 64.5 percent of the stomachs examined. The mean number of eggs per feeder was 22.4 (1 fish contained 113 eggs), and the mean number per stomach examined was 14.4 eggs. Eggs were found in only 1/3 of the 1968 samples and

Table XI. Extent of feeding upon sockeye fry by mountain whitefish

Date	Location	No. of Samples	No. Containing Fry	%	No. of Fry	No. per Feeder	No. per Stomach
April 27	Island	1	0	0	0	0	0
28	Tower Pool	2	0	0	0	0	0
May 2	Tower Pool	5	0	0	0	0	0
3	Tower Pool	2	0	0	0	0	0
	Island	1	0	0	0	0	0
4	Island	6	1	16.7	1	1.0	0.17
9	Island	2	0	0	0	0	0
10	Island	4	0	0	0	0	0
11	Lake	5	1	20.0	2	2.0	0.40
	Tower Pool	2	0	0	0	0	0
	Island	3	0	0	0	0	0
	Fishway	2	0	0	0	0	0
13	Island	3	0	0	0	0	0
14	Fishway	2	1	50.0	3	3.0	1.50
16	Island	4	1	25.0	1	1.0	0.25
	Tower Pool	1	0	0	0	0	0
20	Fishway	3	2	66.7	8	4.0	2.67
21	Tower Pool	4	2	50.0	3	1.5	0.75
	Island	1	0	0	0	0	0
23	Tower Pool	1	0	0	0	0	0
25	Fishway	1	1	100.0	44	44.0	44.0
26	Fishway	2	1	50.0	23	23.0	11.5
27	Lake	2	0	0	0	0	0
28	Tower Pool	2	0	0	0	0	0
	Island	1	0	0	0	0	0
June 2	Fishway	2	2	100.0	14	7.0	7.0
4	Fishway	3	0	0	0	0	0
7	Fishway	5	0	0	0	0	0
8	Fishway	4	0	0	0	0	0
TOTAL	Island	26	2	7.7	2	1.0	0.08
	Tower Pool	19	2	10.5	3	1.5	0.16
	Lake	7	1	14.3	2	2.0	0.29
	Fishway	24	7	29.2	92	13.1	3.83
TOTAL	Total	76	12	15.8	99	8.3	1.30

Table XII. Extent of feeding upon sockeye fry by rainbow trout

Date	Location	No. of Samples	No. containing fry	%	No. of fry	No.per feeder	No. per stomach
May 14	Fishway	2	0	0	0	0	0
15	Lake	2	2	100.0	108	54.0	54.00
17	Lake	1	1	100.0	17	17.0	17.00
20	Lake	4	2	50.0	53	26.5	13.25
	Fishway	2	1	50.0	12	12.0	6.00
21	Tower Pool	1	0	0	0	0	0
	Island	2	1	50.0	31	31.0	15.50
22	Lake	2	2	100.0	84	42.0	42.00
23	Tower Pool	3	2	66.7	9	4.5	3.00
	Island	2	0	0	0	0	0
27	Lake	1	0	0	0	0	0
28	Island	1	1	100.0	5	5.0	5.0
30	Fishway	2	0	0	0	0	0
June 2	Fishway	1	0	0	0	0	0
4	Fishway	2	0	0	0	0	0
	Lake	2	1	50.0	1	1.0	0.50
7	Fishway	2	0	0	0	0	0
8	Fishway	2	0	0	0	0	0
TOTAL	Island	5	2	40.0	36	18.0	7.20
	Tower Pool	4	2	50.0	9	4.5	2.25
	Lake	12	8	66.7	263	32.9	21.92
	Fishway	13	1	7.7	12	12.0	0.92
TOTAL	Total	34	13	38.3	320	24.6	9.42

and then usually only in numbers of one or two per stomach. The eggs were released from the rotting carcasses of the 1968 sockeye spawners and were visibly present in the stream in large numbers in the spring of 1969. Thus, there may be some "beneficial" effects of high egg retention.

Table XIII. Extent of feeding upon sockeye fry by lake whitefish

Date	No. of Samples	No. Containing Fry	%	No. of Fry	No. per Feeder	No. per Stomach
May 11	4	1	25.0	5	5.0	1.25
15	4	3	75.0	9	3.0	2.25
17	3	2	66.7	6	3.0	2.00
20	5	3	60.0	8	2.7	1.60
27	1	0	0	0	0	0
June 1	1	1	100.0	1	1.0	1.00
4	13	0	0	0	0	0
May 11-June 1	18	10	55.6	30	3.0	1.67
Total	31	10	32.3	30	3.0	0.97

DIGESTIVE RATE OF ROCKY MOUNTAIN WHITEFISH

Experiments were conducted to determine the effects of water temperature, food volume, and food type on the digestive rate of mountain whitefish. The results were submitted by Mr. Doug McKone in partial fulfillment of the requirements for the BSc (Honours) degree at the University of British Columbia.

Food was administered with a force-feeder to anaesthetized whitefish and the fish were dissected at intervals to determine time to 100 percent digestion. Food volumes were 2, 5, and 8 items per fish; food types were adult stoneflies, stage 5 sockeye fry, and yolk sac sockeye fry; and water temperatures varied from 5.0 to 12.5 C over the course of the experiment.

Stoneflies were digested somewhat more slowly than sockeye fry, although mature and yolk sac fry were digested at about the same rate. Digestion was more rapid at higher temperatures and a large volume of fry was digested more slowly than a smaller volume (Fig. 10). A more complete analysis of the data can be found in McKone (1970).

SPATIAL AND TEMPORAL DISTRIBUTION OF DRIFT INSECTS AND FRY IN THE FULTON RIVER AND THEIR RELATION TO THE QUESTION OF MIMICRY

It has been suggested (Dill, 1969) that insects and fry may have co-evolved as edible mimics to reduce the extent of predation on either group. This can be only if the two food types are equally available to the predator, i.e. if they occur at the same time in the same place. The present survey attempted to determine if this was indeed the case. If mimicry is to be considered a possibility, it must further be demonstrated that the predator is "deceived", i.e. that it cannot select for food types at the time and in the place that the two food types occur together. An attempt was therefore made to determine food selection by trout and mountain whitefish at various light intensities.

Diel Migration Timing of Drift Insects and Fry

A two-inch wide vertical sampler was constructed for this study. It comprised a narrow aluminum frame with marquisette bags at one-foot intervals and was inserted into

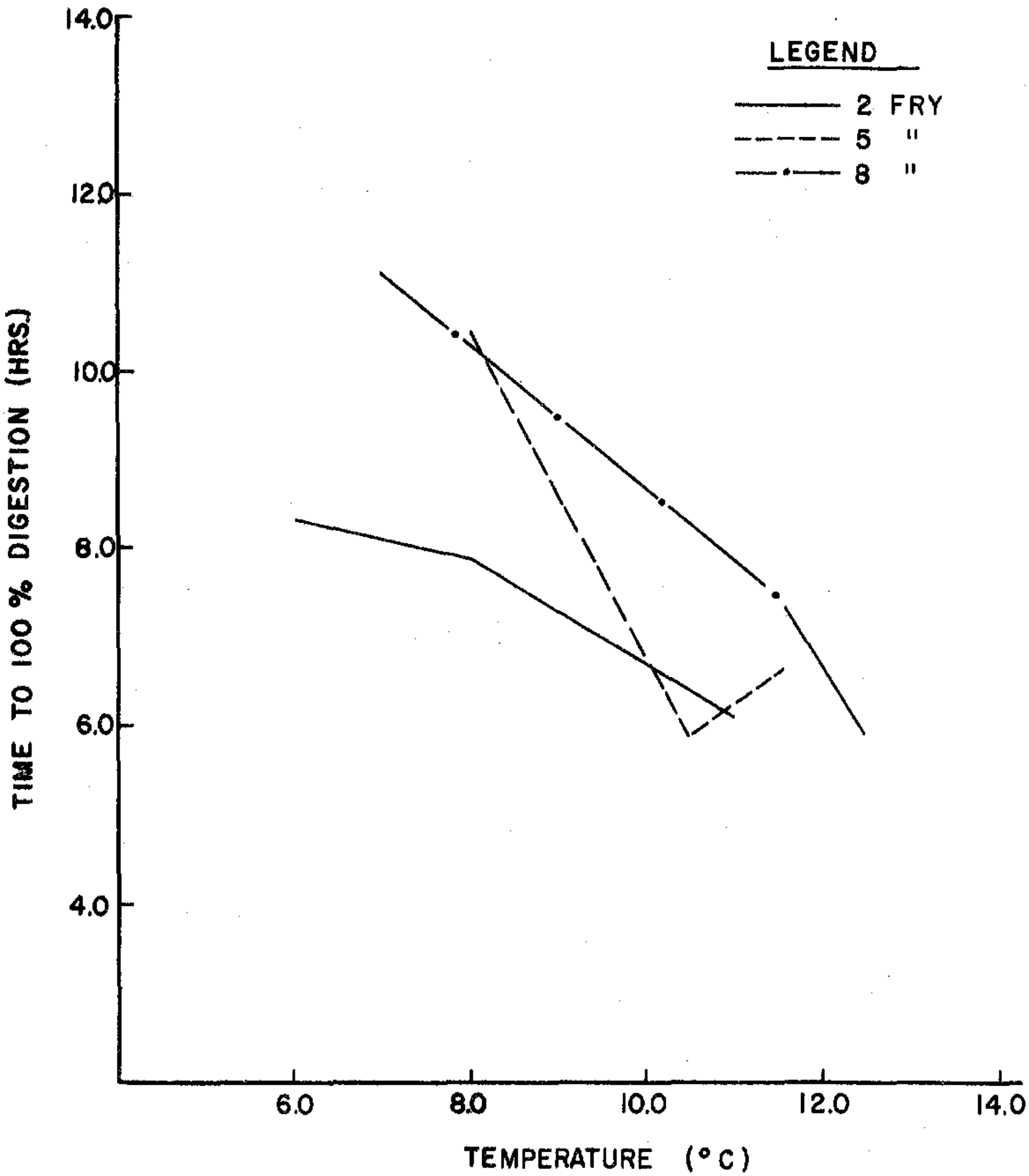

Figure 10. Effect of temperature and food volume on digestive rate of mountain whitefish (Prosopium williamsoni).

the narrow mouths of the converging throat traps on the Fulton enumeration fence. Trap 5 was selected for the study and samples were taken every hour from 2100 to 0500 hours on two consecutive nights (June 4-5 and 5-6). The trap was fished the first 50 minutes of each hour on June 4-5 and the first 30 minutes on June 5-6. The nightly migration patterns of both insects and fry are shown in Table XIV. The percentages shown are calculated after summing catches over three depths and two days.

Table XIV. Diel migration pattern of drift insects (all species combined) and fry in the Fulton River (hourly figures expressed as % of total number)

Time	Fry	Insects
21-2200	.526	.049
22-2300	5.882	.331
23-2400	37.576	8.294
24-0100	24.407	30.331
01-0200	15.013	32.715
02-0300	8.077	17.483
03-0400	6.233	9.238
04-0500	2.282	1.556

The migration pattern of the sockeye fry appears to be at least one hour earlier than that of the insect drift, but the patterns are generally similar.

Seasonal Migration Timing of Drift Insects and Fry

The seasonal migration timings of the fry populations were determined by standard time and area index methods, using the Fulton River fence traps. These same traps and methods were used to obtain daily numbers of insects, except for the following modifications: only 1 trap (#3) was used as an index and was fished for only two 20 minute periods per day (between 2300 and 0100 hours); area checks were made every four days using traps 1, 3, 5, 7, 9; and time checks were made every four days, seven sets per day. The daily fry and insect migration figures are compared in Fig. 11. Although individual species of insects were counted, Fig. 11 shows the pattern for total number only. The pattern of the insect drift was similar in shape to those of both fry migrations, but followed them by about 2-3 days. Further, the total number of insects was small compared to those of fry.

Vertical Distribution of Drift Insects and Fry

The vertical sampler described above was used to determine the vertical distribution of drift insects and fry passing the Fulton fence on two consecutive nights, June 4-5 and June 5-6. Since the water level was two inches higher the second night the fishing depth of the individual bags varied. The results, expressed as organisms/inch, are shown in Table XV. These figures are summed over all times, 2100-0500. The variation from night to night is probably due to the change of the first bag's mean fishing depth from one to two inches. Both fry and insects move predominantly near the surface but this is more apparent for insects.

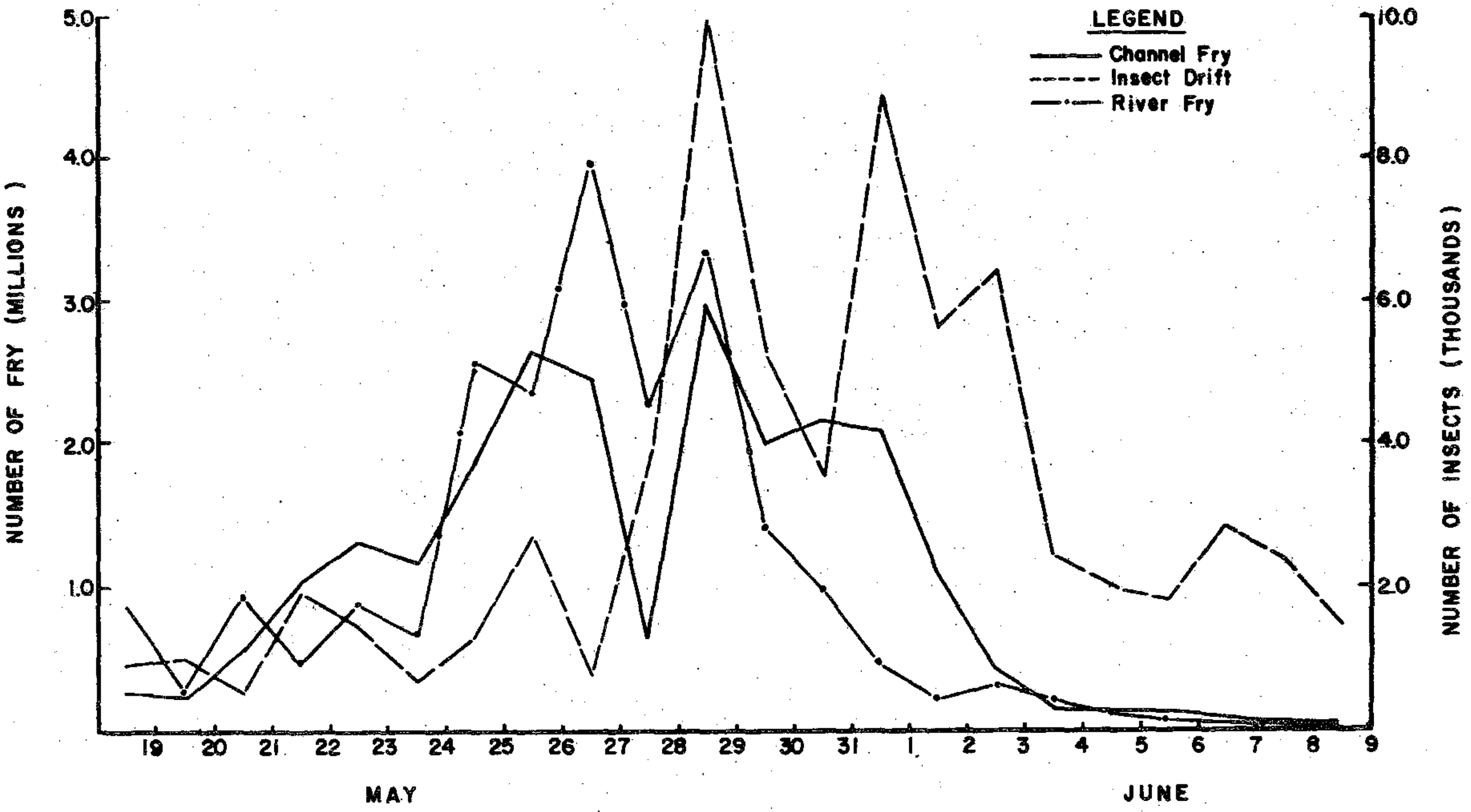

Figure 11. Seasonal migration timing of river fry, channel fry, and drift insects in the Fulton River, 1969

Table XV. Vertical distribution of insects and fry

Date	Depth	Number per Inch	
		Fry	Insects
June 4-5	0- 2"	43.50	1280.00
	2-14"	25.58	50.17
	14-26"	24.92	73.08
June 5-6	0- 4"	43.25	34.78
	4-16"	16.50	22.83
	16-28"	6.25	27.92

The Effect of Light Intensity on Food Selection by Predators

The following study was conducted in the fishway exit of the spawning channel. A 2-inch stretch mesh gillnet was placed across the lower end of the fishway, a fyke-type insect drift sampler operated at the top end of the fishway, and a photometer placed on the bottom of the river, about 5 ft from the bottom end of the fishway, in about 6 ft of water.

A Photovolt Model 520-M photometer was used to monitor light levels. It was modified as follows by Instrument Service Laboratories Ltd., of Vancouver: (1) an underwater housing was constructed for the instrument and underwater cable provided so that all controls could be surface operated; (2) two motor driven filter turrets were constructed, one containing color compensating and the other neutral density filters; and (3) the photocell was provided with an incident light attachment allowing light to be collected over 180°. The photometer system is shown in Fig. 12.

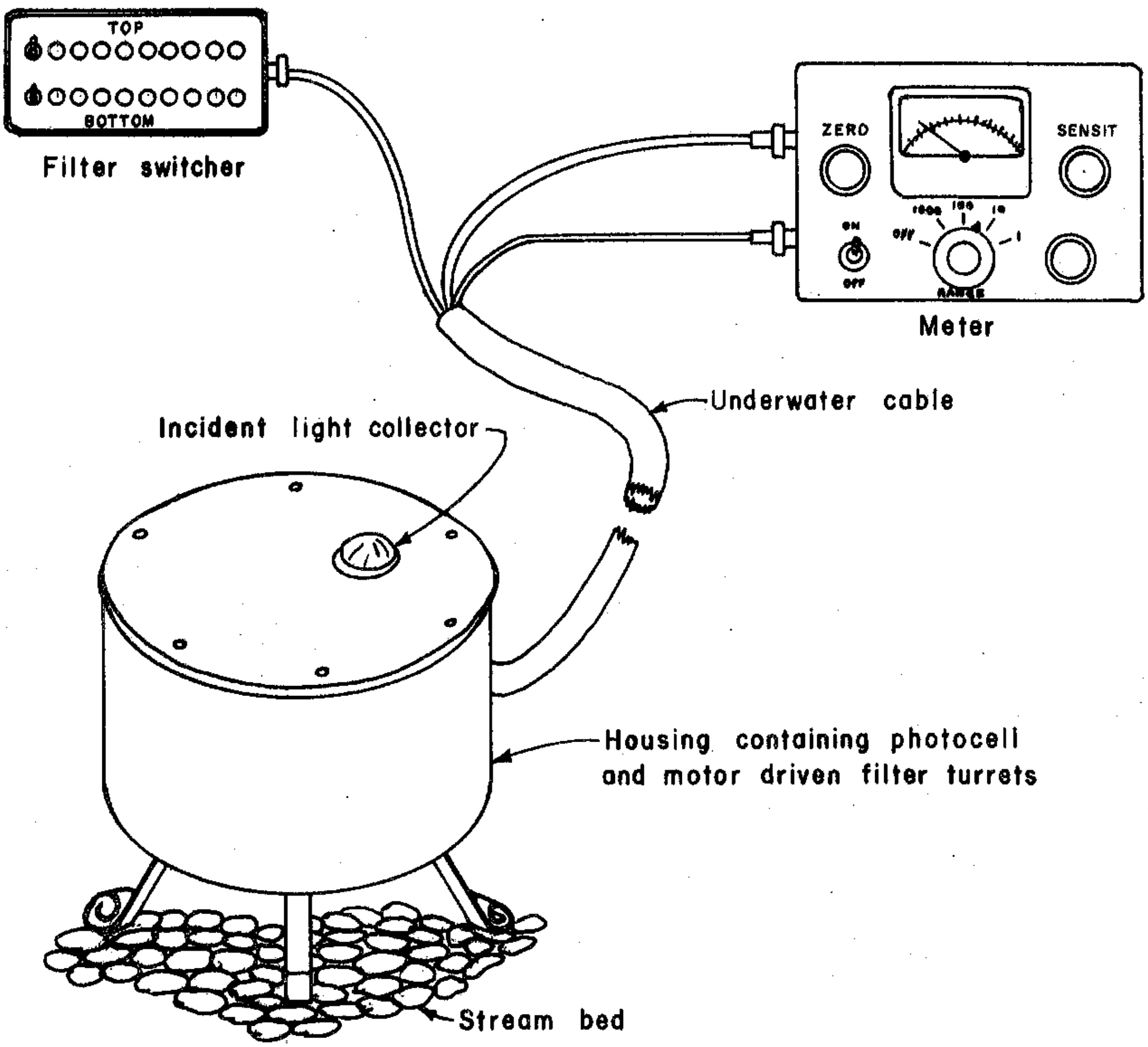

Figure 12. Underwater photometer used in the food selection study.

Photometer readings were taken every hour for each section of the spectrum: total, red, green, blue, cyan, magneta and yellow. Drift samples were obtained each hour as were stomach samples of rainbow trout and whitefish when these were caught (no fish were ever caught between 0100 and 0400 hours, when light levels were lowest). The species composition of the drift varied hourly and daily during the study period (June 9-14) and only Ephemerella (mayfly) larvae were commonly present in both the drift and stomach samples. Electivity indices for Ephemerella were calculated as:

$$EI = \frac{|S - D|}{S + D}$$

where S = % occurrence in stomach

D = % occurrence in drift

These values for electivity index are plotted against total light levels in Fig. 13 for both trout and whitefish. Over the range of light levels examined, the ability to select for food type is apparently not impaired. Unfortunately, no data is available for light levels below about .0003 foot candles. Since the peaks of the fry and insect migrations occur at light levels lower than this (at approx. .000002 ft candles) it is still not possible to determine whether predators can select for either insects and fry during the night, i.e. whether the type of mimicry proposed could operate.

It should be noted that the light levels obtained were only approximate ones since the instrument was calibrated

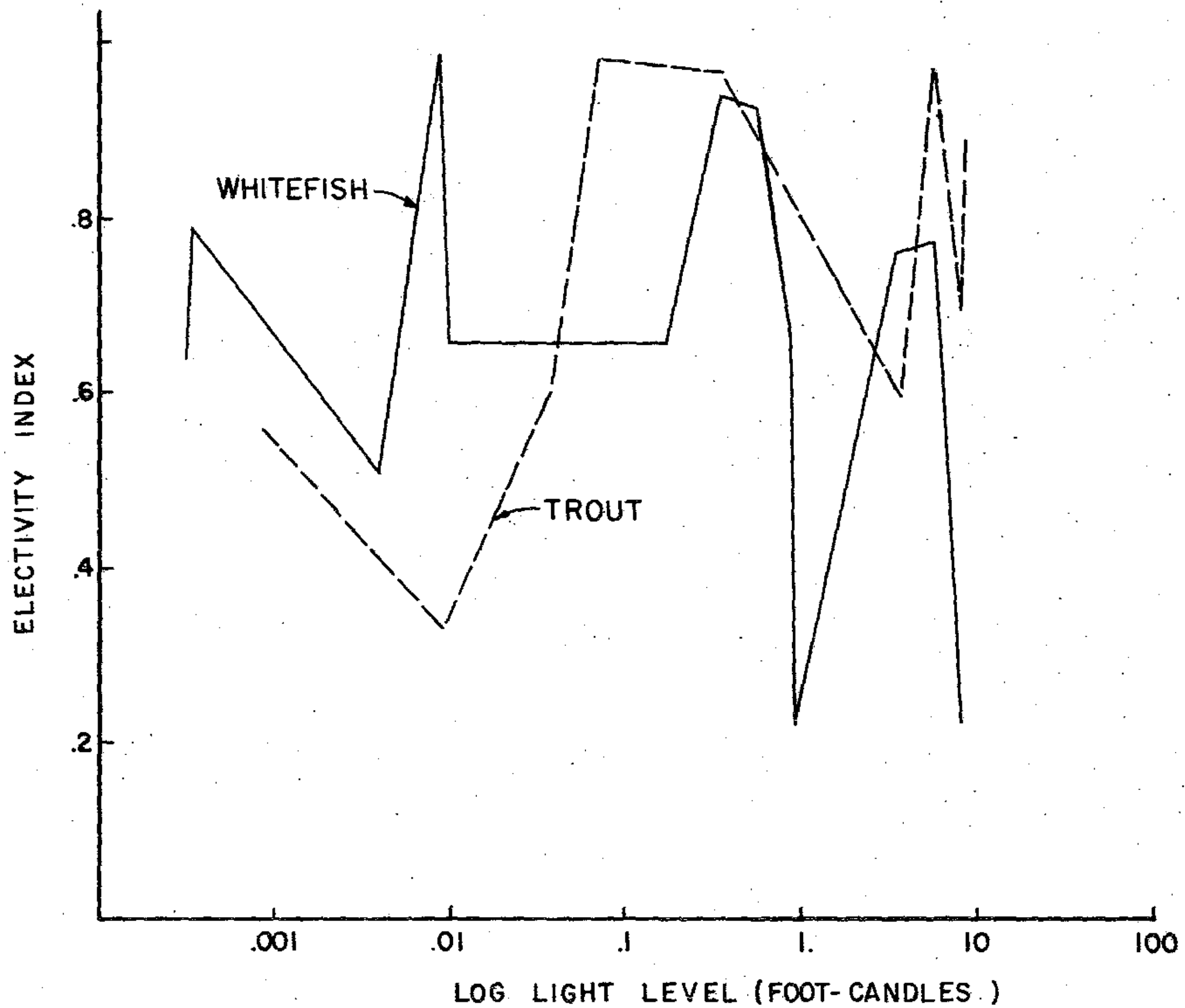

Figure 13. The relationship between total light level and electivity index for rainbow trout and mountain whitefish

without the incident light attachment and since the exact correction figures for the filters are not known. The present instrument should be properly calibrated before any detailed analytical work is done.

CONCLUSIONS

1. Channel fry were both significantly heavier and significantly longer than river fry in 1969.
2. Channel fry were more mature at the time of migration than the river fry, although the magnitude of this difference was less than that recorded in 1968. The magnitude of the difference in discharge between the two situations was also less than in 1968, supporting the hypothesis that discharge level is an important determinant of fry quality, through the mechanism of emergence timing.
3. Larger sockeye fry apparently have greater swimming endurance than smaller fry. The relationship between endurance and development stage is more complex, and there is a suggestion that moderately mature fry are the best performers. Seasonal variation confounds the above results.
4. Smaller sockeye fry are more susceptible to predation than larger fry.
5. Less mature sockeye fry are more susceptible to predation than more mature fry.
6. The extent of predation upon sockeye fry can be reduced by providing an alternate food supply. This was demonstrated in both the laboratory and field studies.

7. Vulnerability of sockeye fry to predation depends upon three independent factors: fitness, absolute abundance, and relative abundance.
8. In 1969, rainbow trout were more consequential predators than mountain whitefish in the river. Extensive predation by rainbow trout also took place in the lake adjacent to the river mouth.
9. Lake whitefish apparently move into the river mouth area in response to high levels of fry abundance, but do not remove many fry.
10. The digestive rate of mountain whitefish is a function of food type, food volume, and water temperature.
11. The spatial and temporal distributions of fry and insects are similar enough that they are equally available to predators. Studies indicate that the ability of the predators to demonstrate a food preference is not impaired by low light levels, although no data is available for those light levels at which fry and insects are most abundant.

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