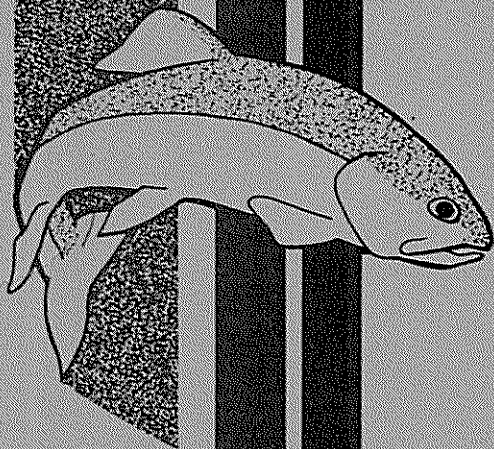


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The Reproductive Environment  
of the  
Gerrard Stock Rainbow Trout

by  
*G. F. Hartman and D. M. Galbraith*



Province of British Columbia  
Ministry of Recreation and Conservation

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THE REPRODUCTIVE ENVIRONMENT OF THE  
GERRARD STOCK RAINBOW TROUT

by

G. F. HARTMAN<sup>1</sup> and D. M. GALBRAITH

Fisheries Research Section

and

Habitat Improvement Section  
Fish and Wildlife Branch  
Department of Recreation and Conservation  
Victoria, B. C.

Fisheries Management Publication No. 15

October 1970

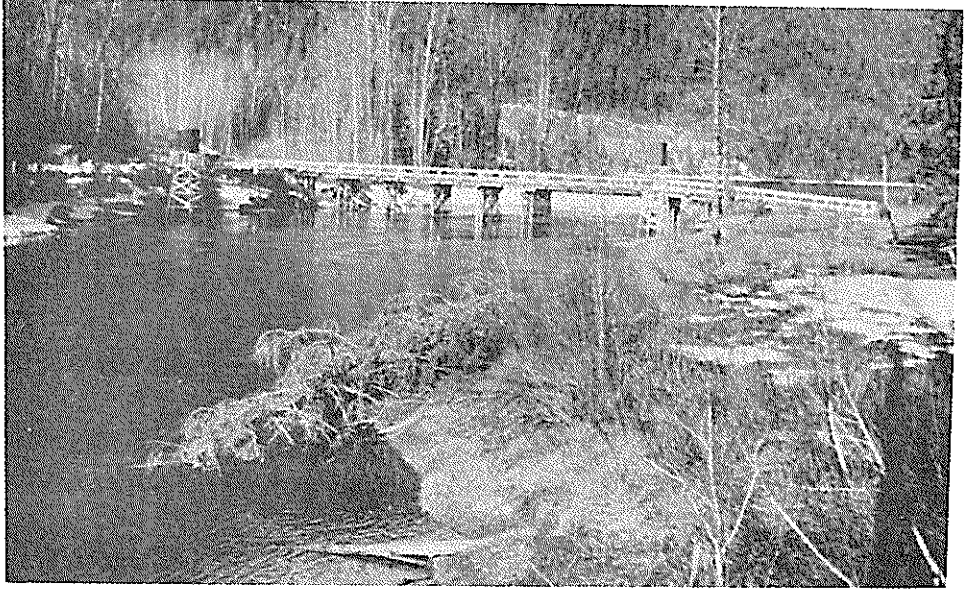
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#### ABSTRACT

Between 300 and 700 large rainbow trout (*Salmo gairdneri*) from Kootenay Lake (southeastern British Columbia) spawn in a 0.5 km section of Lardeau River between Trout Lake and Mobbs Creek. This portion of the river is distinguished from the remainder below Mobbs Creek by having lower turbidity, more stable temperature and possibly more stable discharge. Between Trout Lake and Mobbs Creek prespawning trout rest in three large pools. Spawning fish utilize two restricted locations with a total area of about 7000 m<sup>2</sup>. Most heavily used spawning locations have a water depth of 175 to 200 cm. and velocities of 50 to 90 cm per second. Nests are most densely distributed on elevated ridges on the river bottom, where gravel is composed largely of material from one to 100 mm particle size. Recommendations for biological programs and physical habitat improvement are suggested and discussed.





The Gerrard site on the Lardeau River



# CONTENTS

	Page
INTRODUCTION . . . . .	1
THE STUDY AREA . . . . .	1
SIZE . . . . .	1
GEOLOGY . . . . .	1
PRECIPITATION . . . . .	1
TOPOGRAPHY . . . . .	4
RIVER GRADIENT . . . . .	4
TURBIDITY . . . . .	4
MATERIALS AND METHODS . . . . .	6
PHYSICAL CONDITIONS . . . . .	6
Topography of spawning area . . . . .	6
Gravel sampling . . . . .	6
Water temperature . . . . .	6
River discharge . . . . .	6
Velocity patterns . . . . .	6
DISTRIBUTION AND NUMBER OF SPAWNERS . . . . .	8
NEST SUPERIMPOSITION . . . . .	8
EGG LOSSES ON SPAWNING AREA . . . . .	11
RESULTS . . . . .	11
PHYSICAL CONDITIONS . . . . .	11
Topography of spawning area . . . . .	11
Gravel . . . . .	11
Water temperature . . . . .	13
River discharge . . . . .	13
Water velocity and current pattern . . . . .	13
DURATION OF SPAWNING . . . . .	26
FISH AND NEST DISTRIBUTION . . . . .	26
RELATION OF SPAWNING AREAS TO PHYSICAL FEATURES . . . . .	37
TROUT EGG LOSSES AND NEST SUPERIMPOSITION . . . . .	40
EFFECTS OF MINOR CHANGES IN SPAWNING AREA . . . . .	45
DISCUSSION . . . . .	45
MANAGEMENT RECOMMENDATIONS . . . . .	47
ACKNOWLEDGEMENTS . . . . .	50
LITERATURE CITED . . . . .	51



## INTRODUCTION

Kootenay Lake, in southeastern British Columbia (Fig. 1) supports a sport fishery for trophy rainbow trout (Salmo gairdneri) of a size and quality equaled in few other places in North America. Many of these large fish spawn in a section of the Lardeau River approximately 250 metres long at the outlet of Trout Lake (Fig. 2). Several dozen large rainbow trout have been reported moving through the Duncan Dam in April when the reservoir is low. Previous to construction of a dam below the outlet of Duncan Lake in 1967 (Fig. 2) large trout spawned in the Duncan system. However, the majority of all spawners observed utilize the short 0.5 km section of the river at Gerrard immediately below Trout Lake. Since several hundred pairs of these trout spawn in this restricted area of the river, the present investigation attempted to determine if there were special physical and biological features there, to describe patterns of spawner distribution, and to assess the degree of overcrowding and nest superimposition.

Attempts may be made in the future to establish the Gerrard stock of fish in self-sustaining populations in other systems and it may be desirable in the future to expand or improve existing spawning areas near the Trout Lake outlet. Therefore water temperature regimes, water velocity, depth and bottom characteristics of the intensely used parts of the spawning area are described in detail. Social behaviour of the spawning fish will be dealt with in another paper.

## THE STUDY AREA

### SIZE

The drainage area of the Duncan River system is 4,040 km<sup>2</sup> (1560 mi<sup>2</sup>) but large Kootenay Lake rainbow trout only spawn in a specific region 7,000 m<sup>2</sup> in area on the Lardeau River at Gerrard (Fig. 2).

### GEOLOGY

Glacial activity in the Duncan system is described in a subsurface investigation carried out from October to December 1960 (B. C. Hydro Report 543, 1960). Pockets of glacially deposited gravel are located below the junction of the Lardeau and Duncan rivers (Fig. 2), however, upstream in both systems there is little remaining surface evidence of such deposits. The possible exception to this is the Gerrard site. Cobbles here are well rounded and were at one time stream bed load which could conceivably have been glacial. This stream could also have been the present day Mobbs Creek, as boulders deposited by the creek at Gerrard in the Lardeau River are well rounded.

### PRECIPITATION

Duncan River system lies within a generally high rainfall area. Higher elevations receive up to a maximum of 60 - 100" of precipitation per year (Fig. 2). Lardeau River, Duncan River and smaller tributary streams all

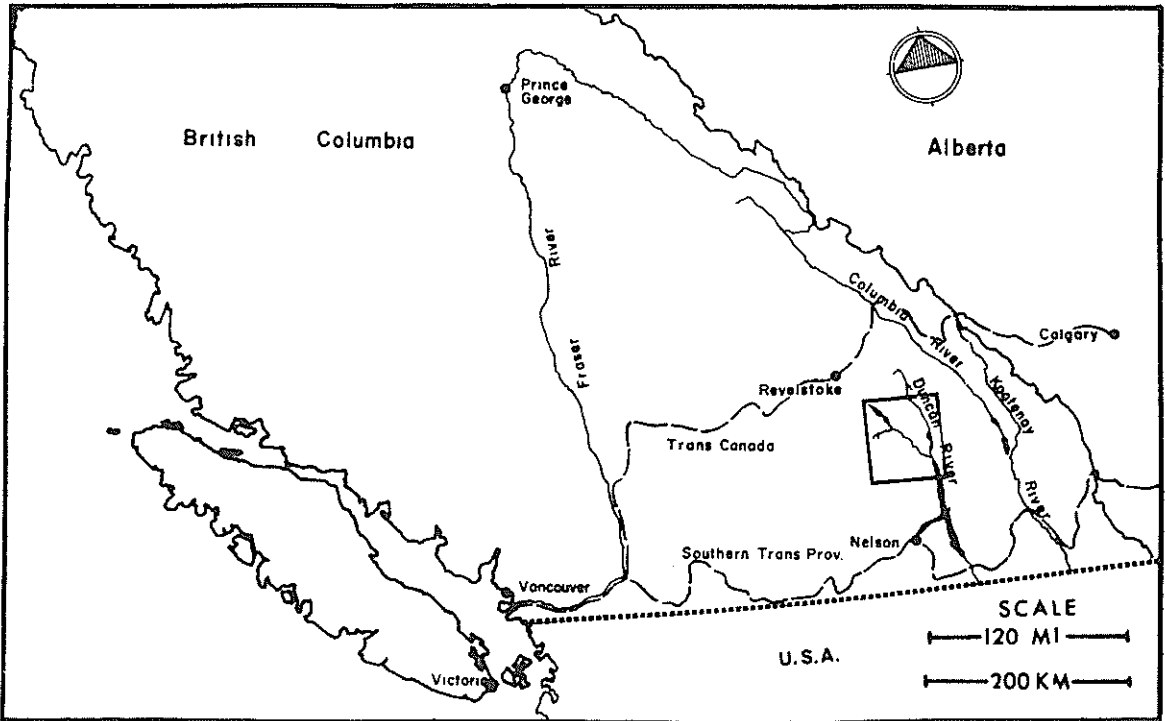


Fig. 1. Location (inset square) of the Duncan-Lardeau River area and Trout Lake in southern British Columbia.

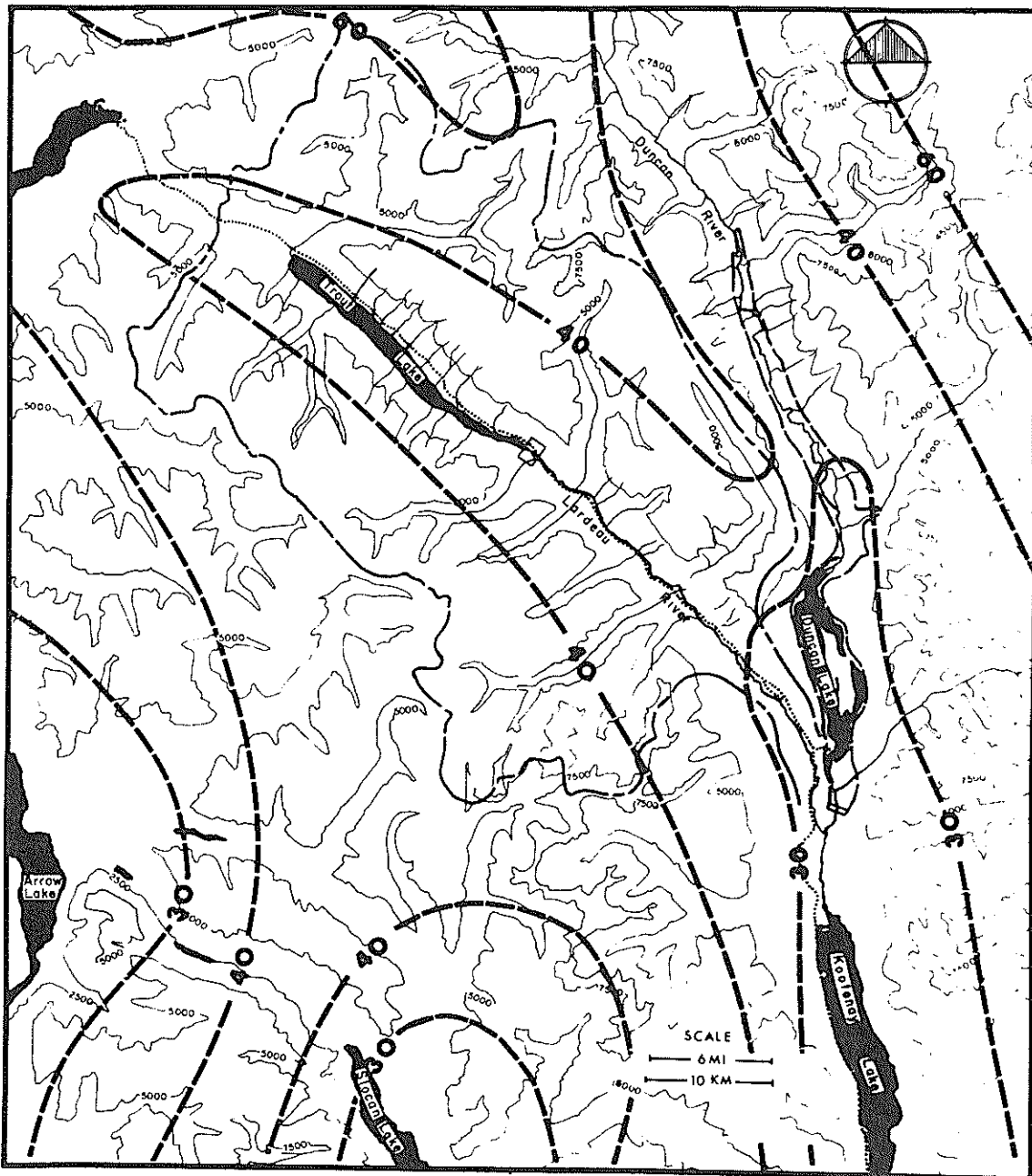


Fig. 2. The Duncan-Lardeau River system. Trout Lake and the Lardeau River watershed is included within the broken line (---) and the Gerrard site within the rectangle at the outlet of Trout Lake. The high water line of the impoundment formed by a dam below Duncan Lake is indicated by a dashed line (---). Precipitation isopleths (30, 40, 60 inches) are indicated by heavy dashed lines. Elevation contours (only 5000 and 7500 feet) are also shown.

have headwaters which commence at higher elevations and receive similar precipitation. Therefore, there is very little to distinguish between individual drainage basins in the Duncan system with respect to annual precipitation per square mile of drainage basin.

#### TOPOGRAPHY

The Duncan River system is bordered on the east by the Purcell Mountains and on the west by the Selkirk Mountains. The tributaries of the Duncan are similar with respect to basin topography as all streams arise in steep headwater areas and terminate either in the Lardeau or Duncan rivers (Fig. 2). With the exception of Meadow Creek this termination is invariably abrupt and bed load materials carried by the streams are swept out into the larger tributaries or lakes. Thus before spawning can occur in a stream or river the surrounding land form must provide a relatively flat area where bed load materials can be deposited.

Mobbs Creek entering from the south, contributes a considerable quantity of rounded cobbles to the Lardeau River, and its alluvial fan has helped to create the natural dam which forms Trout Lake. The gravel bars on which the rainbow trout spawn lie upstream from the present confluence of Mobbs Creek with the Lardeau River. The outflow from Trout Lake has cut down through these alluvial deposits, washing out the fine sediments and leaving behind the cobbles and gravel.

#### RIVER GRADIENT

Average gradient of Lardeau and Duncan rivers is 15 and 2.5 ft per mile respectively (2.85 and 0.6 m per km) except for that portion of Duncan River above Mobbs Creek (Fig. 3), 36 miles (ca 58 km) upstream from Kootenay Lake. Gradient of Mobbs Creek, typical of the smaller tributaries, is 1.00 ft per mile (ca 19 m per km, Fig. 3). The river gradient from Trout Lake to Mobbs Creek is considerably less than that downstream. Head loss in the main spawning area (assumed to be from Gerrard bridge to area 50 m downstream) is 0.37 ft (ca 11 cm), and gradient is 0.24%.

#### TURBIDITY

Trout Lake acts as a settling basin for the Lardeau River and provides silt free water at Gerrard. At the outlet water clarity remains high until Mobbs Creek is reached. Turbidity from erosion in lower Mobbs Creek basin in May and June and from glacial snow melt in July and August colours Lardeau River. Turbidity at Gerrard during periods of discolouration in May and June indicate sediment content of 20 to 30 ppm while at Marblehead (ca 10 miles or 16 km upstream from Kootenay Lake), it varies from 20 to 150 (unpublished data, Dr. Acara, Fish and Wildlife Branch).

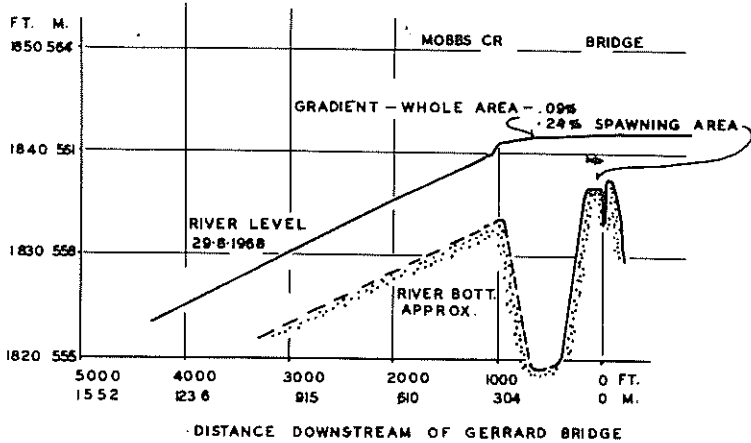
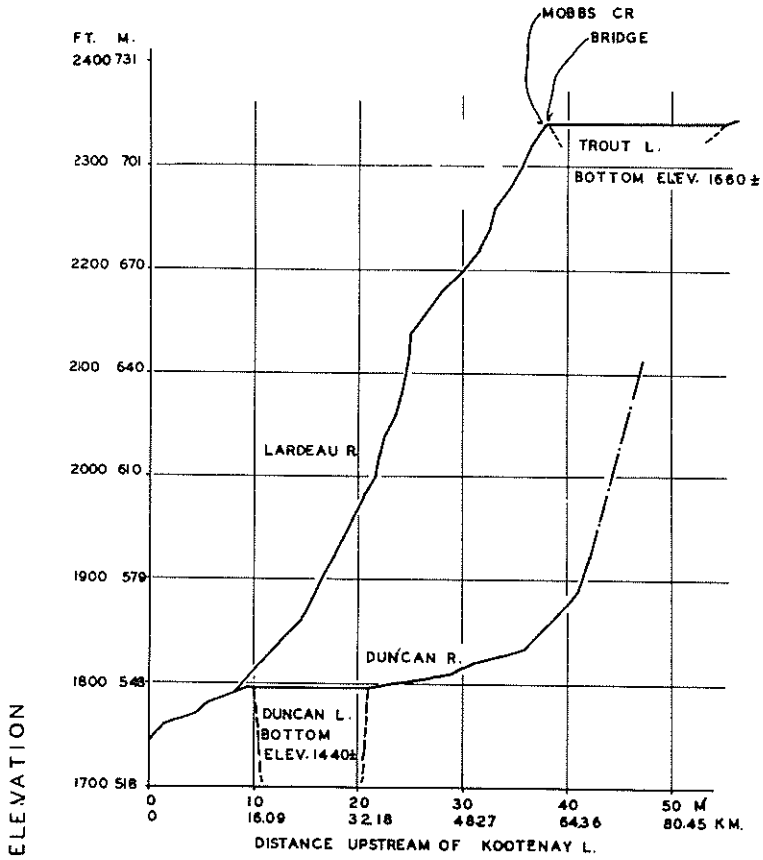


Fig. 3. Profiles of the Duncan and Lardeau rivers and of the Lardeau River from Trout Lake to below Mobbs Creek.

## MATERIALS AND METHODS

### PHYSICAL CONDITIONS

#### Topography of spawning area

Detailed topographic mapping of the river bottom was carried out in July 1967 on area S-E, (Fig. 4) by standard survey methods.

#### Gravel sampling

Gravel samples were taken in December 1966, on the spawning area (Fig. 4) with a shovel when the river was very low. Fish used these areas for spawning at high water. Areas sampled were either dry or only partially covered with water and loss of fine material was very low. In areas where grain size of gravel was 10 cm (4 inches) or less, a 30 cm x 30 cm area was sampled to a depth of about 18 cm (7 inches). Where the substrate was coarser, containing stones over 20 cm (8 inches), a larger sample, 60 cm x 60 cm, 18 cm deep was sampled. Standard gravel analyses were made.

#### Water temperature

River temperatures were recorded on Weksler continuous temperature recorders. One recorder was located on the south shore of the river, ca 120 m below the Gerrard bridge (Fig. 4). A second recorder was installed at the "Y-Camp" station about 1 km below Mobbs Creek, and a third at "29 Mile", about 8 km below the outlet of Trout Lake. Continuous recorders were frequently checked against calibrated pocket thermometers.

#### River discharge

Daily water levels were read from staff gauges located on the Gerrard bridge and on the south side of the river about 120 m below the Gerrard bridge. The discharge of the river was determined at a low level (December 6, 1967), two intermediate levels (July 25 and August 10, 1967) and during very high flow (June 7, 1967) about 31 m below the Gerrard bridge (see transect E, Fig. 4) using a Gurley 625 meter with a "read-out" type recorder.

#### Velocity patterns

Eleven transects were established across the Lardeau River (transects A to K, Fig. 4) and one down its centre for 30 m (LL-LM, Fig. 4). Water depth, velocity and surface flow direction were recorded at 3 m intervals on each transect across the river, and at 1 m intervals along the transect down the centre of the river. Water velocities were recorded at depths of 15, 30, 60 and 90 cm, etc., until bottom was reached and at 20 cm above the bottom.

Depths were read directly from the marked cable supporting the flow meter. At each measurement point current directions at the surface were determined.

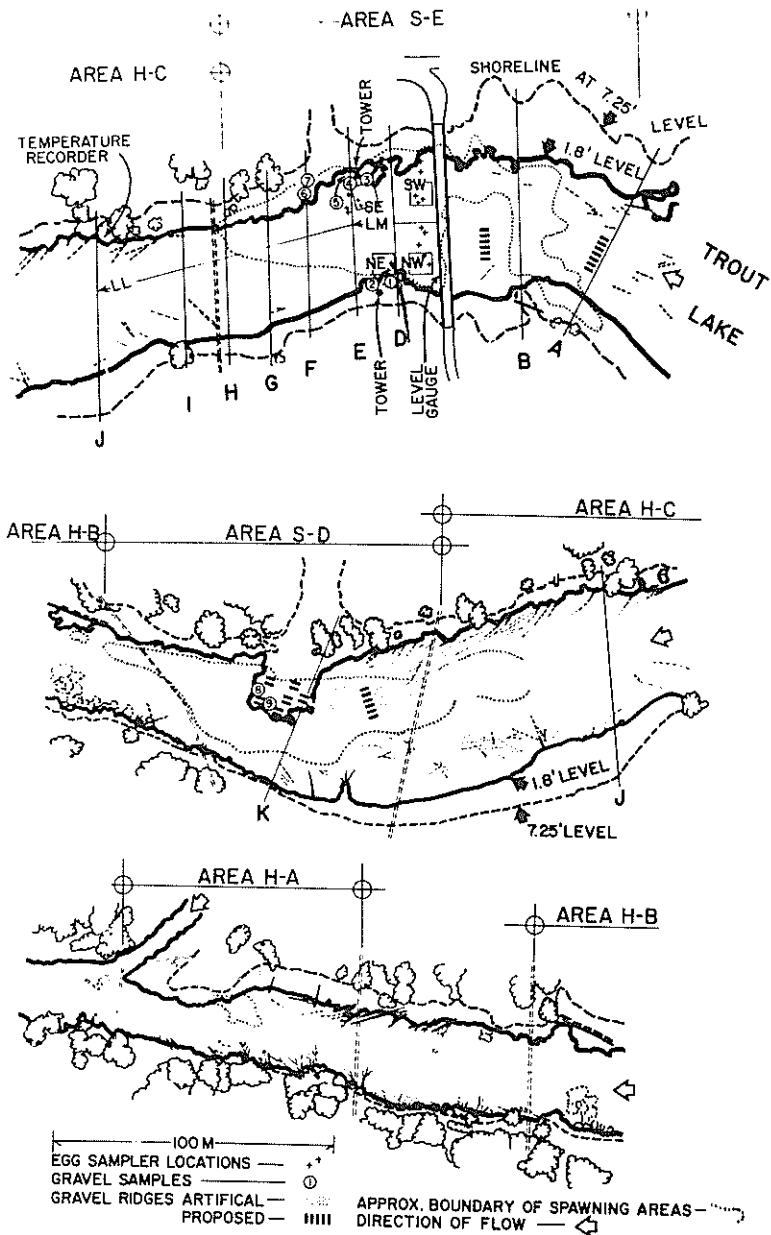


Fig. 4. Approximate outline of the Lardeau River, Trout Lake to Mobbs Creek, at 1.8' and 7.25' level on the bridge gauge. Locations of egg samplers, gravel samples and tested bottom changes, boundaries of spawning areas, transect lines, grids, towers, and monitoring sites are shown. Grids, 8 m x 8 m are indicated as SE, SW, NE and NW.

Since difficulty was encountered in suspending and holding the boat in place, as required to meter a large, swift river, the method and the apparatus used will be described in detail. Fig. 5A shows the arrangement of boat, meter, suspension cable and marking line.

A suspension cable, stored on a large winch, ca 200 m capacity (Fig. 5B), was pulled across the river with a hand line and attached to a small capacity winch. It could be tightened from either end.

A boat was attached to the suspension cable by two hinged "wings" which could be elevated or depressed freely so that measurements could be made regardless of river height. The tips of the "wings" were attached to the suspension cable by snaps on nylon ropes allowing both sides of the boat to be freed almost instantly to avoid floating logs (Fig. 6A). The marking line, parallel to the suspension cable and two meters upstream from it, was divided into 3 m intervals. This system allowed the boat to be held at fixed points for measurement of flow. The boat, suspension cable and marking line were moved downstream from transect to transect.

#### DISTRIBUTION AND NUMBERS OF SPAWNERS

Total counts of spawners have been obtained by daily observations from the stream bank over the spawning season, each year from 1961 to 1969. Such counts include all fish between Mobbs Creek and Trout Lake. Counts were made by one or two observers from the Gerrard bridge and from the north side of the stream using polarizing sunglasses. Occasional cross checks were made with one observer on each side of the river at wide or deep sections.

In 1966 and 1967, locations of fish and sites where nest digging was observed were plotted on maps (scale 1 cm = 3.25 m). Fish counts and map plots were usually made between 0700 and 0900 hours when light conditions permitted best observation. Reliable counts could not be made on windy or rainy days. Fish positions were plotted with reference to coloured stones and a grid of fine strings over the river. Fish positions in the heavily used area (S-E, Fig. 4) were plotted by observing from the bridge and from 6 m towers located on either side of the river. Two observers usually worked together to insure location of all fish possible.

Times of first and last sighting of fish with distinctive natural marks, colour, size or tags were recorded to approximate their length of stay on the spawning area.

#### NEST SUPERIMPOSITION

Limitations of staff made it impossible to plot the location of all nest digging. However, four squares, 8 m x 8 m were marked off on the stream bed with nylon cords (Fig. 4) and a partial record of nest digging on these squares was made in 1966. In 1967 an attempt was made to record all nest construction that occurred within the four squares. The positions of nests and superimposed nests were recorded quite precisely. Observations were however only made on 13 out of 23 days in 1966 and 26 out of 30 days in 1967. On these days

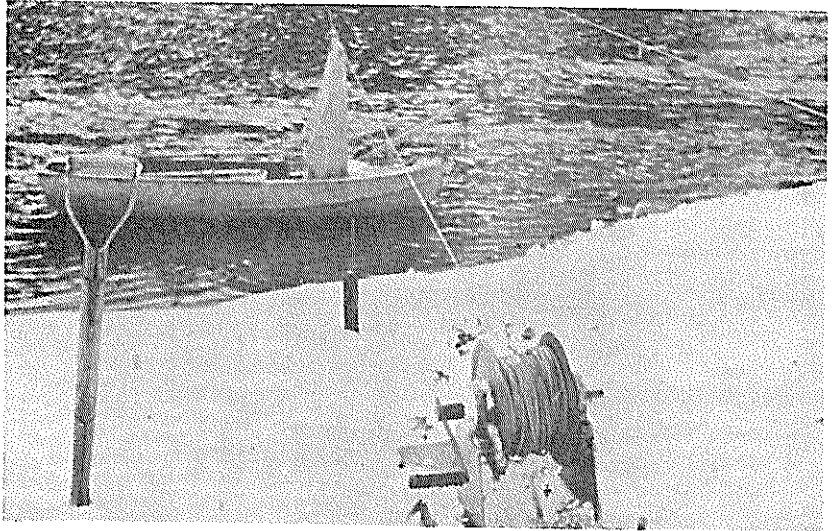
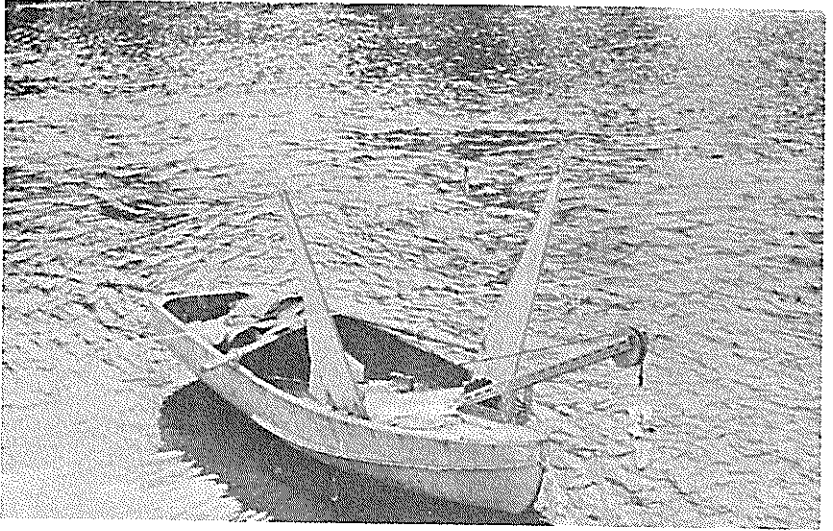


Fig. 5. Arrangements for moving water current meter across the Lardeau River.  
A. Boat with boom and movable wings attaching it to the cable.  
B. Boat attached to cable with marker line ahead of the boat. The winch used to adjust cable tension and store cable is in the foreground.

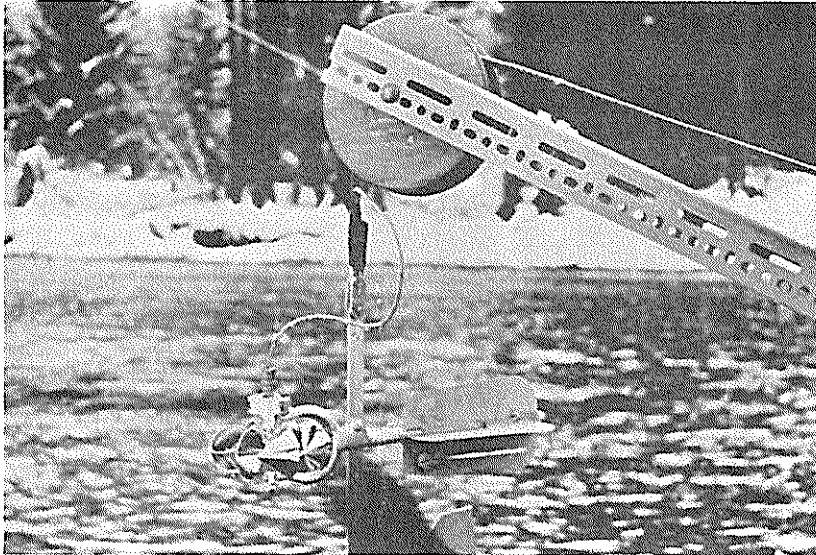
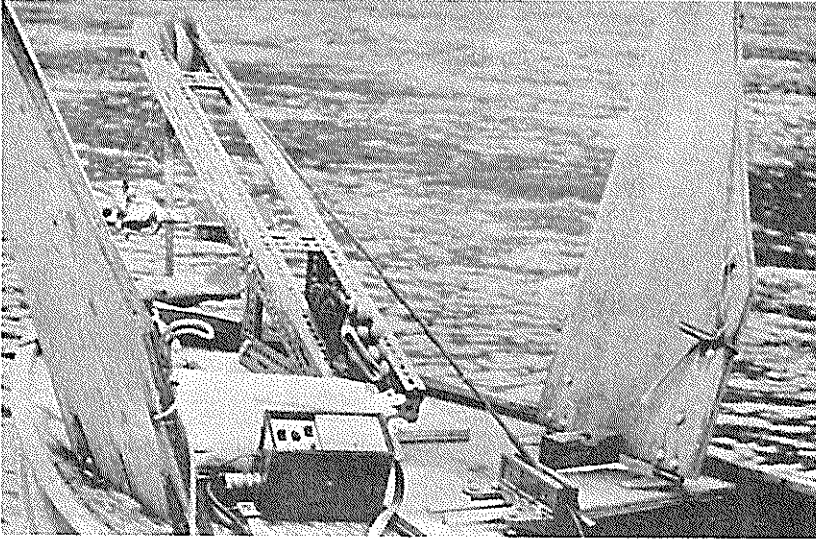


Fig. 6. Arrangements for locating water current meter within boat.  
A. "Read out" meter and clamp used during stream metering work.  
B. End of boom and Gurley 625 flow meter.

fish were not watched continually so data pertaining to the 8 m x 8 m plots were not complete. Disturbance of gravel occurred during darkness but could not always be plotted precisely.

#### EGG LOSSES ON SPAWNING AREA

Preliminary attempts were made to develop and evaluate methods of measuring egg disturbance or displacement. Two low profile wedge-shaped screen samplers (58 cm wide, 3 meshes per cm) were attached to a single line, weighted 2 or 3 m upstream from the sampler and anchored to the bridge, from which their positions could be controlled. Each sampler was operated at one location for approximately 12 hours in the day, then cleaned and replaced for approximately 12 hours of night operation. Eggs were preserved in Stockard's Solution.

Mountain whitefish (Prosopium williamsoni) which moved from Trout Lake onto the spawning area in late afternoon and back toward the lake in the early morning were sampled using a dish-shaped net, about 1.5 m in diameter, and by hook and line. The net was dropped onto the river bed and was pulled quickly upward when whitefish swam over it. On two occasions samples were taken with gill nets set in the lake near the outlet. Trout eggs from each whitefish stomach were counted and preserved in Stockard's Solution.

Trout eggs from the samplers and from whitefish stomachs were examined under a binocular microscope to determine condition and stage of development using criteria based on work by Knight (1963).

Attempts were made to determine numbers of whitefish passing from the lake to the spawning area, however since they probably continued moving after dark, estimates were minimal.

### RESULTS

#### PHYSICAL CONDITIONS

##### Topography of spawning area

The bottom topography in the major spawning area (transect B to G, Fig. 7) was very irregular. A survey of the river bottom from Trout Lake to transect J, (Fig. 7) shows that there were several ridges crossing all or part of the river in the vicinity of the Gerrard bridge. A large ridge crossed the river about 25 m upstream from the bridge where a fish trap was formerly located. Immediately downstream from the bridge, between transects C and G there were 8 ridges of gravel, 4 of which reached most of the way across the bottom of the river (Fig. 7). In some locations the crests of the ridges were about 0.75 m higher than the low areas adjacent to them.

##### Gravel

Samples of gravel from the prime spawning area for rainbow trout immediately below the Gerrard bridge did not exceed a grain size of 100 mm,

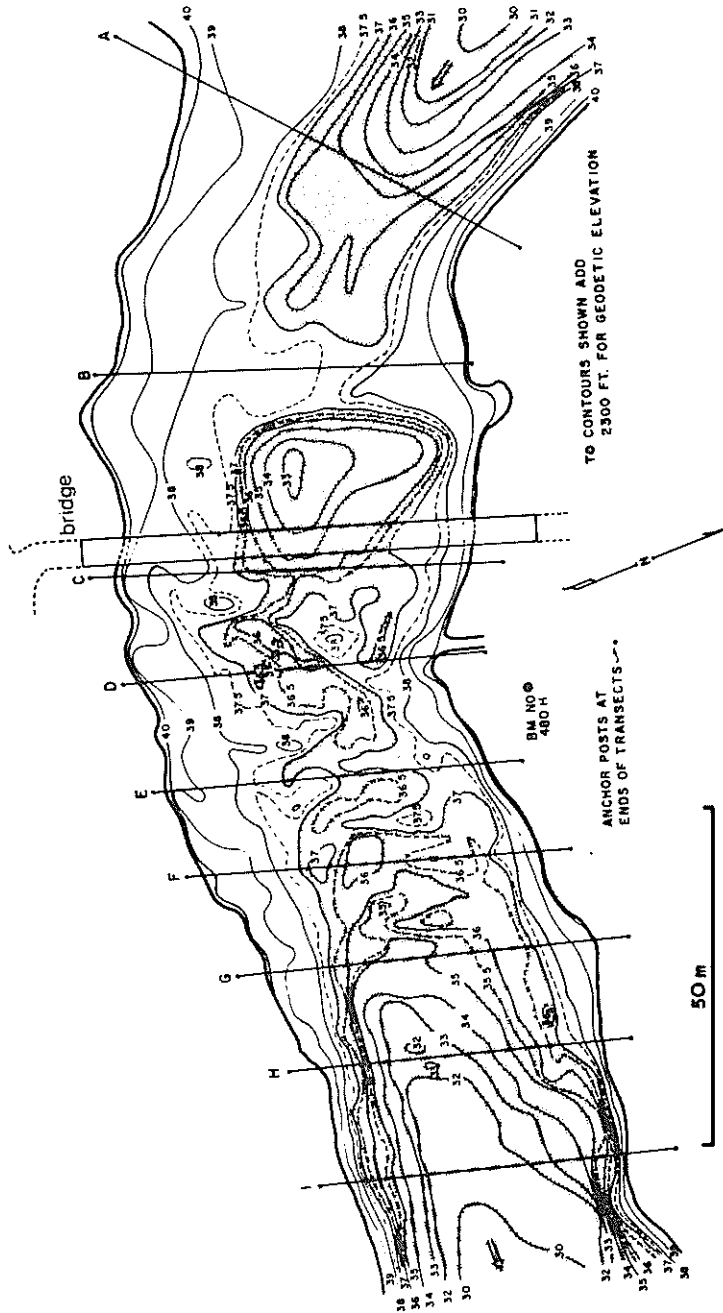


Fig. 7. Topography of the Lardeau River bottom in the main spawning area at the Gerrard bridge.

whereas those from less heavily used areas contained some material exceeding even 500 mm (Fig. 8; detailed data in Table 1). Although no clear differences were evident in small particle size (< 10 mm) between gravel heavily used and less used for spawning, there did nevertheless seem to be reasonably characteristic grading curves for the former which were distinctive at least in the larger particle size range.

#### Water temperature

Throughout the spawning and incubation periods, water temperatures were generally higher in the area of the Gerrard bridge than further downstream at "Y Camp" or "29-Mile" station (Fig. 9). During 1967, water temperatures at the Gerrard bridge were 1 to 6.5°C higher than those at "Y Camp" and 1 to 6°C higher than those at "29-Mile". In 1966, Gerrard temperatures ranged from 1 to 2.5°C higher than those at "Y Camp". Thus Mobbs Creek has the effect of cooling the Lardeau River as well as discharging turbid water into it.

#### River discharge

The metered discharge of the river at transect E is plotted against gauge readings (Fig. 10). The four gauge levels and discharges used to establish the curve lie within the usual range of flows at Gerrard. Day to day changes in discharge at Gerrard are not marked from early spring to late summer (Fig. 11) and may reflect the stability usual at the outlet of a lake. Discharge further downstream in the Lardeau River (Marblehead) is of course greater and perhaps subject to more rapid and extensive fluctuations (Fig. 11). Furthermore such fluctuations may have more pronounced effects on water velocity and gravel condition in areas where the river gradient is relatively steep, such as at Marblehead.

#### Water velocity and current pattern

Water velocity patterns 20 cm above the bottom of the river and 30 cm below the surface, at three rates of discharges are shown for the area used most intensively by spawning fish (Figs. 12 and 13). Conditions of low flow to about 50% of maximum discharge are represented.

Water velocities over the main area used by spawners tended to remain consistently over 30 cm per second near the bottom of the river. Velocities near the surface (Fig. 13) were generally higher. Water velocities and flow direction were affected by channel depth and shape, and by structures such as bridge piles and old fish trap foundations. Lines of flow were curved gently in an arc from about 100 m below the bridge to 100 m above it (Fig. 18). Below the bridge area where the river widens and deepens the current appeared to spread and project water masses toward the north bank, but not toward the south bank (Figs. 15 and 16, transects H, I, and J). Below this area, at S-D (Fig. 4), the direction of flow was deflected sharply north by a large bar of heavy rock and gravel, at low water levels (Fig. 14, transect K). As the river level increased the direction of flow straightened and most passed directly over the bar (Figs. 15 and 16, transect K). Figure 17 shows conditions at transect E at near peak discharge.

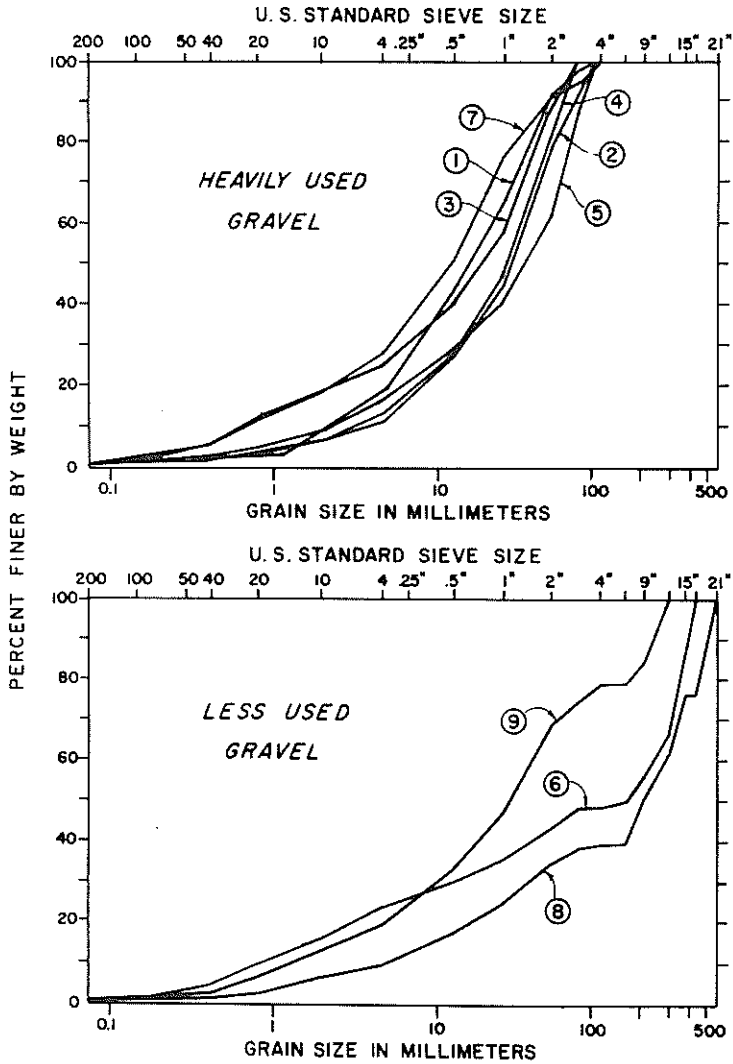


Fig. 8 Gravel size grading curves for samples from the Lardeau River at Gernard representing areas heavily used (upper) and less used (lower) by spawning rainbow trout. See Fig. 4 for location of sample numbers.

Table I. Per cent of gravel passing different sieve sizes (U.S. standard) in 9 samples, GR-1 to GR-9, taken from spawning sites near the Gerrard bridge.

Sieve Size	Sample Number								
	GR-1	GR-2	GR-3	GR-4	GR-5	GR-6	GR-7	GR-8	GR-9
21"	-	-	-	-	-	-	-	100.0	-
18"	-	-	-	-	-	100.0	-	76.4	-
15"	-	-	-	-	-	86.5	-	76.4	-
12"	-	-	-	-	-	66.9	-	61.8	100.0
9"	-	-	-	-	-	56.2	-	50.6	84.0
6"	-	-	-	-	-	49.7	-	39.4	78.8
4"	100.0	100.0	-	-	100.0	49.7	100.0	39.4	78.8
3"	97.4	90.2	100.0	100.0	86.8	49.7	95.7	38.5	75.0
2"	90.9	78.7	80.5	87.8	60.4	44.0	91.7	34.8	69.0
1"	65.4	45.0	47.1	57.9	40.1	36.1	76.8	25.1	47.4
1/2"	43.1	26.5	27.8	40.0	29.1	30.8	51.3	17.1	33.2
No. 4	18.7	11.1	12.6	25.1	16.3	24.8	28.1	9.8	19.8
10	8.8	6.9	6.5	18.3	8.9	16.9	18.4	6.5	13.4
20	2.8	3.1	2.9	12.0	4.8	10.2	11.5	2.9	6.6
40	0.9	1.1	1.3	5.5	2.7	5.2	5.9	1.1	2.3
80	0.4	0.5	0.7	1.9	1.4	2.2	3.0	0.4	0.8
100	0.3	0.5	0.6	1.6	1.2	1.9	1.9	0.3	0.6
200	0.2	0.3	0.5	1.2	0.9	1.3	1.4	0.2	0.5

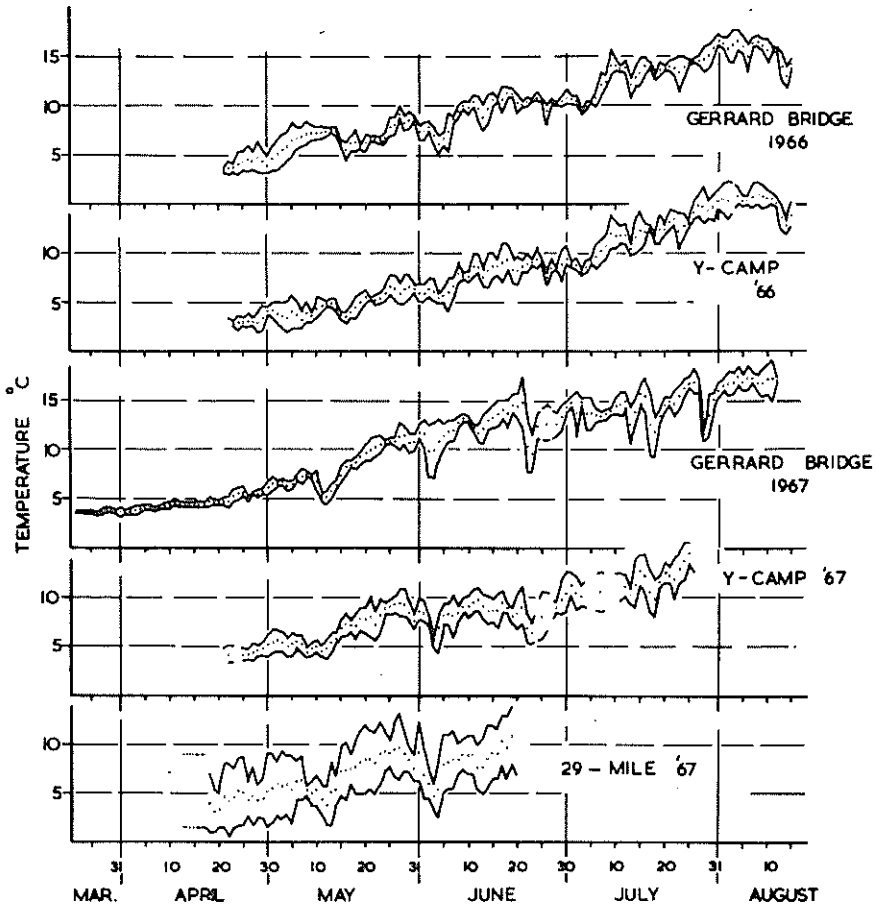


Fig. 9. Water temperatures at Gerrard bridge, "Y Camp" and "29-Mile" Stations in 1966 and 1967. Maximum, minimum and means (dotted) are shown.

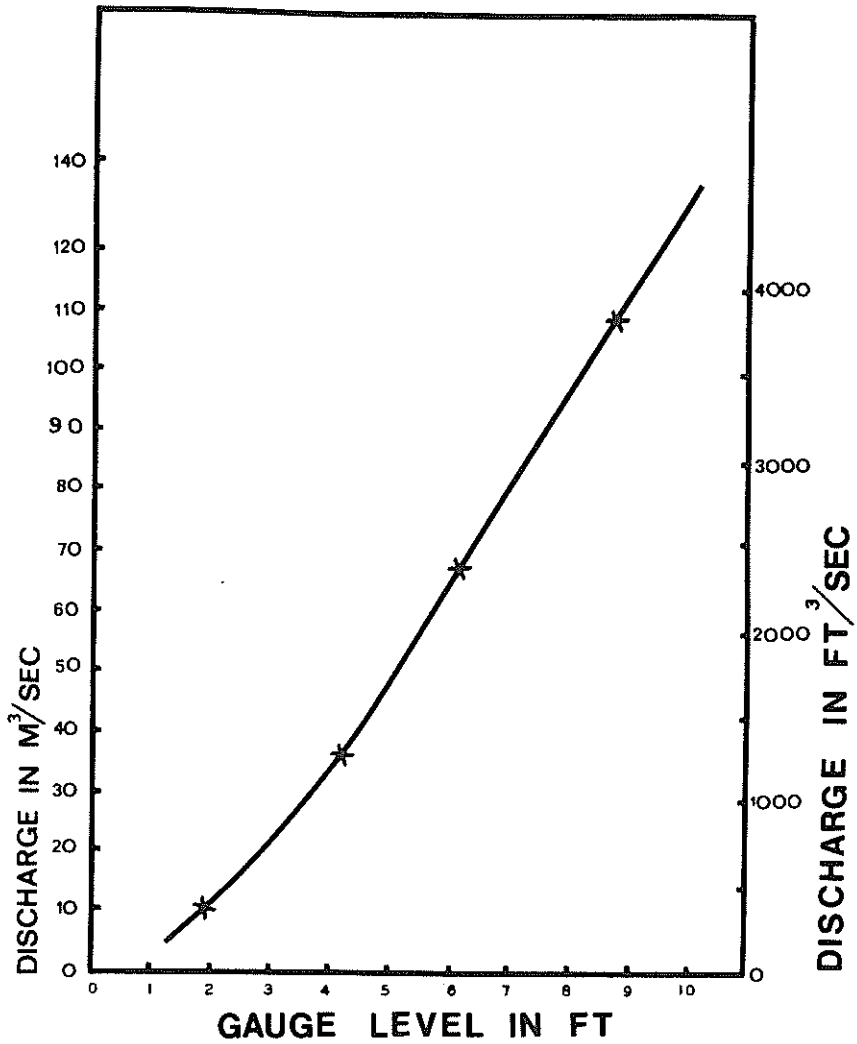


Fig. 10. Relationship between gauge level and river discharge in m<sup>3</sup>/sec. and ft<sup>3</sup>/sec. at the Gerrard bridge during 1967.

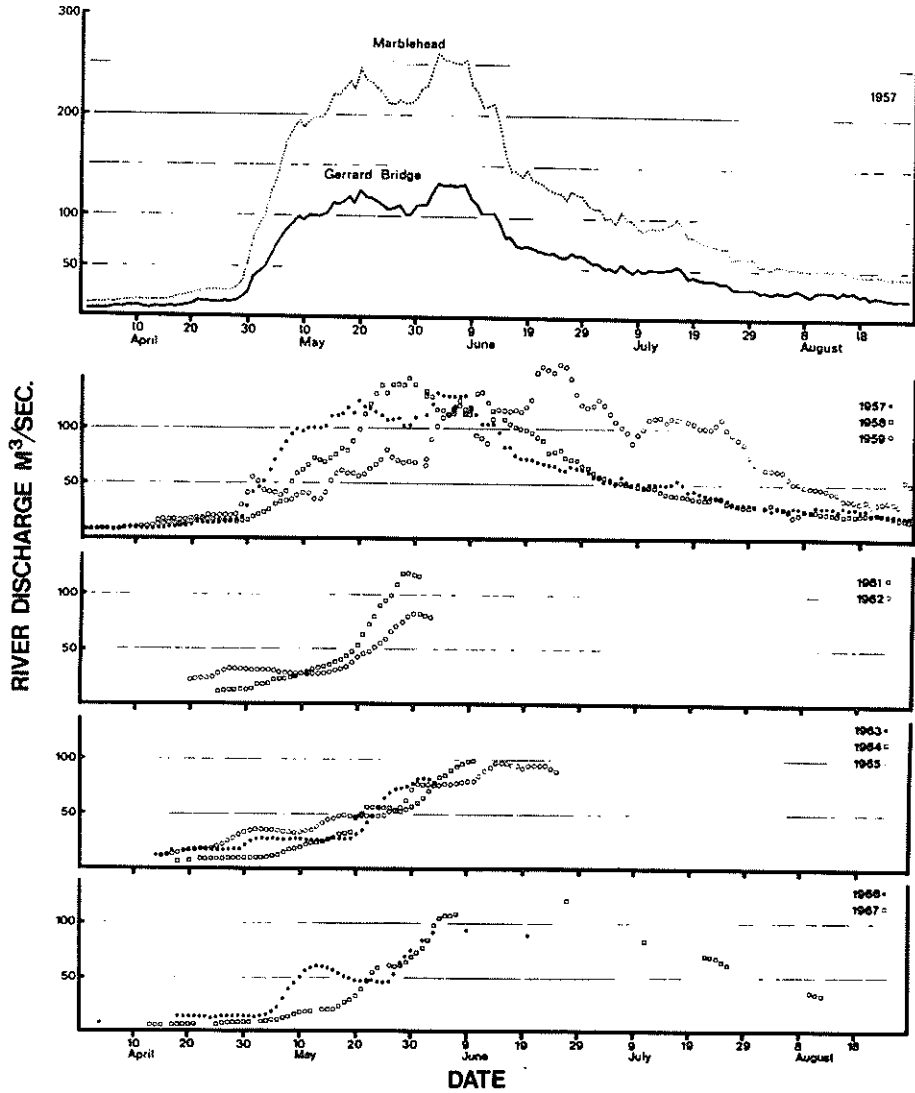


Fig. 11. Lardeau River discharge at the Gerrard bridge during and after the rainbow trout spawning period from 1957 to 1967. Data for 1960 not available; uppermost curves compare discharge at Gerrard and further downstream at Marblehead.

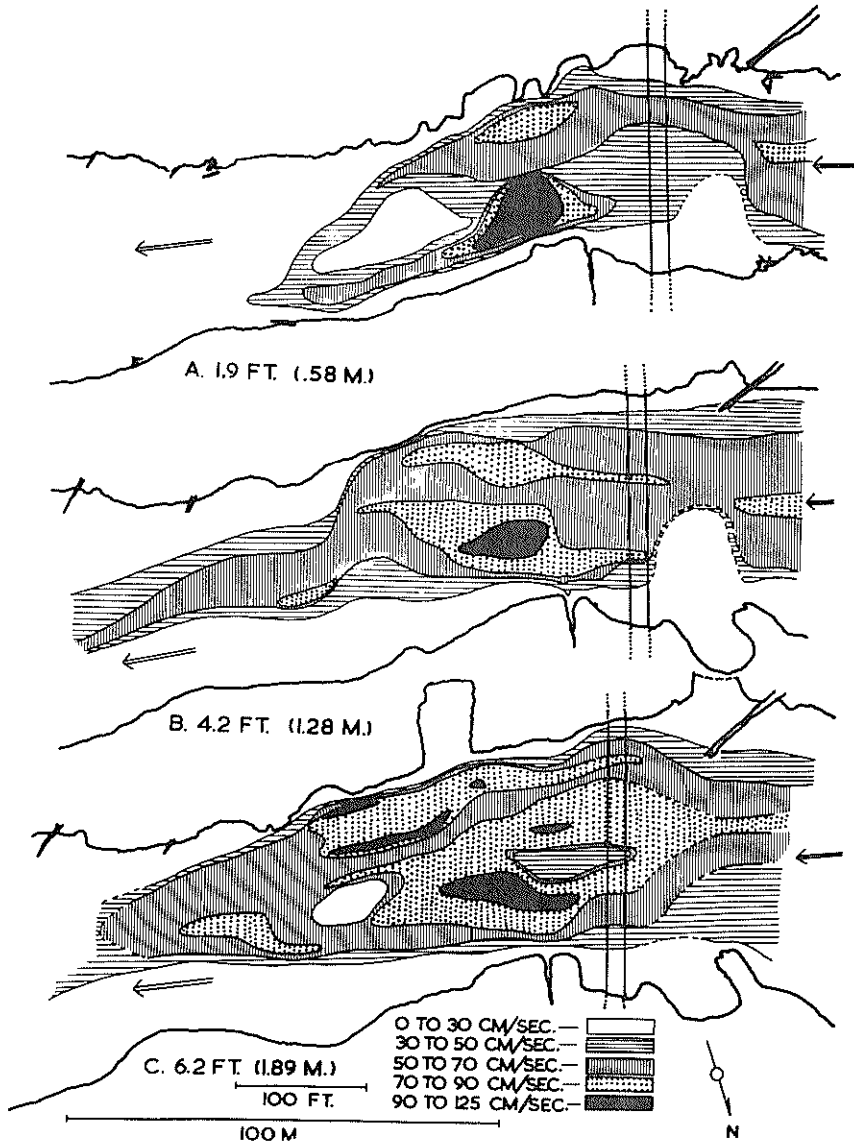


Fig. 12. Water velocity pattern at a height 20 cm above the bottom of the river at gauge levels 1.9, 4.2 and 6.2 ft. Dotted lines at stream margin indicate the position of the Gerrard bridge.

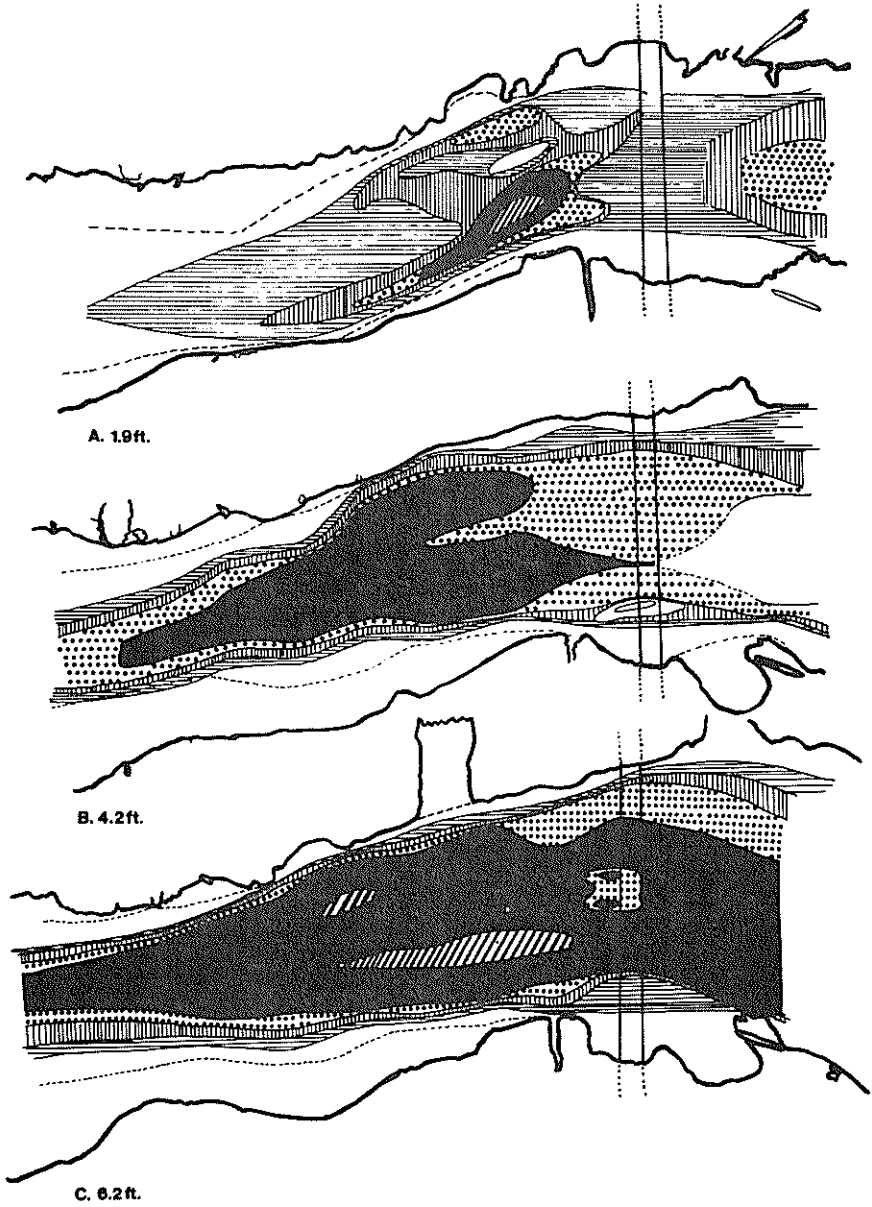


Fig. 13. Water velocity patterns 30 cm below the surface of the river at gauge levels 1.9, 4.2 and 6.2 ft. Legend as in Fig. 12.

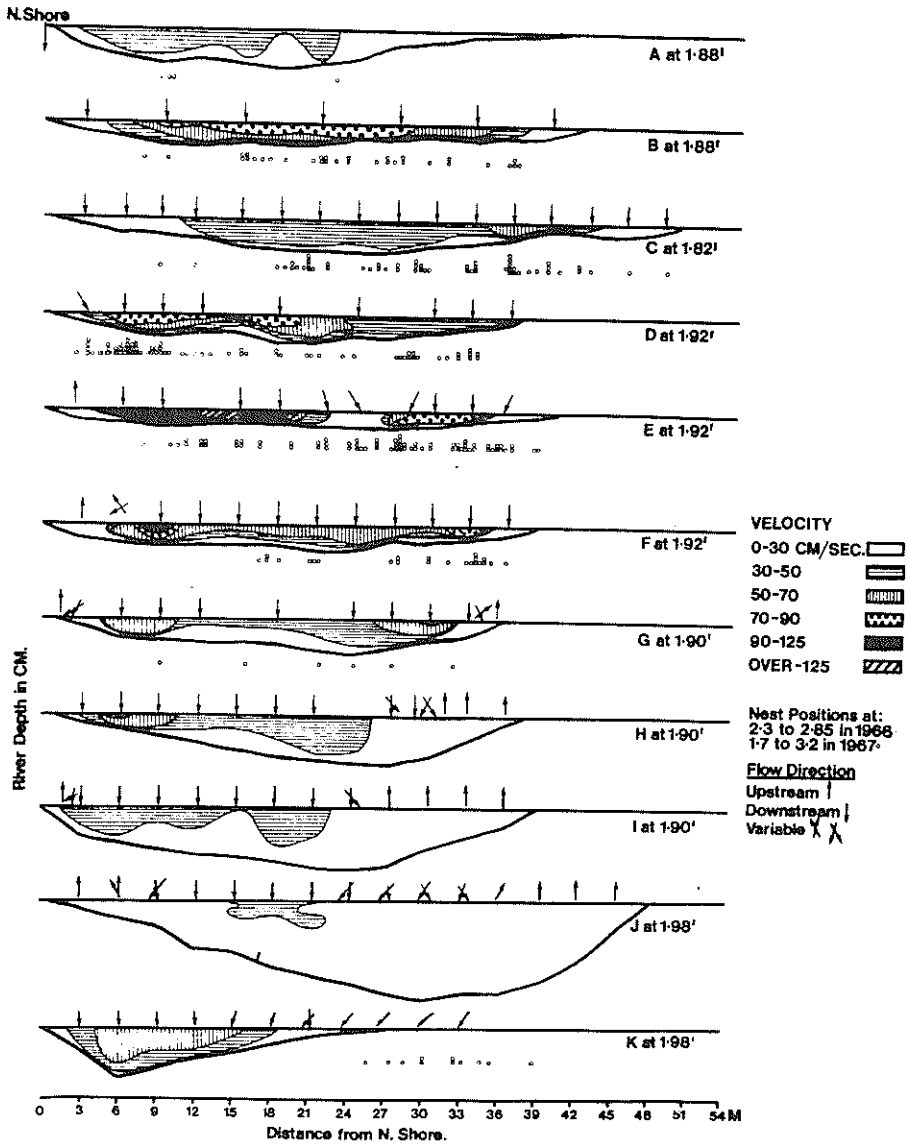


Fig. 14. Water velocity profiles at 11 transects, gauge levels 1.88 to 1.98 ft. Directional characteristics of current are indicated by arrows above each profile. Positions of fish nests near the transect lines, during periods when gauge levels ranged from 1.7 to 3.2 ft, are indicated.

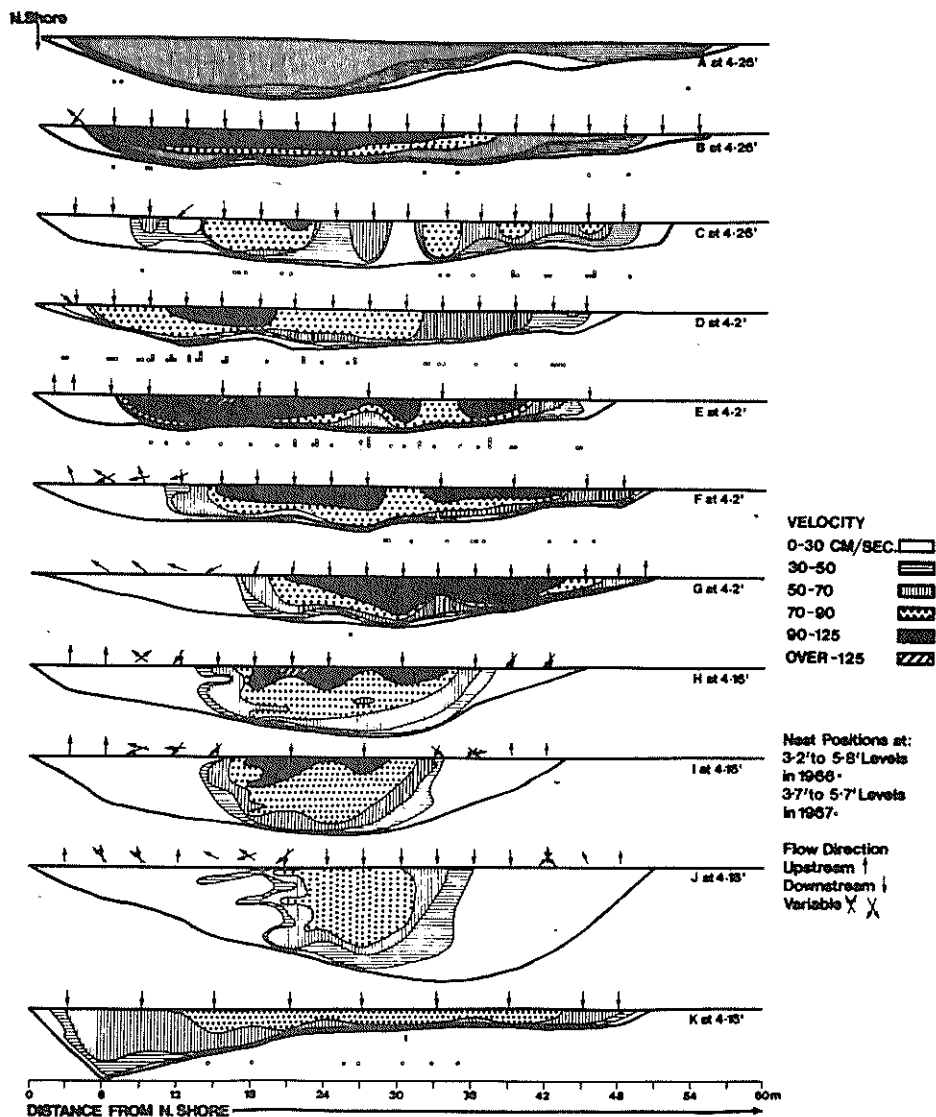


Fig. 15. Water velocity profiles at 11 transects, gauge levels 4.16 to 4.26 ft. Directional characteristics of currents indicated by arrows above each profile. Positions of nests, near the transect lines, during periods when gauge levels ranged from 3.2 to 5.8 ft, are indicated.

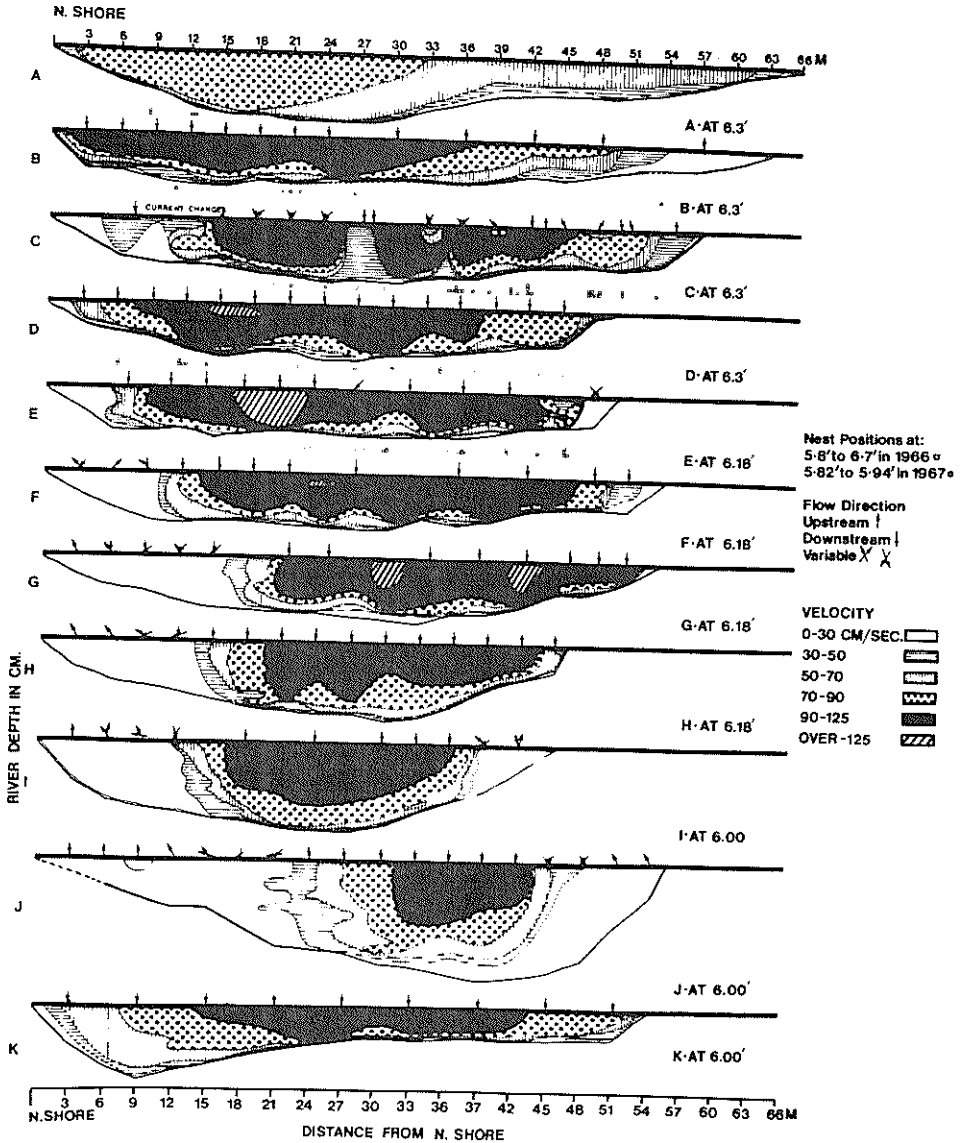


Fig. 16. Water velocity profiles at 11 transects, gauge levels 6.00 to 6.3 ft. Directional characteristics of the current are indicated by arrows above each profile. Positions of nests, near the transect lines, during periods when gauge levels ranged from 5.8 to 6.7 ft, are indicated.

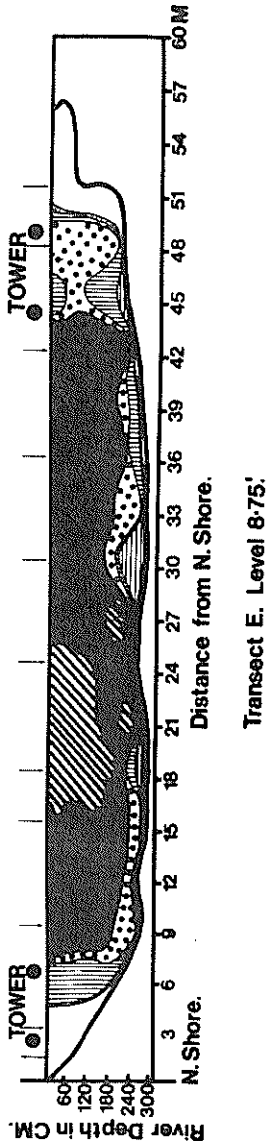


Fig. 17. Water velocity profile at transect E, gauge level 8.75 ft. Directional characteristics of the current are indicated by arrows above each profile. Positions of nests, near the transect lines, during periods when gauge levels ranged from 5.8 to 6.7 ft, are indicated.

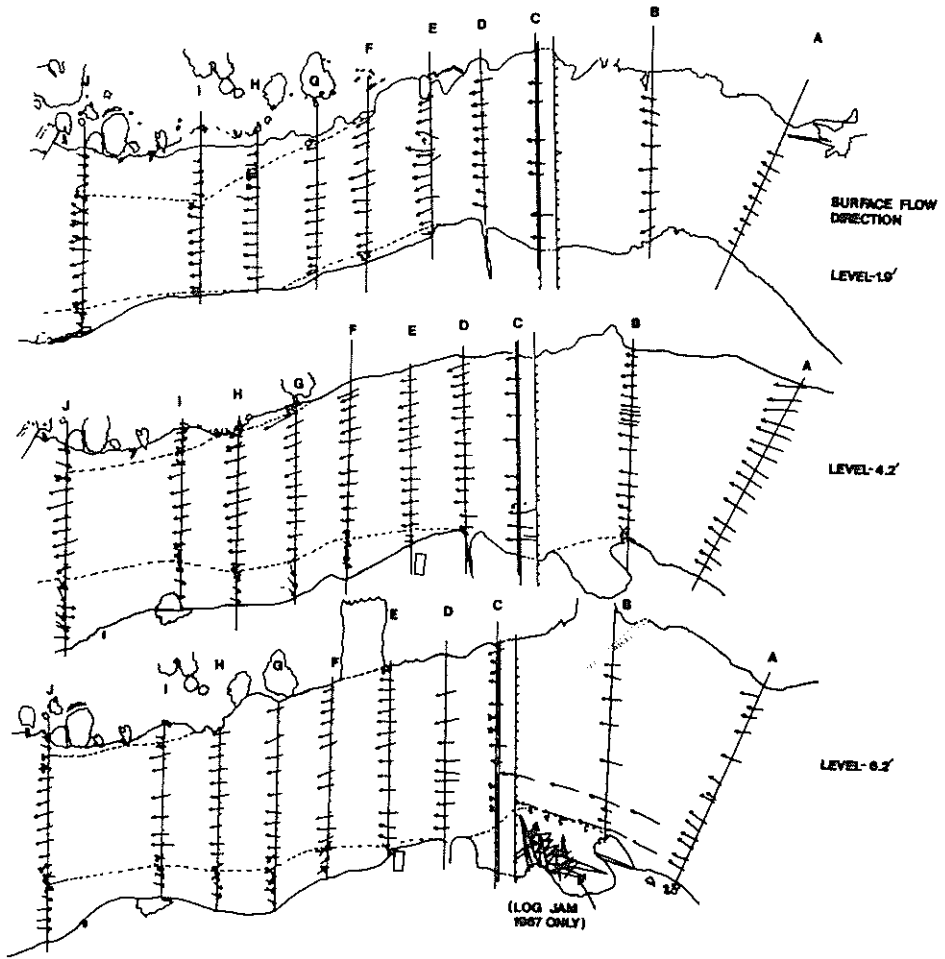


Fig. 18. Direction of surface flow at gauge levels 1.9, 4.2 and 6.2 ft.

In the areas of the river between transect B and I, and further downstream, much of the water along the margin of the stream was still or moving upstream. The arrows at the water surface, Figs. 14, 15 and 16 indicate flow direction. The dashed line and adjacent shoreline include the areas where 'upstream' flow occurred (Fig. 18). Current direction in the area of the dashed line was unstable (Figs. 14, 15 and 16). Surface water velocities in the upstream flow areas reached as high as 32 cm per second.

Water velocity profiles and approximate depth are shown in Fig. 19 for a longitudinal section of the river following the line indicated, LL, on Fig. 4. Figure 19 and Figs. 14, 15 and 16 indicate that velocity of the water near the bottom was high over the area of the river used for spawning. At transects I and J, below the major spawning area, the velocity gradient from the bottom toward the surface was not sharp. More detailed measurements of water velocity and direction in a longitudinal section LM (see Fig. 4 for location) are presented in Fig. 20, A and B. Water velocity at the crests of the gravel ridges, marked R in Fig. 20, were greatly increased and water velocities between the ridges were reduced. Current direction immediately downstream of the ridges was erratic and in some cases reversed in direction (Fig. 20).

#### DURATION OF SPAWNING

Spawners were on or holding below the Gerrard spawning area for 6 or 7 weeks each year (Fig. 21). Active spawning occurred over 5 or 6 weeks, but the period of high spawning numbers lasted for only 3 or 4 weeks. During 1966, early arriving fish remained on the spawning area for about 20 to 28 days. Fish arriving late in the spawning season remained only 6 or 7 days. On the basis of visual counts and length-of-stay data, the 1966 run was estimated to consist of 650 fish. The highest daily shore count was 249 fish in 1966. Fish may not necessarily remain for the same average length of time in different years. The time of arrival and time over which fish were present varied annually (Fig. 22). It therefore may not be sound to extend the relationship between shore counts and estimated total run in 1966 to any other year.

#### FISH AND NEST DISTRIBUTION

Observations, encompassing the major spawning area, were made of the distribution of fish, and sites where nest digging occurred in 1966 and 1967 (Figs. 23, 24, 25 and 26). The solid line, representing stream margin at the higher gauge level and dashed line representing the margin at the lower gauge level are approximate because precise maps of the river margin at all gauge levels were not available. Distribution of digging sites and fish in Figs. 27 and 28, cover the second important spawning area and two major holding areas. Plots of fish and nests around the second spawning area (Figs. 27 and 28), were not made for the same three water level intervals as those at the major spawning area (Figs. 23 to 26). The distributions in Figs. 27 and 28, at 1.7' to 3.0' and 1.75' to 3.0' respectively, were made for times when there was little or no flow over the bar. Distribution data were related to stream levels to demonstrate the effect of the bar on the timing of movement of fish onto downstream areas.

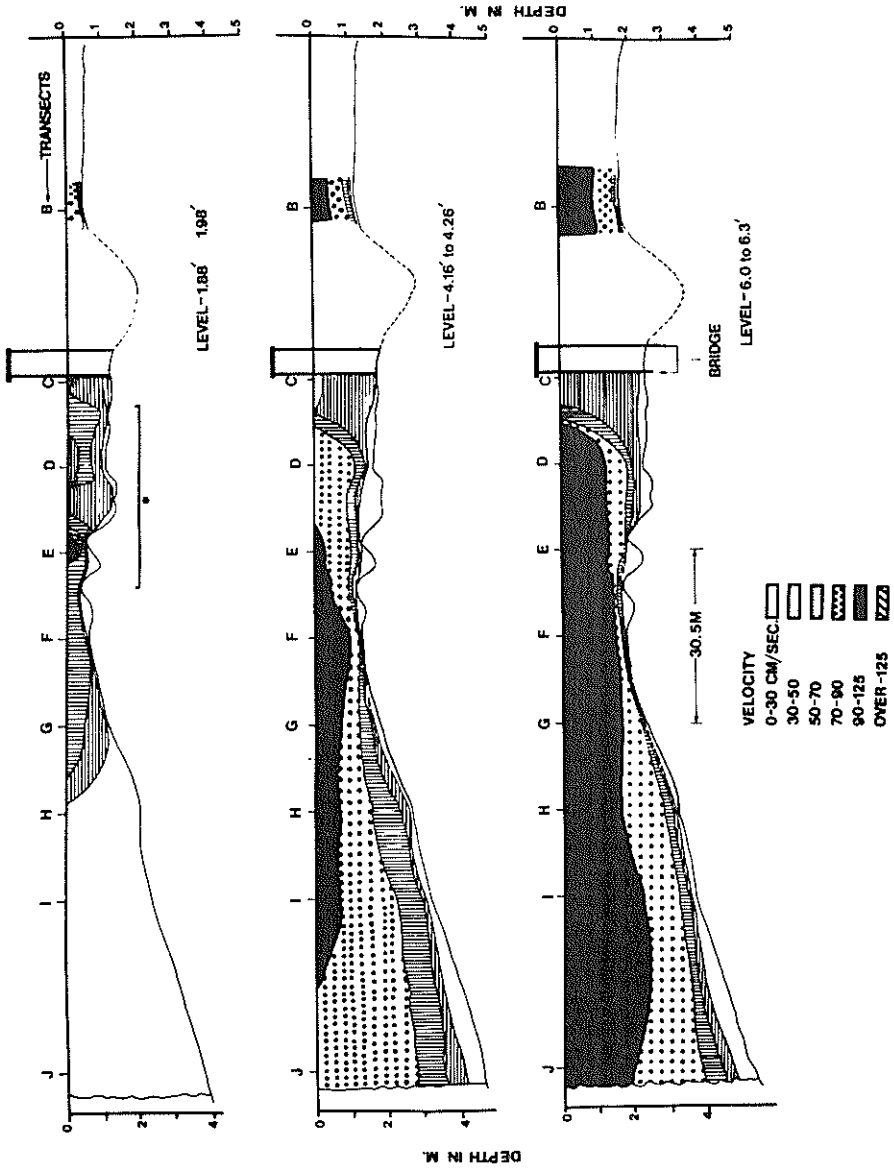
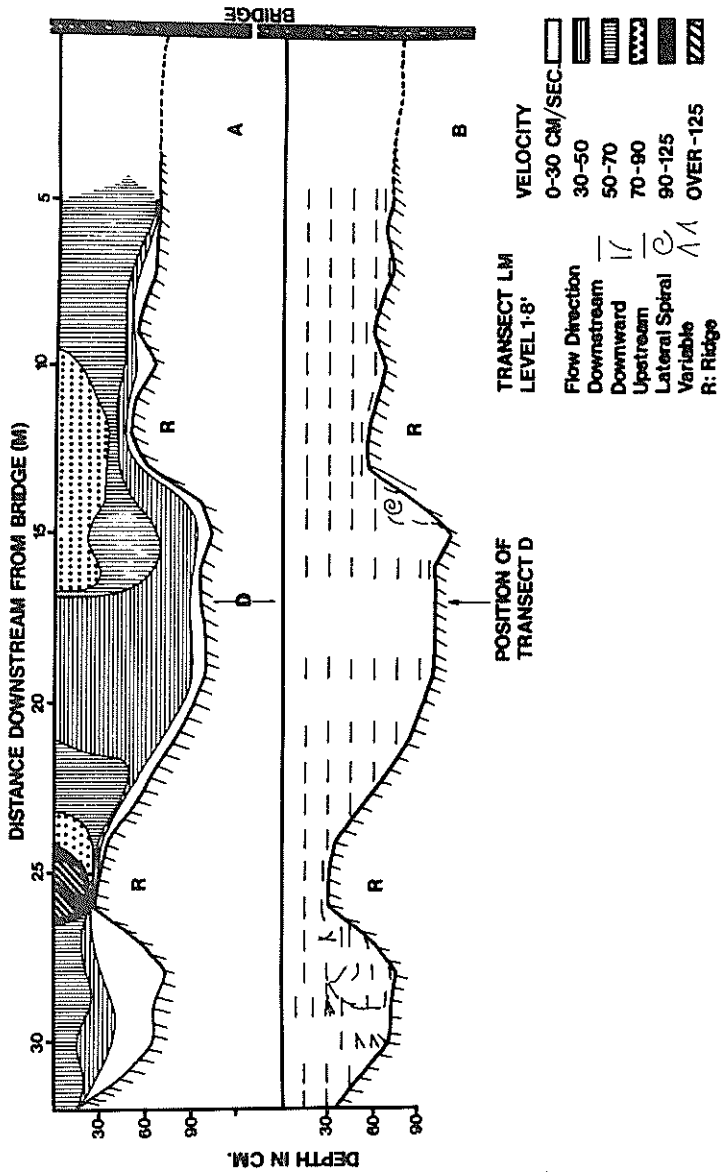


Fig. 19. Bottom profile and velocity profile along LL, (Fig. 4), at gauge level ranges indicated on the figure. Positions of transects B to J are indicated.



3. 20. Bottom profile, water velocity profile and current characteristics along LM, (Fig. 4), at gauge level 1.8 ft.

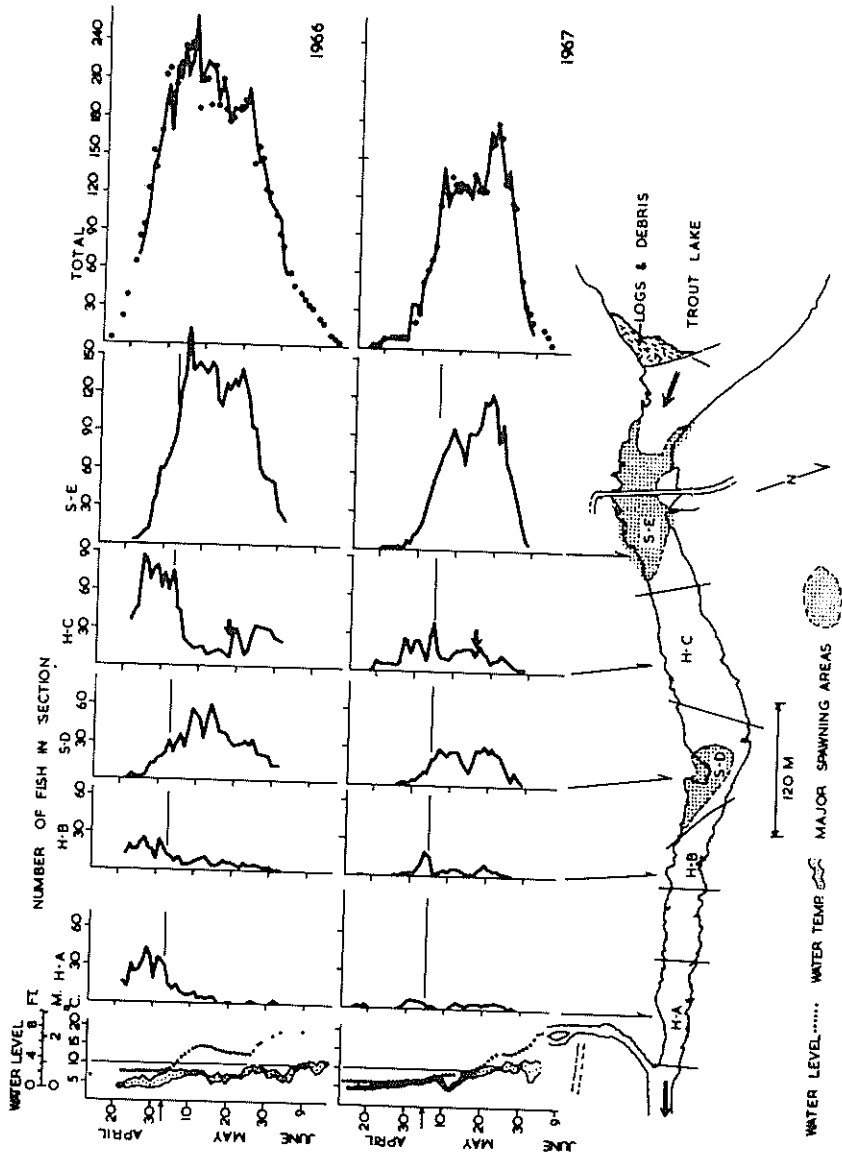


Fig. 21. Number of fish in three holding pools, H-A, H-B, and H-C, and two major spawning areas, S-D and S-E, between Mobbs Creek and Trout Lake outlet. Temperature and water level for the two seasons shown left of the figure. Circles in the part of the figure showing "Total" number of fish represent shore counts made by Mr. G. Palmer. Numbers of fish in H-C made up largely of spent fish after May 20 (see heavy arrow). Thin arrow on the time scale indicates time at which fish appear to move from holding pools to spawning areas.

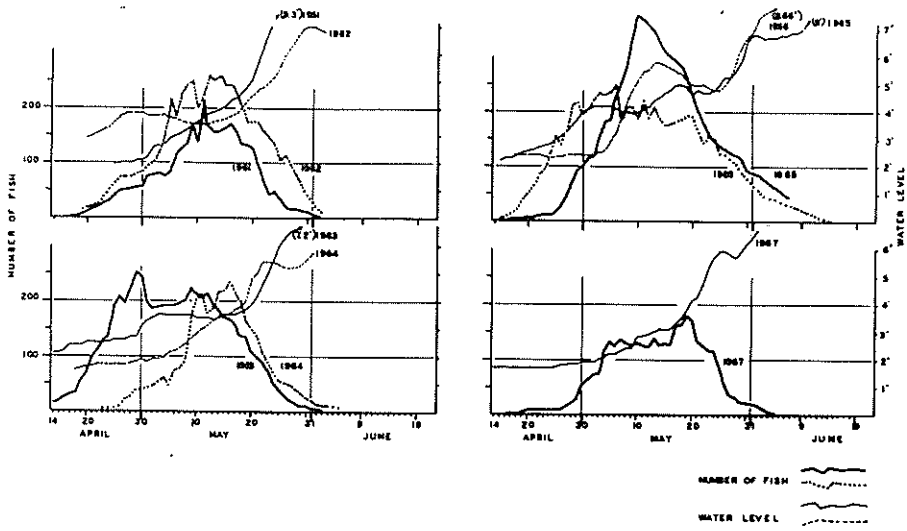


Fig. 22. Shore counts of fish in the Gerrard area from 1961 to 1967. River levels for corresponding years are shown.

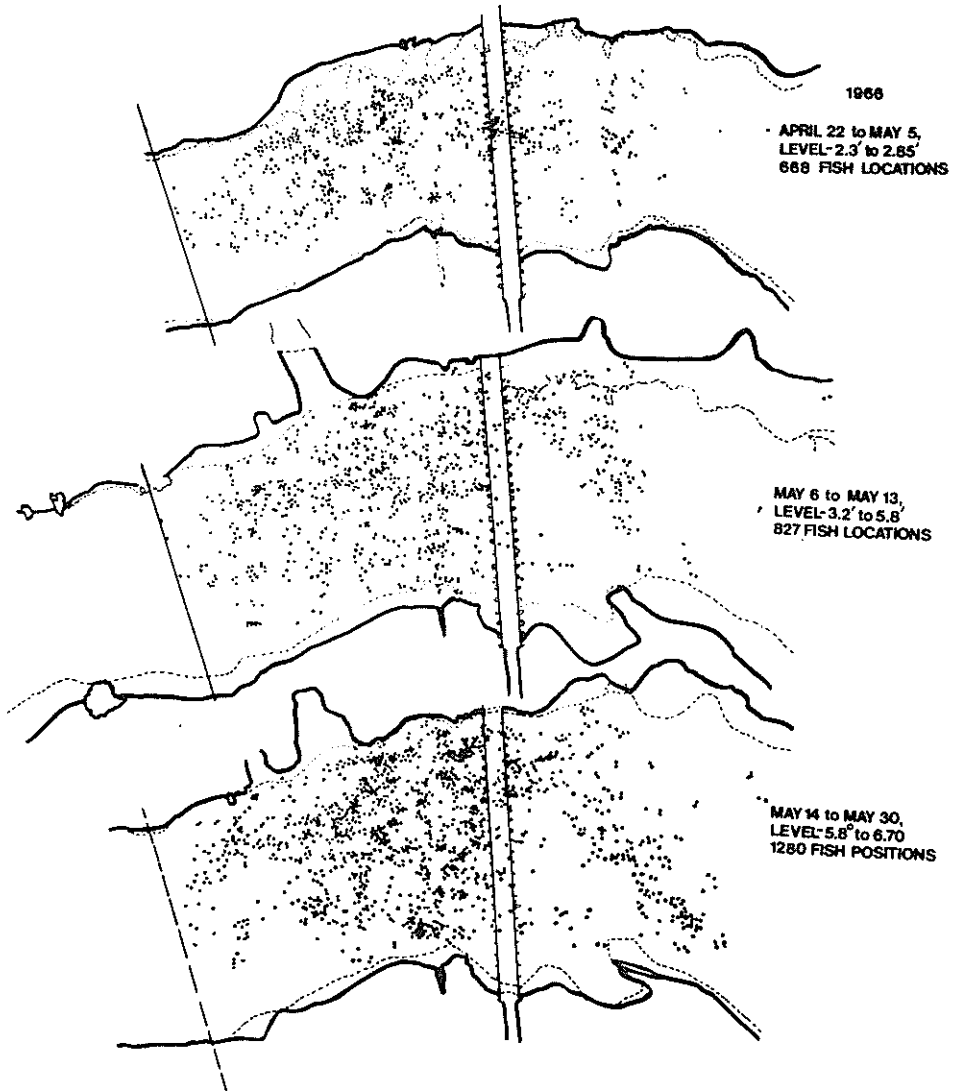


Fig. 23. Area S-E and positions of fish accumulated from daily observations during 1966. Water level ranges at which observations were recorded are indicated beside each outline map.

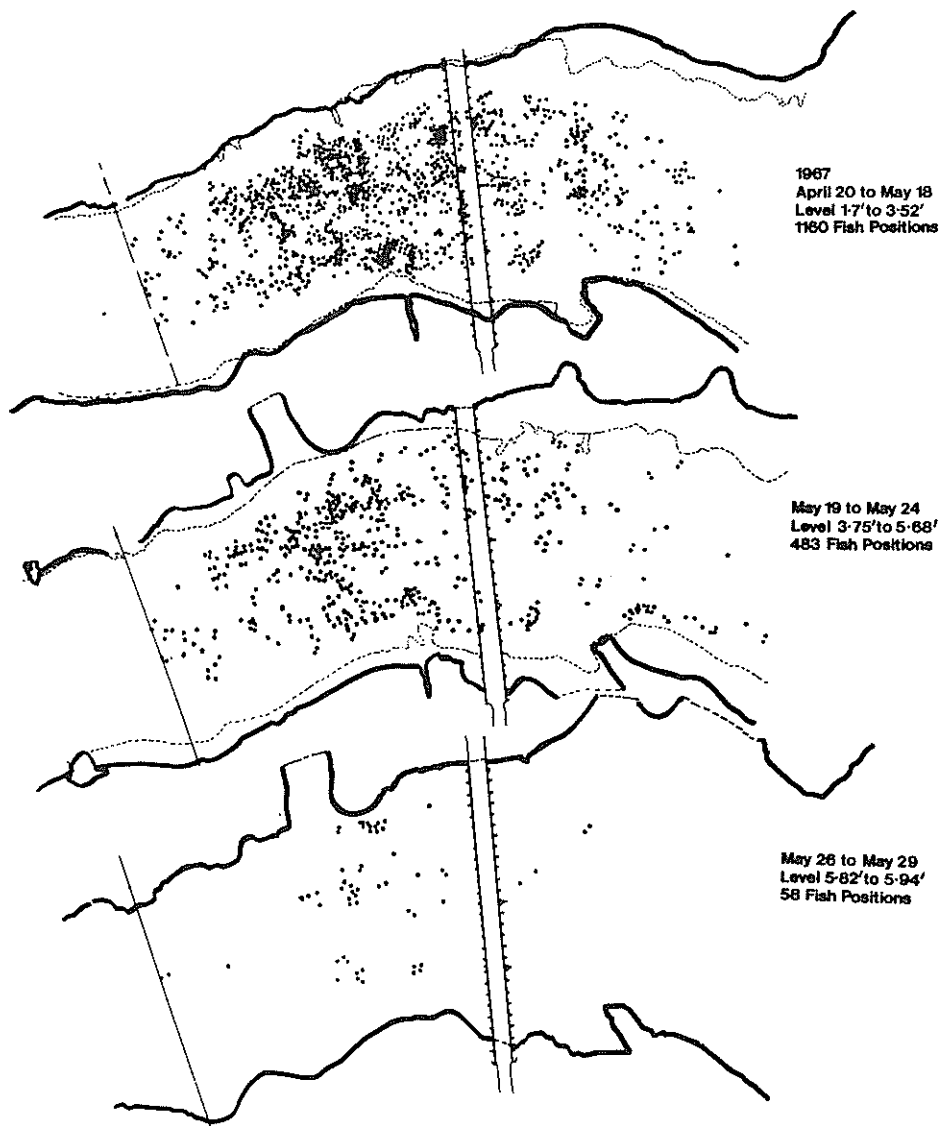


Fig. 24. Area S-E and positions of fish, accumulated from daily observations during 1967. Water level ranges at which observations were recorded are indicated beside each outline map.

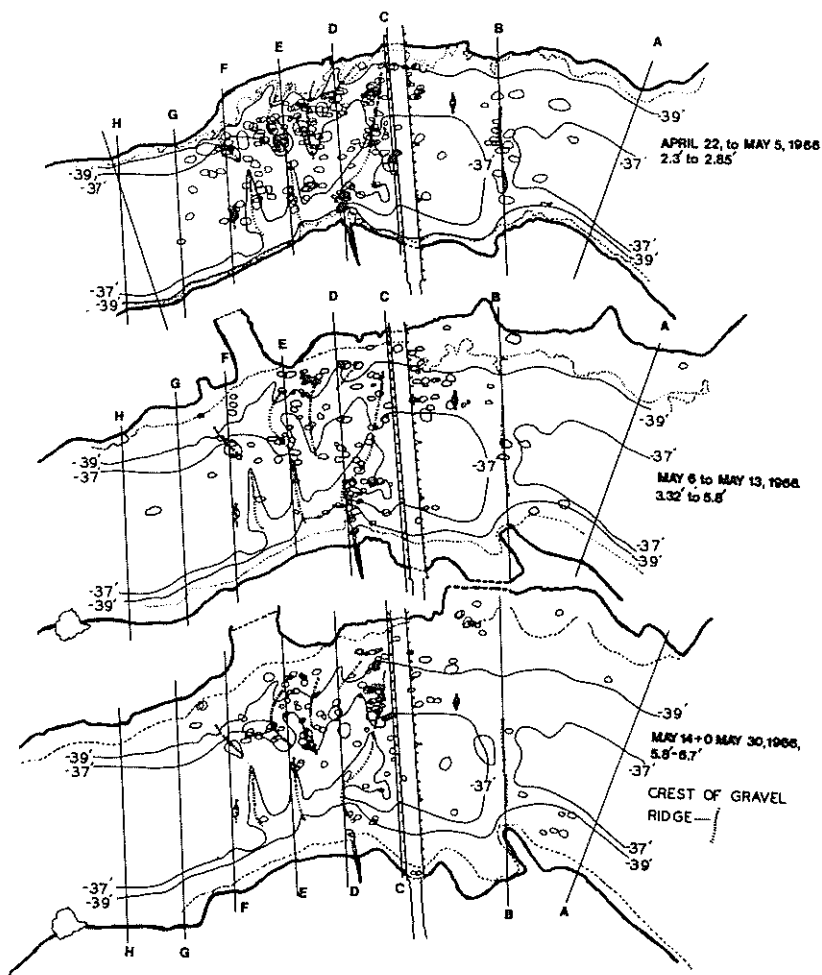


Fig. 25. Area S-E and positions, size and shape of nest sites where fish were observed digging in 1966. Solid line and dotted line show approximate shorelines at the upper and lower water levels indicated beside each outline map. Contour lines -37' and -39' (correspond to elevations 2337' and 2339' from topographic survey) indicate the shape and positions of the major gravel ridges in the spawning area.

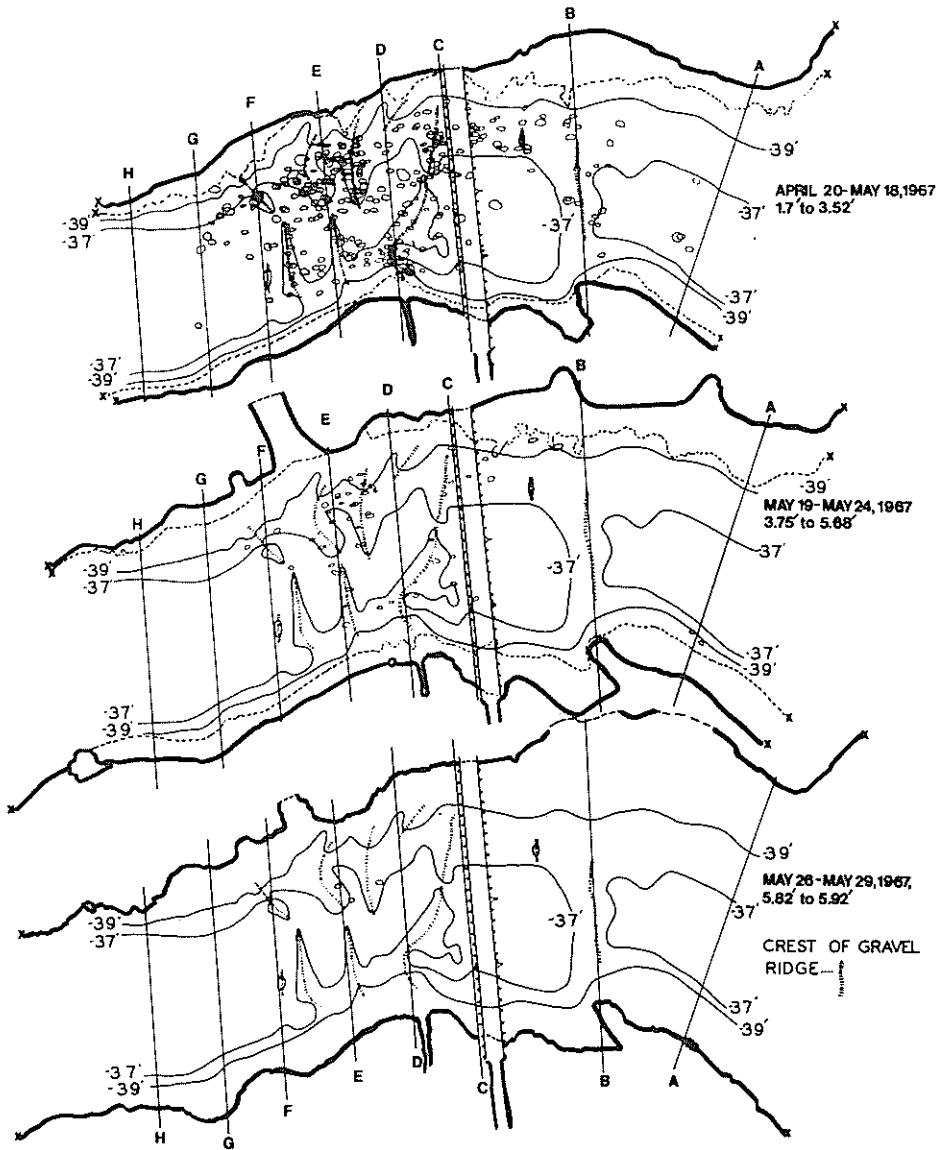


Fig. 26. Area S-E and positions, size and shape of nest sites where fish were observed digging in 1967. Solid line and dotted line show approximate shorelines at the upper and lower water levels indicated beside each outline map. Contour lines -37' and -39' (correspond to elevations 2337' and 2339' from topographic survey) indicate the shape and position of the major gravel ridges in the spawning area.

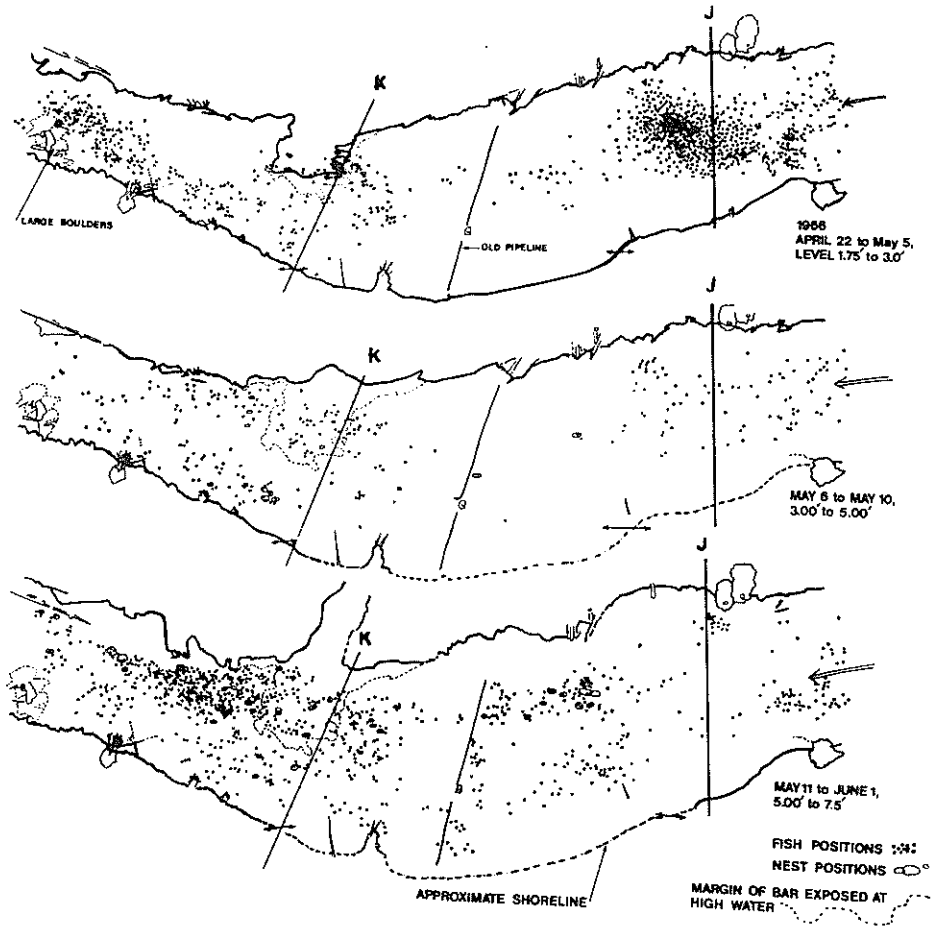


Fig. 27. Area S-D, below 'old pipeline' and part of H-C above it. Positions of fish and nests, accumulated from daily observations during 1966. Fine dotted line shows position and shape of the large rock and gravel bar as it is when exposed at about 1.7 ft. Solid line shows approximate shoreline at gauge levels near the upper end of the range indicated beside the outline map.

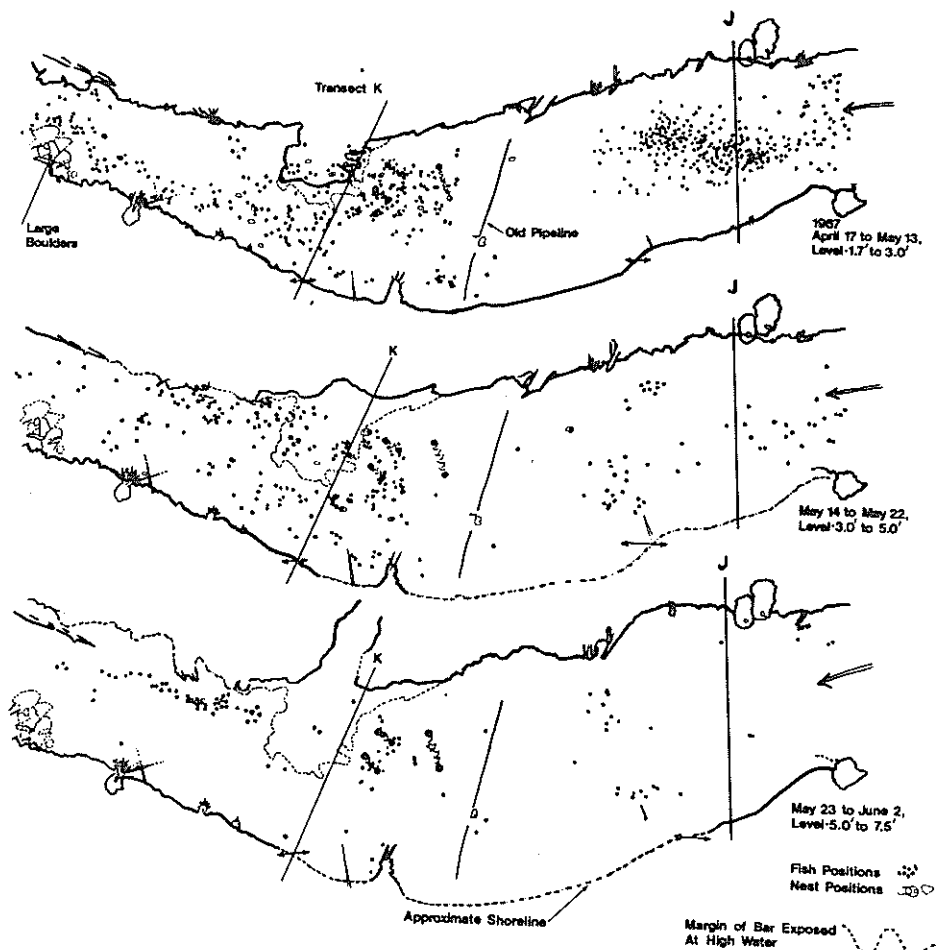


Fig. 28. Area S-D, below 'old pipeline' and part of H-C above it. Positions of fish and nests accumulated from daily observations during 1967. Fine dotted line shows the position of the large rock and gravel bar as it is when exposed at about 1.7 ft. Solid line shows approximate shoreline near the upper end of the range indicated beside the outline map. Positions of hand made gravel ridges are indicated by alternating brackets between dots, upstream from transect K.

The distributions of fish (Figs. 23 and 24) do not indicate what fish were doing in various areas. A comparison of fish distribution (Figs. 23 and 24) with nest site distribution (Figs. 25, 26) indicates where most spawning took place and where fish positioned themselves before or after spawning. The fish held and spawned in quite different parts of the river.

During early phases of the spawning period large numbers of fish held positions for 5 or 6 days in a pool near the large boulders shown in the left (downstream) part of Figs. 27 and 28 (H-B on Fig. 4), in the area at the right end of Figs. 27 and 28, (H-C on Fig. 4) and near Mobbs Creek before moving onto nearby spawning areas.

The distance from holding areas to spawning areas was short. In the area of the bar (S-D, Fig. 4), fish apparently moved across to the south shore of the river in order to take up spawning positions.

The major area in which fish hold position before spawning lies in the region at and below transect J (Figs. 27 and 28). In 1966 there were as many as 60 to 80 fish per day in or about this large holding pool at transect J (H-C, Fig. 27). Water velocities in this area remained below 30 cm per second at the time for which fish were holding.

A small number of fish dug nests near the south side of the river, immediately upstream from Mobbs Creek. However virtually all nest construction occurs in the two stretches of stream dealt with in Figs. 23 to 28. In the vicinity of the bridge, (S-E, Fig. 4, and Figs. 25 and 26), virtually all spawning takes place between transects A and G. The heaviest distribution of nests, however, lies in a smaller area of river approximately 70 m long, extending downstream from immediately above the bridge. In the second spawning area (S-D, Fig. 4 and Figs. 27 and 28) scattered spawning occurs along about 95 m of river. Efforts to locate and plot nest digging sites were less intense in the area in Figs. 27 and 28, (S-D in Fig. 4), than in areas in Figs. 25 and 26 (S-E in Fig. 4) and nest counts therefore were not quantitatively comparable. Counts of nest sites on the north and south halves of the river indicated that about 75 percent of the nests were dug along the south half of the river. At area S-D during the early phase of spawning most nests were constructed on the upstream side of the bar (Figs. 27 and 28). In the later phases of the spawning period, after water levels reached and exceeded the gauge level of 3 ft, most nest digging occurred on the south side of the river below the bar (Figs. 27 and 28).

#### RELATION OF SPAWNING AREAS TO PHYSICAL FEATURES

There were certain combinations of physical conditions in the areas heavily used by spawners. These will be outlined together, because gradient water velocity, gravel composition, and bottom topography are all interdependent.

The majority of nests and spawning fish occurred in areas where water depth ranged from 0.5 to 2.5 m. Within this range most intensive nest

digging took place in areas where depths ranged from 1.75 to 2.0 m (Figs. 14-16).

Water velocities, 20 cm above bottom, in the areas heavily used for spawning tended to remain between 50 and 90 cm per second at all levels of river discharge. Because spawning predominantly occurred in such higher velocity regions, they usually were characterized by a sharp velocity gradient from bottom to the surface (Figs. 14-16). Surface velocities were therefore not necessarily a good indication of suitable spawning sites. Little nest construction occurred below transect G at high water even though water velocities near the bottom were 50 cm per second or more. Water velocities below transect G at low discharge were 30 cm per second or much less. Comparison of nest plots in Figs. 25 and 26 with water velocities 20 cm above the bottom (Fig. 12) indicates that little nest construction occurred anywhere where velocities were 30 cm per second or less. Figure 14 may be somewhat misleading in that it indicates nests were constructed in water 10 to 15 cm deep, and flowing at much less than 30 cm per second near transect K. However, the nests plotted on this, and other profiles, were made over a range of water depths. Nests on transect K were made when the water was 35 to 40 cm deep and moving more rapidly. At the time fish spawn in the area below the bar (Figs. 27 and 28 and S-D, Fig. 4) water depths are somewhat greater, but velocities appear to be similar to those over the bar.

Gravel in the area of maximum spawning activity is represented by samples GR-1, 2, 3, 4 and 5 (Table I). Viewing box observations suggest that much of the gravel in the unsampled, although heavily used, areas of the river between transects C and F was similar to gravel in samples GR 1, 2 and 3, Table I.

Nests in the areas with gravel, depth and water velocities meeting the conditions outlined above, were heavily clumped in some locations. A visual comparison of the positions of the submerged gravel ridges with the positions of nests showed that fish constructed nests on the higher portions of the river bottom. Depending on water levels, between 42 and 67 percent of nests were constructed near ridge crests on 22 to 30 percent of the total area (Table II, Figs. 25 and 26). Above the bridge, most nest construction occurred on or upstream from a submerged ridge traversing the river. The relationship of nest position to bottom topography in area S-D (Figs. 4, 27 and 28) is less clear. Fish appeared to congregate for spawning immediately upstream from the bar, which is an old alluvial fan, at the time the main thrust of the flow impinged on the bar and was deflected to the north. However, under the conditions when the river inundated the bar, most nest construction occurred downstream from it.

The combination of features noted above, i.e., relatively high early spring river temperatures, clear water, medium depths, stable but not high water velocities and irregular bottom topography probably all combined to make the Gerrard site very suitable if not ideal for spawning.

Table II. Number and per cent of nests constructed near ridge crest, i.e. within 3 m of crest of gravel ridge (see Figs. 25 and 26).

	WATER LEVEL (GAUGE)			
	1966		1967	
	2.3-2.85'	3.35-5.80'	5.8-6.7'	1.7-3.52'
Nests near ridge crest - No.	60	66	94	2
% of total nests observed	42	46	43	67
% of area near ridge crest <sup>1</sup>	30	25	22	30
				29
				141
				55
				43
				25
				22

<sup>1</sup> Estimated from the approximate total area of bottom (related to water level) over which nest digging occurred.

## TROUT EGG LOSSES AND NEST SUPERIMPOSITION

Egg loss on the spawning area was attributable in large part to nest destruction. Figure 29 indicates that fish often dug over previous nests in certain areas. In 1966 and 1967, in the four 8 m x 8 m squares, nests were superimposed or very nearly so, in the following number of instances where digging sites were plotted; 1966, S.W.-6 out of 29 cases, S.E.-9 out of 40 cases, N.W.-0 out of 3, and N.E.-0 out of 13 cases; 1967, S.E.-4 out of 30 cases, S.E.-19 out of 65 cases, N.W.-0 out of 6 cases and N.E.-6 out of 31 cases. A total of 44 out of 217 nests were over or very near previous nests. The effects of nest superimposition, as recorded, are not easy to assess. The information should be considered along with data on egg loss measured by samplers.

During the period of operation, an equivalent of about 10 days in 1967, the two samplers caught 124 trout eggs (Table III). All the eggs obtained were sampled on or before May 20 indicating that egg disturbance was most serious when water levels were comparatively low, but numbers of fish were high (Fig. 21).

The two samplers covered roughly 2% of the stream width, but the distance upstream from which eggs may have come is unknown. In one instance eggs probably came from a nest about 4 m upstream from the sampler. About 25% of the 115 eggs examined had apparently died before being sampled. Nearly 60% of the eggs were in the early stage (first day) of development (Table IV).

During the period while trout were spawning, mountain whitefish were observed moving downstream from Trout Lake onto the spawning area, sometimes in groups of 200 to 500, usually in the latter part of the afternoon or evening. Many whitefish were observed ascending the river toward the lake early in the morning - 0400 to 0600 hours. Daylight observations alone suggest that as many as 2,000 to 4,000 whitefish per day may have moved onto the spawning area.

A portion of the eggs in the stomach contents of 97 mountain whitefish captured on the spawning area, and 41 captured in the lake near the outlet, was examined. Of the 109 eggs examined, most were almost completely digested and consisted of chorions only. Of the 26 eggs which were less decomposed most were in early stages of development (Table IV).

The frequency of egg uptake by whitefish appears to be quite variable (Table V). Of 97 fish captured in the river 50 had no eggs or egg fragments in their stomachs, while 47 fish contained from 1 to 24 eggs each. The 97 fish from the river contained an average of about 2.6 eggs, while whitefish from the lake had an average of about 0.4 eggs in their stomachs. Samples of whitefish angled on the spawning area in previous years have been reported to contain about 5 or 6 trout eggs per fish.

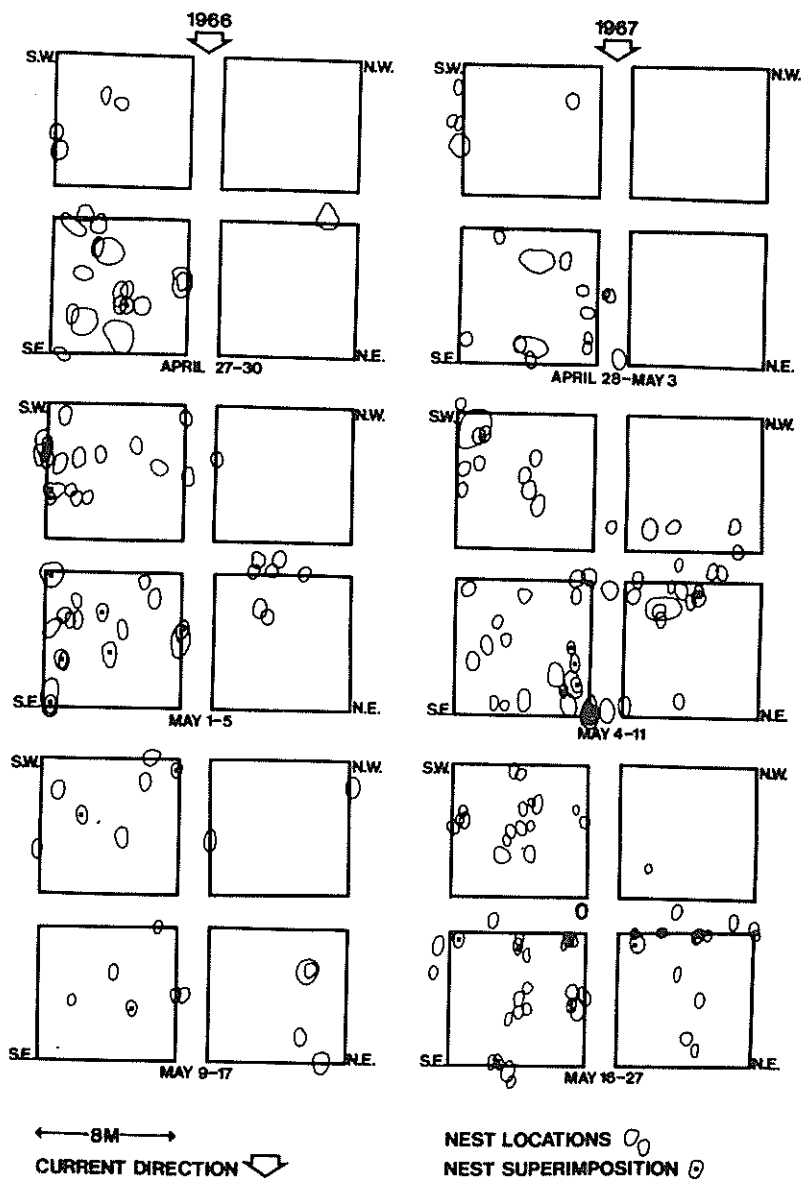


Fig. 29. Locations where nest digging and nest superimposition occurred on the four 8 m x 8 m grids during 1966 and 1967.

Table III Numbers of trout eggs obtained in samplers at Gerrard  
May 7 to May 24, 1967.

<u>Sample Interval</u>	<u>No. of Eggs</u>	<u>Sample Interval</u>	<u>No. of Eggs</u>
May 7 to 8 (night)	20	May 19 (day)	0
8 (day)	4	19 to 20 (night)	2
8 to 9 (night)	7	20 (day)	0
9 (day)	13	20 to 21 (night)	0
9 to 10 (night)	70	21 (day)	0
10 (day)	2	21 to 22 (night)	0
10 to 11 (night)	1	22 (day)	0
11 (day)	0	22 to 23 (night)	0
11 to 12 (night)	0	23 (day)	0
18 to 19 (night)	5	23 to 24 (night)	0
			<hr/>
		TOTAL	124

Table IV. Numbers and condition of trout eggs taken in egg samplers and from whitefish stomachs. Sampling on two days, eg. May 7-8, indicates 12 hour sample period over night of May 7 to May 8. Eggs from egg sampler - E.S., eggs from whitefish from the river - W-R, eggs from the lake - W-L.

Date - 1967	Dead eggs		Live eggs						Unknown stage	Source
	all stages	no development	1, 2 or 4 cell stage	8, 16 or 32 cell stage	64 cells to embryonic shield formation	Neural level stage or past	5 days or more			
May 7 - 8	5	0	9	2	0	3	1	E.S.		
May 8	2	0	0	0	0	0	1	E.S.		
May 9	4	0	0	0	0	0	0	E.S.		
May 9 - 10	16	6	47	1	0	0	0	E.S.		
May 10	2	0	0	0	0	0	0	E.S.		
May 10 - 11	0	0	0	0	0	1	0	E.S.		
May 18 - 19	2	0	0	0	0	1	1	E.S.		
May 19 - 20	0	0	0	0	0	2	0	E.S.		
Total	31	6	56	3	0	7	3			
May 8	0	0	0	0	0	0	21	W-R		
May 8	0	0	0	0	0	0	9	W-L		
May 11	0	0	0	0	0	0	2	W-R		
May 12										
May 15	0	6	10	1	3	0	43	W-R		
May 16	0	0	0	0	0	0	8	W-L		
May 21	0	3	1	0	0	2	0	W-L		
Total	0	9	11	1	3	2	83			



## EFFECTS OF MINOR CHANGES IN SPAWNING AREA

Large stones were removed from several small areas about 2 m x 2 m and two low narrow ridges of gravel about 4 m long and one 8 m long, were made near the same area (Fig. 4) in early April 1967. Spawning fish appeared to select sites on the bar near transect K, (Fig. 4, S-D), where the largest stones had been removed. Much of the nest digging immediately upstream from the bar (Fig. 27, 28) took place on such cleared areas. No fish constructed nests on the low artificial gravel ridge which was constructed upstream from transect K (Fig. 4). Fish did however, appear to remain in the vicinity of this artificial ridge as though it exerted some attraction.

## DISCUSSION

It is significant that in the Lardeau and Duncan rivers, very little of the total river area is used for spawning. Although reproduction of trout has been reported in several parts of the Duncan-Lardeau river system (Larkin, 1951), evidence was based largely on the occurrence of fry and not on observations of spawning fish. Cartwright (1961) reported that no redds were found below Mobbs Creek in 1958 and 1959. Since 1961, trout have frequently been seen in the river below Mobbs Creek, usually in pools or resting areas. Spawning trout have been reported in the Duncan River, near the lake outlet and near Glacier Creek. However, most fish appear to have consistently used the Gerrard spawning site and the concentration of spawning fish there suggests that conditions in this portion of the river are distinctly advantageous for trout reproduction.

Eight large tributaries, draining glaciers, discharge into the Lardeau River between Mobbs Creek and Marblehead (Fig. 2). The water from these streams is turbid and cold during the period when trout eggs are normally incubating at Gerrard. Mean temperatures in the lower Lardeau River at "29-Mile" were several degrees below those at Gerrard during periods when eggs were developing at Gerrard (Fig. 9). Temperatures of the Lardeau River below Mobbs Creek range from 1.5 to 6.5°C lower than those above Mobbs Creek. As suggested by Hartman (1969), higher temperatures and consequent earlier hatching may provide fry from the Gerrard area with an advantage in size and age over fry from the lower river. River temperatures at "29-Mile" exhibited a wider daily fluctuation than those at Gerrard bridge and at "Y Camp" station.

Geology, precipitation and topography are generally similar throughout the main tributaries. Although conclusive data were not obtained, it would appear that the area at Gerrard and the area at the outlet of Duncan Lake (previous to the construction of the Duncan Dam) are characterized by low gradient, low or moderate turbidity and stable flows. Furthermore, the outlet spawning area may provide emergent fry with a continuous supply of planktonic food organisms. Since the flooding of the Duncan site, the Gerrard area is the primary spawning area remaining in the stream system. It is likely that several factors contribute to making the Gerrard site so suitable for trout reproduction.

On the assumption that repeated and intensive use of a spawning area

by a population of trout indicates habitat suitability, detailed information about such heavily used spawning areas can provide the best guidelines for the improvement of marginal spawning areas or the construction of new ones.

The distribution of most nests in areas where water velocities, 20 cm above the bottom, remained moderately high at all river discharge levels (Figs. 12, 25 and 26), suggest that seasonal flow stability is an important factor in determining site suitability. In areas of S-E where water velocities 20 cm above bottom fell below 30 cm per second at low water, the gravel was not used, even in periods of high water when velocities are 50 to 70 cm per second (Figs. 12, 25 and 26). Fish may avoid such areas because variable velocities result in unsuitable gravel characteristics. However, trout spawned in areas below the bar (S-D, Fig. 4), at high water when velocities were high (Figs. 27 and 28). At low water, when the river did not flow over the bar, water velocities over much of these areas, immediately downstream, were less than 30 cm per second.

In the main spawning area (S-E, Fig. 4), it is likely that a combination of factors including depth, velocity, gravel size and bottom topography contribute to make conditions very suitable for reproduction. Stuart (1953) pointed out that intragravel flow is highest at or near the apex of gravel mounds in a channel. Figure 20 shows that velocities and hence intragravel gravel flows, are greatest at the crests of the transverse gravel ridges. Trout at Gerrard may detect subsurface flow directly, or choose areas of good subsurface flows indirectly by selecting specific topographic features of the river bottom.

Because fish tend to select raised areas of the river bottom at the Gerrard site, the total bottom area used for spawning is smaller than the gross area of the river bottom apparently available. Thus, considerations of the availability of space taking into account only spawner abundance and gross area of spawning gravel, may not present a realistic picture of conditions of crowding on optimum sites. Cartwright (1961) estimated the total spawning area to be about 9000 yards<sup>2</sup> (or about 7500 m<sup>2</sup>). The estimate of 7020 m<sup>2</sup> by Hartman (1969) is close to this figure. Of the total spawning area of 7000 to 7500 m<sup>2</sup>, most intensive use occurred on an area of about 1320 m<sup>2</sup> immediately below the Gerrard bridge (Hartman 1969). The locations of nest digging sites (Figs. 25 and 26) indicate the size and configuration of this area. Within this heavily used spawning area of about 1400 m<sup>2</sup>, fish were not randomly distributed and most nests were placed on gravel ridge tops, the total area of which was considerably less than 1320 m<sup>2</sup>. In the 8 m x 8 m squares (Fig. 4) it was evident that nests on the higher parts of the river bottom were very close to each other or were directly superimposed (Fig. 29). Such superimposition was most serious on the S.E. square (Fig. 29).

In large degree aggressive activity of male trout determines the size of area occupied by a pair or group of fish. Some males defend areas of 100 m<sup>2</sup> or more (Hartman 1969). Superimposition of nests is therefore most likely to occur as a result of successive spawning in the same area. Because fish spawn

successively and because they tend to select the same local areas of the spawning bed it is not realistic to simply divide the total area by the total number of female fish to obtain a measure of space used by each pair of fish.

Extrapolation from limited data suggest that egg losses may be substantial. In 10 days, nets covering about 2% of the river width sampled 124 eggs. At this rate, losses across the full width of the river for an arbitrarily selected 5 m segment of the river could be 6,200 eggs. If one assumes this level of loss to apply to the full length of the spawning area, i.e., about 60 m at the bridge site, losses could be in the order of 135,000 eggs over the spawning period of 20 days, the approximate duration of near peak numbers of fish.

A substantial fraction of the eggs examined from whitefish stomachs were those that had been displaced or were not buried after spawning. Some development had taken place in 17 out of 26 eggs that could be classified according to development (see Table III, from whitefish, "W-R"). Since some of the eggs ingested by whitefish were displaced, estimates of the total egg consumption by whitefish may be of further value. If 2,000 whitefish per night are assumed to pick up eggs over the spawning area at a rate of 2.6 eggs per fish for 20 nights, total egg ingestion would be in the order of 104,000 eggs. This is based on a conservative estimate of whitefish numbers. On the basis of this limited data, total numbers of eggs displaced and lost or ingested, would be in the order of 239,000 eggs. However the egg samplers may have taken eggs which otherwise would have been eaten by whitefish. It may, therefore, not be legitimate to simply add the two totals together as has been done.

The significance of these egg losses depends to a large extent on whether or not displaced eggs would develop if they were not taken by predators. If eggs experience high mortality after displacement resulting from superimposition, their consumption by whitefish is of no significance. If they survive displacement, then loss through predation is undesirable.

#### MANAGEMENT RECOMMENDATIONS

1. To clarify some of the questions raised it is recommended that more extensive series of egg samplings be carried out during runs of different size. A positive relation between egg loss and spawner density would tend to confirm the existing evidence of overcrowding. Experiments should be carried out to determine the survival rate of eggs that are dug out of nests and displaced. An expanded program of whitefish stomach sampling, using non-selective capture methods, preferably on fish leaving the spawning area in the early morning, should be conducted concurrently with egg sampler studies. These studies could be carried out inexpensively and with little or no disturbance to spawners.

2. Concurrent to egg and whitefish stomach sampling, a program of stream bottom clearing should be carried out to improve the gravel in an area 10 m wide and about 40 m long on the south shore of the river, immediately above the bridge.

3. Experimental gravel placement should be tried in three places (Fig. 4). At transect B to F water velocities are normally high enough for

spawning fish at all river levels. An artificial gravel ridge, 10 or 15 m long, 4 m wide, and 0.45 m high, placed directly under and parallel to transect A (Fig. 4) should be developed over a 3 year period. The 3 year period for spawning area construction is recommended because such a time interval would allow evaluation of fish use and would also allow an opportunity to observe the condition of the old trap sill at transect B. If activities at transect A appeared to be leading to erosion at transect B they could be stopped.

A second comparable ridge should be developed, at the same time, across the bottom of the large pool immediately upstream from the bridge (Fig. 4). It is suggested that this ridge be built slowly in a series of three depositions. The ridge should run transverse to the current so that flow direction is not altered.

A third gravel ridge 10 m long, 4 m wide and 0.45 m high, should be placed as indicated in Fig. 4, above the bar at S-D. Consideration should be given here to ridge angle and height so that flows are not directed laterally to the north at high water and thus reduce the suitability of the bar and areas below it for spawning.

4. Several small patches, 3 m x 3 m, should be cleared of some of the large stones (see six 3 m x 3 m squares on the bar at S-D, Fig. 4). These cleared and slightly excavated areas should be filled with finer washed gravel of grain size distribution shown in Fig. 8, GR-1 to GR-5. Because it is quite possible that the bar at S-D (Fig. 4) could be eroded if too much of the coarse boulder material is removed, most of the rocks that compose the bar should be left in place. Not more than 5 or 6, 3 m x 3 m plots should be developed. No large power machines, i.e., bulldozers or heavy loaders should be placed directly in the river to carry out the gravel deposition or rock clearing operations.

The operations outlined would produce about 150 m<sup>2</sup> of new spawning area. Such an area would accommodate 8 to 10 females at a theoretical density lower than that which occurs in S-E. Since females frequently tend to construct one nest ahead of the next in a series, behaviour on the artificial ridges should be observed carefully to determine whether the 4 m width is adequate. If such a local improvement scheme is initiated, fish behaviour and gravel use should be recorded each year to determine how frequently females begin nests on the artificial ridges and then leave them incomplete. Such nest desertion may be highest in the first year when the gravel ridges are low and incomplete. Water velocity measurements should be taken over the ridges at each stage of development. The area of new spawning habitat created may be relatively small, but would determine the feasibility and success of such improvements.

A detailed topographic survey of the spawning area was completed in 1967 (Fig. 7). A second topographic survey is recommended before extra spawning areas are created. A third topographic survey at the end of the three year program of spawning area enlargement would provide information on effects of alteration on the major spawning area. These surveys would serve as a control for studying the effects of changes in the Gerrard area. Further topographic

surveys are recommended in any event because of the distinct possibility of bottom changes, particularly at the deepest point in the stream at transect B (Figs. 4 and 14, transect B, near the N. shore).

At the end of the three-year program, the severity of overcrowding would be clarified. Egg losses, produced by re-use of spawning areas could be compared at different spawning population densities. The feasibility of local habitat changes could be evaluated. If at the end of 3 or 4 years there is further support for the conclusion that overcrowding and nest destruction occurs and evidence that fish will use the new spawning sites, then habitat expansion on a major scale should be initiated.

5. Detailed studies should be carried out on the feasibility of diverting Mobbs Creek from its present course and causing it to enter the Lardeau River about 1 km further downstream. This would increase the length of river in which water quality characteristics are suitable for reproduction. Consideration of this proposal would necessitate studies on: (1) the topography and elevations east of the lower reaches of Mobbs Creek; (2) the gradient of the Lardeau River immediately below the entrance of Mobbs Creek; (3) the cross sectional areas of the Lardeau River channel immediately below Mobbs Creek; (4) the effects of Mobbs Creek outflow on present levels in the Lardeau River above Mobbs Creek; (5) the stability and size of material in the banks and bottom of the Lardeau River at the confluence of Mobbs Creek. Further consideration of the Mobbs Creek diversion plan would necessarily depend on engineering surveys dealing with the above points.

In a major improvement project below the present outlet of Mobbs Creek, a series of 3 or 4 substantial spawning area units is recommended. These should in a large way replicate holding pool and spawning area relationships as they exist in the areas H-B, S-D, H-C and S-E. Suitable depth, velocity, topographic and gravel conditions are illustrated and described in this paper. The pools constructed between individual units of the spawning area should be large, in the order of 50 m long and 5m deep. Largest numbers of trout held in pool H-C, which was longer and deeper than H-A or H-B (Fig. 21). The optimum distribution of spawners over the 3 or 4 sub-spawning areas in the artificial channel and the existing spawning areas S-D and S-E, is likely to be best controlled by size and distribution of pre-spawning holding areas.

The gravel ridges which receive heavy use by spawners in S-E, may in part, be created by hydraulic conditions in the river at the lake outlet. Replication of these conditions in an improved channel downstream may in a large way serve to produce the micro-conditions of bottom topography that appear to be sought by spawning fish in area S-E (Figs. 25 and 26).

If major habitat improvement is embarked upon, it would be desirable to precede it with a program in which fry production is artificially increased in temporary hatchery facilities at Gerrard. The objective of this would be to increase the size of the run, to utilize as quickly as possible the full capacity of the new space.

6. Any property in the area of the spawning ground that is not already in the hands of the Crown, should be acquired.

7. Viewing facilities, an information booth and shore protection facilities would be worthwhile public amenities at the Gerrard site.

8. Bulldozers should no longer be allowed to cross the river on the old trap sill at transect B. The appropriate industry representatives should be informed of this.

9. Highway planners should be fully appraised of the value and delicacy of the Gerrard site. If future highway construction necessitates road changes to the north side of the river, construction should be kept high on the hillside far away from the river.

10. Seining operations on the Gerrard site should be restricted as much as possible even in programs aimed directly at augmenting production on the site. Very minor disturbances, helicopters, large numbers of people and seining all disturb the fish and drive them off their nests. Unguarded half-open nests are vulnerable to predation. Disturbed fish may not return to nest sites, and such sites may be more vulnerable to re-digging by other fish.

11. Attempts have been made to establish the Gerrard stock in other areas. Hartman (1969) has suggested that these fish have evolved special size characteristics as an adaptation to a restricted environment with special physical conditions. Attempts to establish such a population elsewhere should be carried out in a lake-river system comparable to the Kootenay-Lardeau-Trout Lake system. The genetic properties of the Gerrard stock may not necessarily be preserved in a small lake with different ecological conditions and a different type of spawning habitat. Furthermore, the genetic potential of these fish may not be best utilized in such small lakes.

12. Documentation of the condition of the riffle area (head 15 cm) should be repeated once or twice in the next 5 to 10 years. The major spawning area may well be undergoing changes resulting from effects of Mobbs Creek fluctuating, and hence producing different flow conditions over the riffle area below the bridge, and from fish continually moving gravel.

#### ACKNOWLEDGEMENTS

For help in the program the authors are grateful to Dr. A. H. Acara, Messrs. J. C. Chatwin, R. Church, J. W. Leggett, J. Maher, Dr. T. G. Northcote and Messrs. W. R. Sjolund, H. Kniess and C. Kaiser. The comments and information given by Messrs. G. Palmer and R. A. Rutherglen are appreciated.

The B. C. Fish and Wildlife Branch supported this work financially. Preparation of figures was supported in part by the National Research Council of Canada and the Department of Zoology of the University of Guelph. Dr. S. B. Smith, former Chief Fisheries Biologist, of the B. C. Fish and Wildlife Branch suggested the study on the Gerrard trout and we are grateful to him.

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