INTERNATIONAL PACIFIC SALMON FISHERIES COMMISSION

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BETWEEN CANADA AND THE UNITED STATES FOR THE
PROTECTION, PRESERVATION AND EXTENSION OF
THE SOCKEYE AND PINK SALMON FISHERIES
IN THE FRASER RIVER SYSTEM

BULLETIN XIX

ENUMERATION OF MIGRANT PINK SALMON FRY IN THE FRASER RIVER ESTUARY

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ABSTRACT

Seaward migrant pink salmon fry of the Fraser River system emanate from tributary and main stem spawning areas situated immediately above the estuarial portion of the river and therefore estimation of total fry production entailed development of techniques for consistent sampling of fry abundance throughout the migration in a section of the river subject to tidal fluctuations. To circumvent tidal fluctuations in stream flow, a pontoon-mounted trap was propelled upstream at 2.5 ft/sec for 15 min periods by a power boat. Resultant data were augmented by operating a similarly propelled gear fitted with conical nets which could be fished to depths of 13.5 ft. At greater depths, data were obtained from a stationary net.

On the basis of data obtained on lateral, vertical and diurnal distribution of fry, the daily trap samples were weighted so that they were representative of fry numbers per unit volume of water during each 24-hr period. Daily fry abundance was then determined from the daily volume of net seaward river flow as estimated at discharge gauging stations situated above tidal influence. The total number of fry was estimated to be 143.6 million in 1962 and 284.2 million in 1964, indicating a freshwater survival of 9.2% and 11.7% respectively.

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INTRODUCTION

The pink salmon *(Oncorhynchus gorbuscha)* runs to the Fraser River, which occur only in the odd-numbered years, consist of five major spawning populations and some 30 small spawning populations (Ward, 1959). The largest population spawns in a 30-mile section of the Fraser River immediately above the mouth of the Vedder River (FIGURE 1). The lower extremity of this spawning area extends into the area of tidal influence. Two other major populations spawn in tributaries (Harrison and Vedder Rivers) which join the Fraser at points just below the limit of tidal influence. A few very minor populations also spawn in streams tributary to the estuarial (tidal) section of the Fraser. Thus, to estimate the abundance of pink salmon fry migrating seaward in the spring of the even-numbered years, either from the main-stem spawning area or from the river as a whole, it was necessary to develop methods of enumerating salmon fry in the estuarial section of the river.

Methods of sampling migrant juvenile salmon in streams and of estimating their daily abundance have been in general use on the Pacific Coast for some years (Hamilton and Andrew, 1954; Schoeneman and Junge, 1954; McDonald, 1960). To varying degrees in all streams, entrained debris as well as fluctuations in water levels and velocities present problems in sampling. In the lower Fraser River, additional problems were presented by the very great width and depth of the stream and by the occurrence of tidal fluctuations in water levels and stream flow. The present report describes the development of sampling equipment, field techniques and enumeration methods used to estimate the abundance of migrant pink fry in the Fraser River in 1964. On the basis of less complete data, an estimate is also made of the abundance of pink fry in 1962.

In the even-numbered years, the seaward migration of Fraser River pink salmon coincides with that of chum salmon fry *(O. keta)* and chinook salmon fry *(O. tschawytscha)*, both of which are present in all years. The International Pacific Salmon Fisheries Commission is responsible for investigations concerning pink salmon while the Canada Department of Fisheries is responsible for investigations of chum and chinook fry. Thus the development of equipment and field techniques was carried out jointly in a cooperative program with the Fish Culture Branch of the Department of Fisheries, first in 1961 and subsequently in 1962 and 1964. In the intervening odd-numbered years (1963 and 1965), when pinks are not present, the Department has conducted similar programs independently (Todd, 1964).

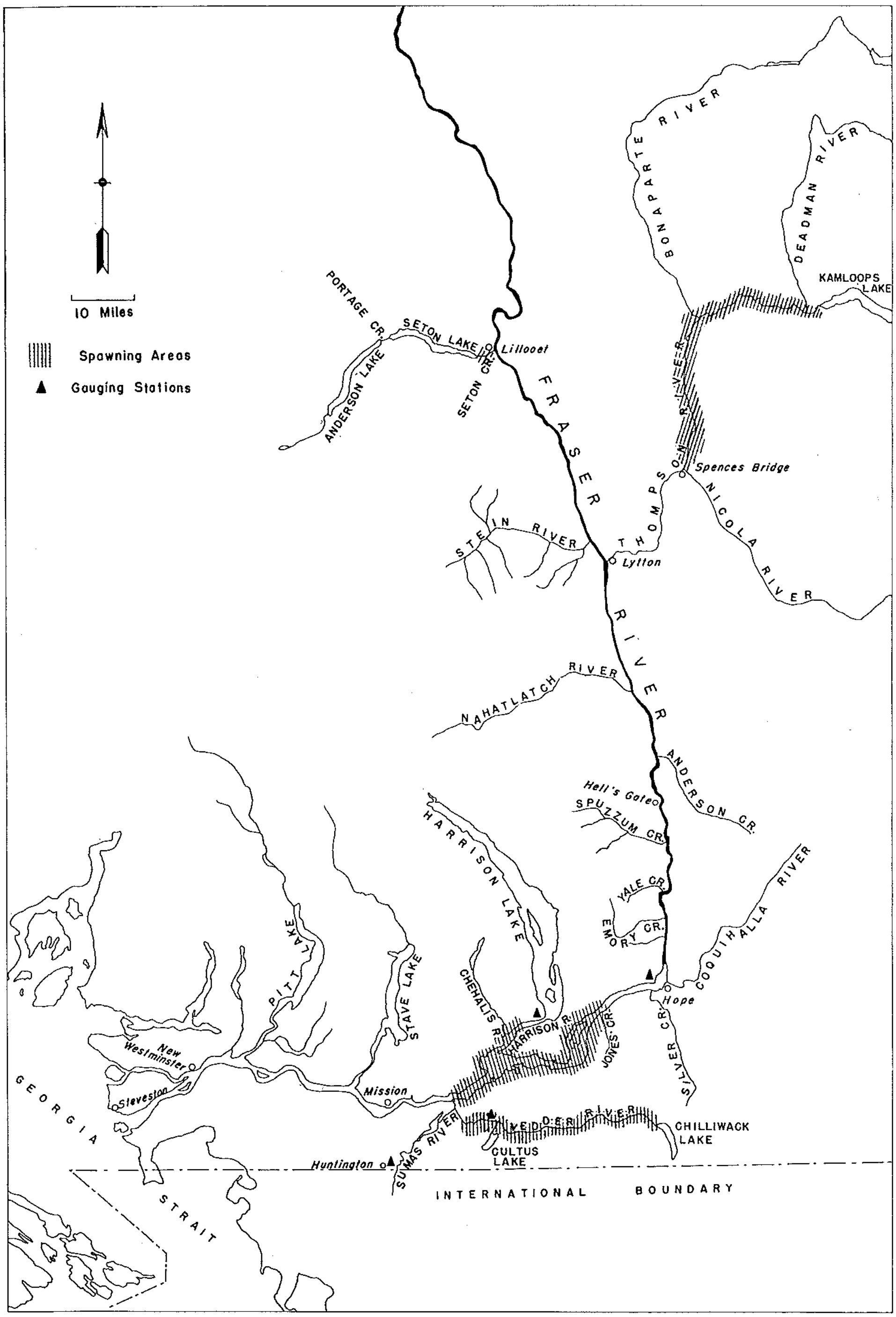

FIGURE 1—Major pink salmon spawning areas of the Fraser River system.

AREA OF OPERATION

The lower Fraser River is navigable for ocean-going vessels to New Westminster, for coastal vessels to Mission and for smaller vessels to Hope and Harrison Lake (FIGURE 1). Small-craft traffic, consisting mainly of tugs with barges and log rafts, is heavy, particularly below the confluence of Pitt River. A large fleet of salmon gill-net vessels operates periodically throughout most of the year in the area between Mission and the mouth of the Fraser.

Tidal influence in the Fraser River is gradually dissipated upstream and ends just above the confluence of the Vedder River about 10 miles above Mission (FIGURE 1). At low river flows (winter and early spring), considerable tidal fluctuation occurs at Mission. Baines (1952 & 1953) found a maximum tidal swing at Mission of 5 ft at a discharge of 34,000 cfs but negligible tidal swing at a discharge of 282,000 cfs. At low flows and maximum tidal swing, current reversals occur at Mission about 2½ hr after local low tide. At high flows, no current reversals occur anywhere in the main river channel.

To estimate the abundance of fry migrating from the Fraser River it was desirable to choose a sampling site below all the major spawning areas but above the area of heavy traffic and large tidal fluctuation. Thus the Mission site, situated about 50 miles from the river mouth, was a compromise, but this area also had

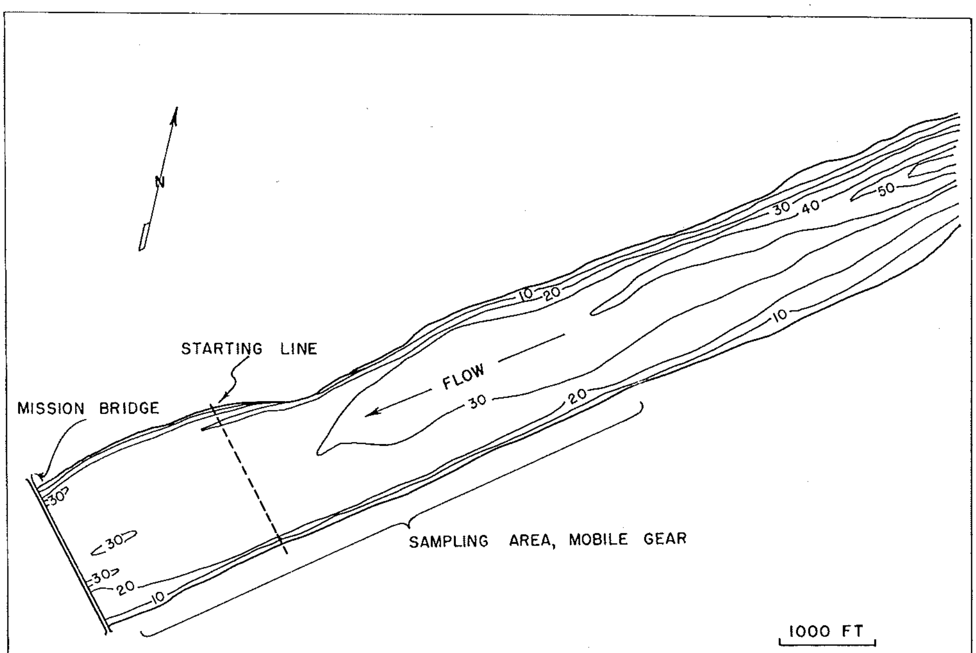

FIGURE 2—Channel topography of the Fraser River in the fry sampling area at Mission with depth contours at 10 ft intervals. Soundings, made by Department of Public Works in April, 1961, refer to local low water (0.5 ft, Geodetic).

some advantageous local features. The bridge crossing provided midstream anchorage for initial exploratory gear and bridge piers provide fixed reference points for the alignment of mobile gear. The straight channel section of reasonably uniform cross-section immediately above the bridge provided adequate space for the operation of mobile gear (FIGURE 2). The stream in this section is approximately 1500 ft wide and 30 ft deep with steep banks and a relatively flat bottom. Velocities during the fry migration period seldom exceed 4 ft/sec. The river is generally very turbid throughout most of the migration period.

Although a few pink salmon spawn in tributaries of the Fraser below Mission and fry from these areas would not be included in estimates of abundance, the numbers involved are negligible. In the years 1957, 1959, 1961 and 1963, the numbers of female spawners below Mission were estimated to be 3,856, 740, 2,735 and 714 respectively and amounted to 0.27, 0.12, 0.42 and 0.059 per cent of the total female spawners in the Fraser system.

SAMPLING GEAR AND OPERATING TECHNIQUES

Development of the various types of gear and of the methods used to sample the seaward migration of pink salmon in 1964 required considerable exploratory experimentation.

Development of Gear

Exploratory sampling of migrant pink fry in the lower Fraser was begun in 1960, using beach seines and a small conical net suspended by a boom in front of a powered skiff operated near the mouth of the river. Although catches were very small and sporadic, observations were sufficient to indicate that pink fry were present throughout the width of the river and were not concentrated near the shore.

In 1961, a year in which pinks were not present, exploratory sampling of salmon fry was initiated at Mission. A series of inclined-plane floating traps of 2 ft x 3 ft aperture were attached by steel lines to the bridge superstructure. The catches of fry (principally chum salmon) indicated that useful samples could be taken by this type of gear. However, during the early portion of the migration, when stream discharge was low, tidal fluctuations resulted in velocities which periodically were too low to retain fry and current reversals occasionally made the traps completely inoperative. Later in the season, high velocities and large floating debris again rendered operation of these traps extremely difficult and somewhat hazardous. Nevertheless sufficient information was gained during periods of adequate flow to indicate that fry were moving seaward in daylight and darkness and that their abundance varied considerably from hour to hour.

To circumvent the adverse effects of tidal fluctuations in velocity, one of the floating traps was fitted with larger pontoons and propelled in an upstream direction by a small fishing vessel at a constant speed relative to the water. From a series of velocity determinations, using a current meter in the mouth of the trap, a relationship was established between engine speed (rpm) and relative velocity. Observations of trap operating characteristics indicated that a relative velocity of about 2.5 ft/sec was most suitable. At higher velocities, fry tended to be damaged in the holding box, while at lower velocities fry tended to avoid or escape from the trap. The duration of each fishing period or "run" with the mobile gear was determined largely by the length of reasonably straight and non-turbulent stream channel available and by the amount of upstream and downstream displacement of the gear from a fixed starting line above the bridge (FIGURE 2). At low stream velocities, early in the season, the gear travelled a considerable distance upstream, while at high stream velocities the gear was displaced downstream. By trial and error a fishing period, or run, of 15 minutes duration was found to be a reasonable compromise of the various factors involved. At the end of each run the catch of each species was counted and released while the gear returned to the starting line.

The gear proved to be very maneuverable and large, floating debris could be avoided readily. Small debris which tended to obstruct the passage of water through the inclined plane of the trap could be removed easily between runs by briefly reversing the vessel and "back-flushing" the gear. Catches in this trap indicated that salmon fry were present in varying abundance across the full width of the river at all times of the day.

To explore the vertical distribution of fry, a weighted, conical net, 3 ft in diameter was suspended by a line and winch from a floating platform moored in the current below Mission bridge. To compare catches, a similar net was fixed at the surface and fished simultaneously. This gear was awkward to operate and at high stream velocities the net and line were deflected downstream by the current, making the true depth of the net difficult to ascertain, particularly in darkness. Nevertheless sufficient catches were made to indicate that salmon fry were present to depths of 12 ft in daylight and darkness. Chum fry, which were the most abundant species present in that year, tended to be concentrated near the surface.

From these preliminary experiments, sufficient information was gained to design more adequate gear for use in 1962, a cycle year for seaward migration of pink fry. A larger inclined-plane surface trap, with an effective frontal aperture 48 in. wide and 39 in. deep was fitted with pontoons and propelled by the motor vessel. With minor modifications, this trap has been the standard surface gear used in all subsequent years and is described in more detail below.

For the 1962 season, more effective "vertical" gear also was devised for fishing to depths of 12 ft. This gear was operated from a platform supported by two 16 ft barges. The bows of the barges protruded forward of the platform to leave an unobstructed well 3.5 ft wide and 4.5 ft long. An angle-iron frame, 15 ft long and 3 ft wide was pivoted near its upper end on a shaft mounted transversely across the open well. By means of a winched line from its upper end, this frame could be rotated so that it extended forward in a horizontal position above the water or was held vertically with its lower end 12 ft below the surface. In the horizontal position, square conical nets (32 x 32 in.) could be attached to the frame so that their upper edges were 0, 3, 6 or 9 ft below the surface when the frame was rotated to the vertical fishing position. To insure constant velocity, this gear was also propelled by the motor vessel and provided information on the vertical distribution of fry throughout most of the migration period in 1962. Although this gear fished well, it was difficult to service, particularly in rough water, and was superseded in 1964 by the gear described below.

Sampling Gear Used in 1964

With the experience gained from experiments in previous years, the equipment and field program in 1964 were designed to obtain some information on all the variables involved in estimating the abundance of migrating pink fry in the lower Fraser River. It was considered that remaining deficiencies in information would be confined largely to inherent errors in the procedures and that these would remain relatively constant from year to year. On this basis the numerical estimates would provide, at the very least, reliable indices of the biennial abundance of pink salmon fry.

MOBILE SURFACE GEAR

The mobile surface gear consisted essentially of a modified 4 ft x 4 ft "scoop net" or floating trap similar to those used for sampling juvenile salmon in fixed positions by various fishery agencies on the Pacific Coast for a number of years (State of Washington, 1956; Schoeneman, *et al.,* 1961). The trap was mounted well forward between two pontoons to insure unobstructed entry of fry at the bow and to provide ample working deck space at the stern (FIGURE 3). In the travelling or non-fishing position, the inclined plane was raised completely free of the water by the main winch. This prevented entry of fish or debris, enabled easy cleaning of the inclined plane and reduced drag. In the fishing position the forward end of the trap was suspended from a transverse beam, the ends of which rested on the pontoons. This arrangement permitted rapid lowering of the trap to a standard fishing position. The height of the after end of the trap, and thus the amount of water flowing from the inclined plane into the live-box, could be controlled precisely by a pair of small winches on the rear deck. In the fishing (lowered) position the effective frontal aperture of the trap was 48 in. wide and 40 in. deep or 13.33 sq ft in area.

The propelling vessel was a 28 ft gill net boat with a 9 ft beam, powered by a 280 hp gasoline engine and fitted with a depth sounder and hydraulic steering controls. The mobile gear was fixed alongside the port side of the vessel by means of lines and rubber fenders with the forward end of the trap slightly ahead of the boat stem. At the end of each 15-minute run, fry were removed from the live-box with a dip-net, counted by species and released into the river. Duplicate records were kept of time, weather conditions, river section, distance travelled, engine speed and catches.

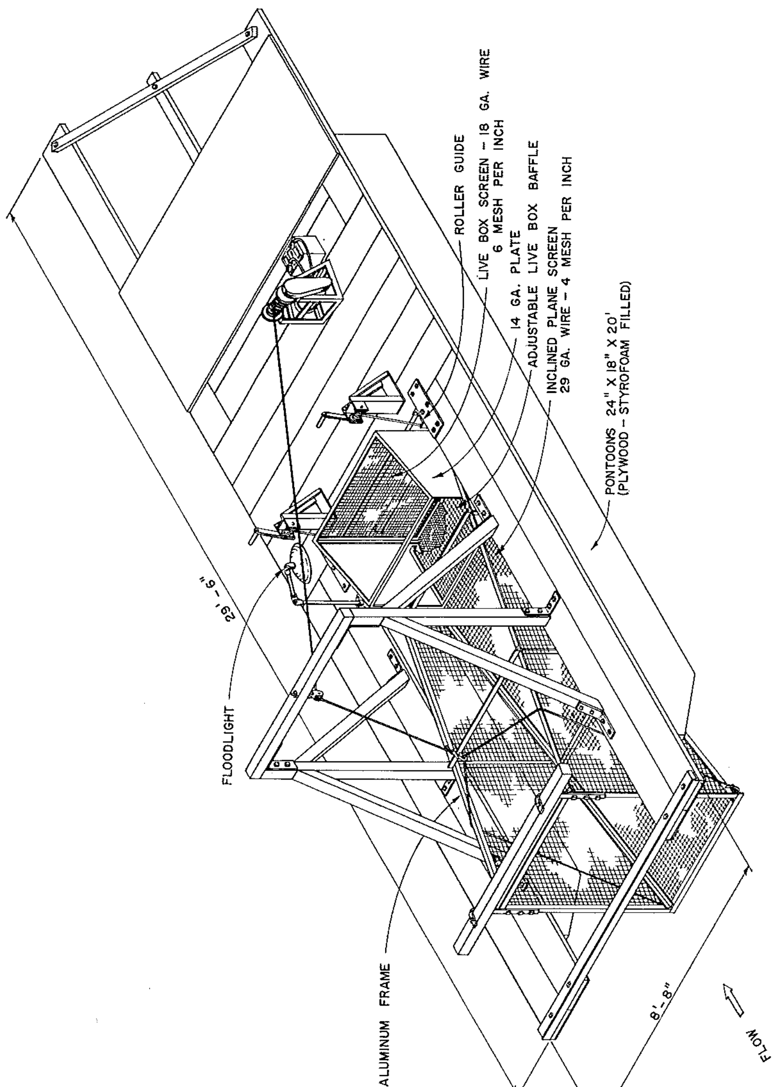

FIGURE 3—Isometric sketch of the mobile surface fry trap used in the Fraser River in 1964.

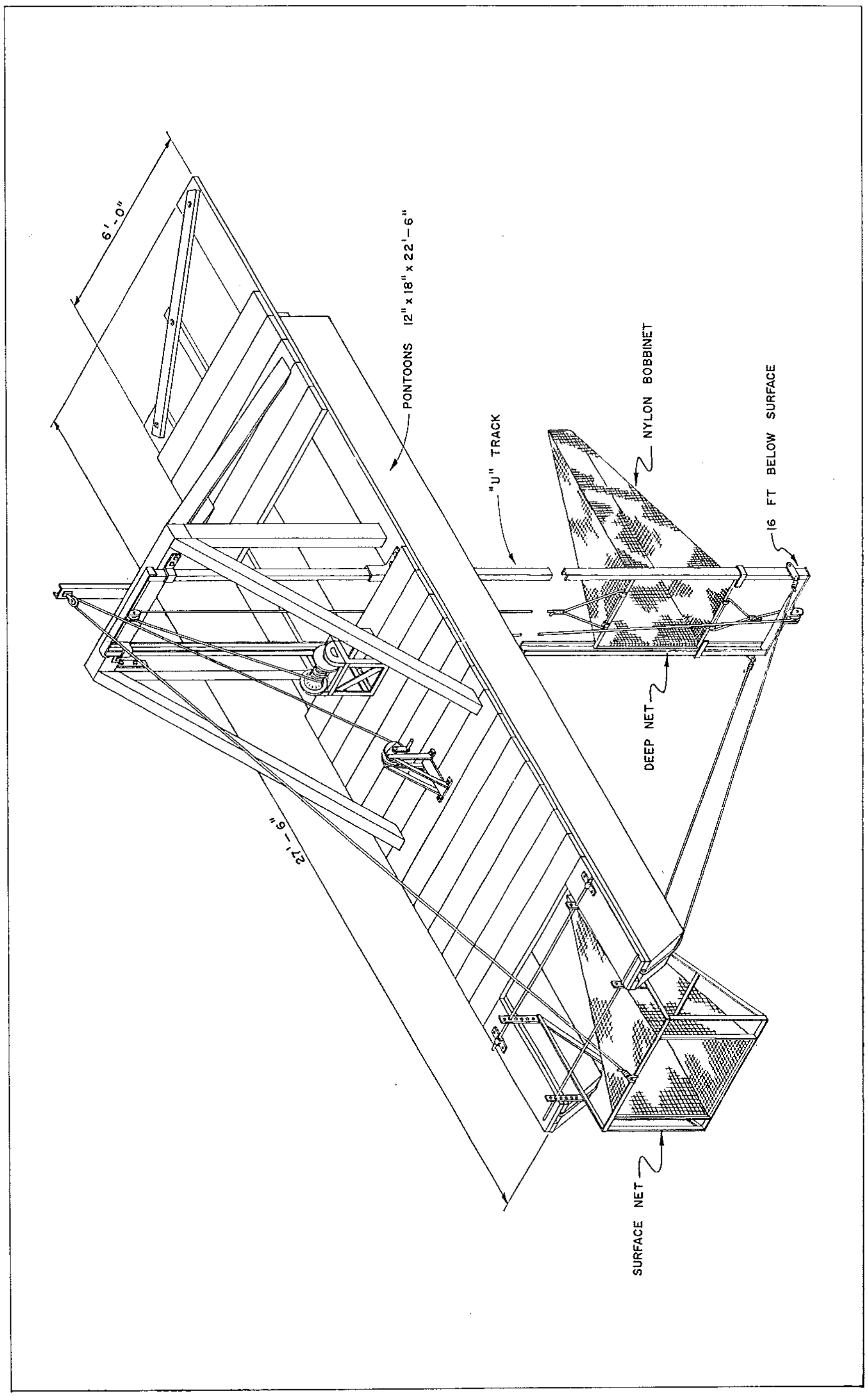

FIGURE 4—Isometric sketch of the mobile vertical gear used in the Fraser River in 1964.

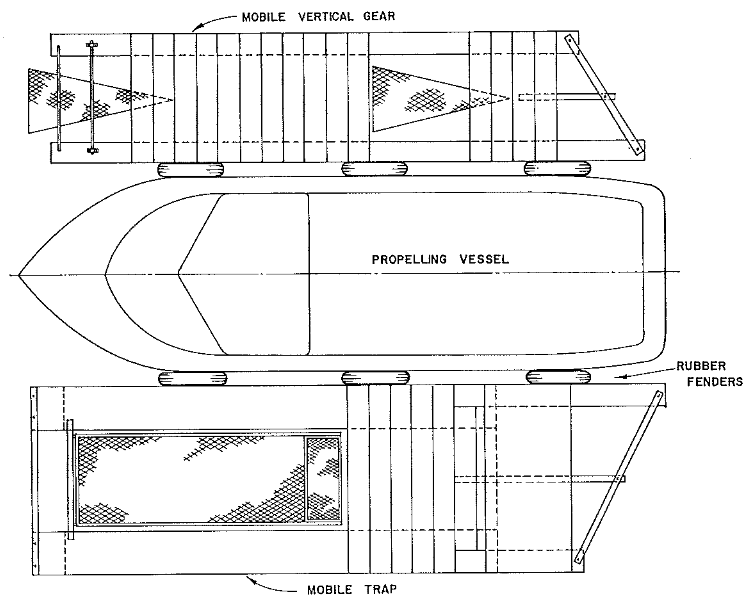

FIGURE 5—Diagrammatic plan view of propelling vessel and mobile gears in operating configuration.

MOBILE VERTICAL GEAR

The mobile vertical gear used in 1964 was similarly mounted on pontoons (FIGURE 4) and fixed alongside the starboard side of the vessel when in operation (FIGURE 5). The actual fishing gear consisted of square-mouthed, wedge-shaped nets about 5 ft long constructed of nylon bobbinet. The forward surface net (36 in. wide and 40 in. deep) was fished continuously in a fixed position but its frame could be rotated upward and inboard to remove the catch. The deep net (36x36 in.) was fixed in a frame which was free to slide vertically inside a U track frame extending 16 ft below the surface. This net could be set at any desired depth within the limits of the track, or raised to remove the catch, by a continuous wire line which passed through upper and lower pulleys to a winch on the deck. Because of anticipated interference by the forward net, the deep net was not fished at positions shallower than 7.5 ft (center of net) and, as will be shown later, even at this depth, catches were not representative because of interference by the forward net. Entire catches in these nets were placed in tubs of water before being counted by species and released into the river.

The starting positions for the mobile gear, in relation to the Mission bridge piers are shown in FIGURE 6.

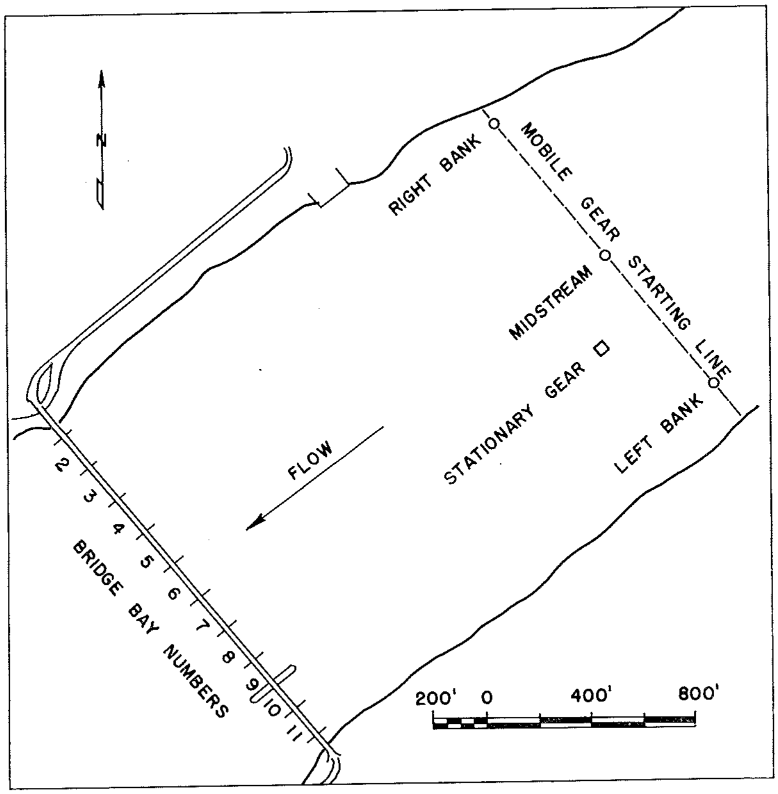

FIGURE 6—Fishing positions of mobile and stationary fry sampling gear in the Fraser River at Mission in 1964.

STATIONARY VERTICAL GEAR

The gear described thus far was found adequate for sampling to depths of 13.5 ft but, since pink salmon fry had been found in 1962 to be as abundant at this depth as they were at the surface, some supplementary gear was devised in 1964 to extend the information on pink fry to greater depths.

Modification of the mobile vertical gear to sample at greater depths was considered impractical because of the great strains which would be imposed on any further extension of the net frame. Impact with the uneven bottom of the stream channel and with sunken logs would also cause serious damage to any such gear. As an alternative, a stationary gear was designed which could be fished at any depth from the surface to the bottom and, by fishing during the same periods, would supplement the information obtained from the mobile vertical gear.

The stationary vertical gear was operated from a platform supported by two 16 ft barges (FIGURE 7). At the after end a small, unobstructed well was left between the barges to facilitate the lowering and retrieval of a square (32 x 32 in.), conical net. A gantry, 5 ft in height, was placed over this well to support a small pulley.

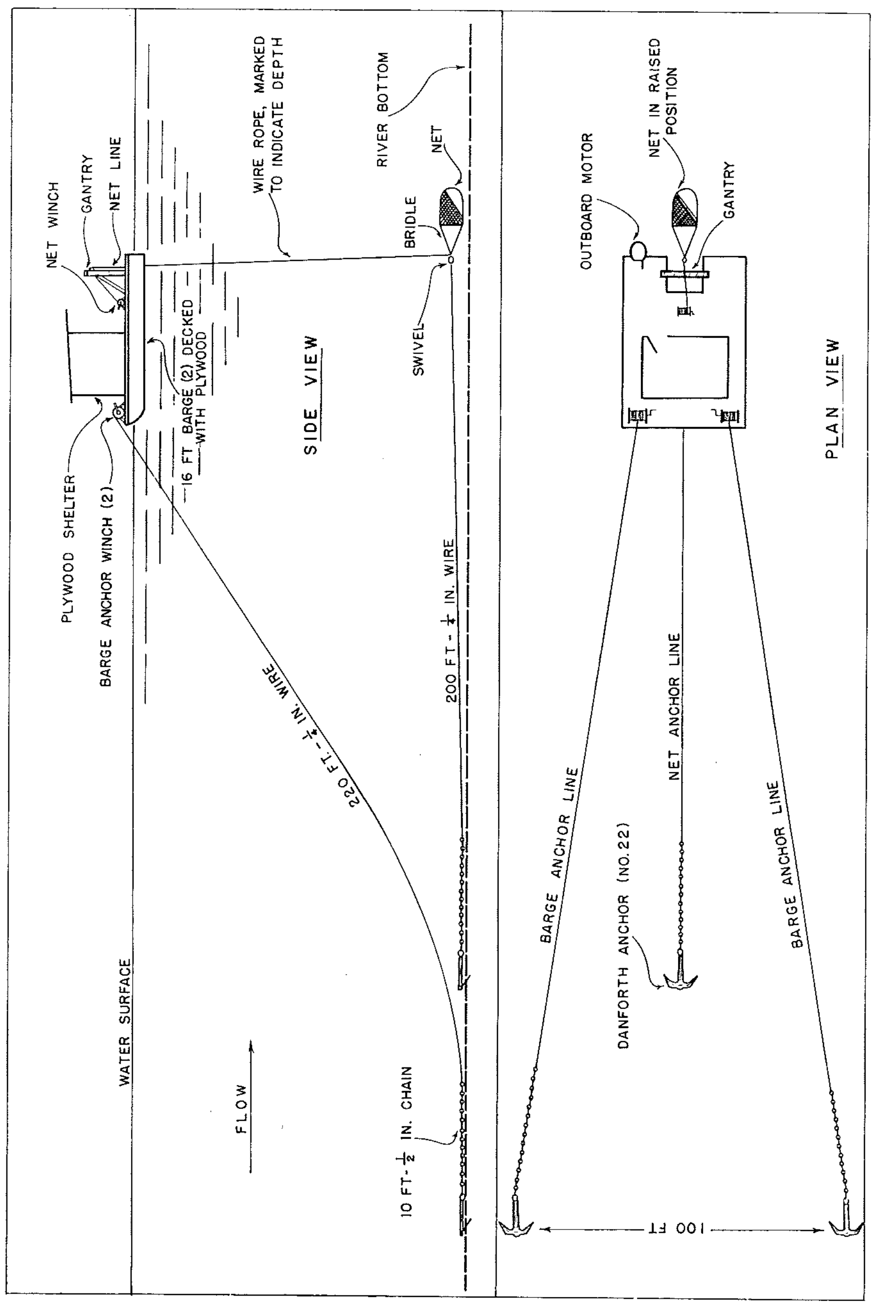

FIGURE 7—Diagrammatic plan and side views of stationary vertical gear used in the Fraser River in 1964.

The line supporting and controlling the height of the net passed from the net bridle up through the pulley on the gantry and thence to a hand winch fixed on the deck immediately forward of the well. Anchor winches were also fixed on each forward corner of the platform. In operation, the platform was moored in a suitable location by means of wire lines extending upstream from the forward winches to anchors previously placed in the river bottom. The longitudinal position of the net was also fixed by a long wire line to an anchor in the bottom upstream. Thus the net was held in the current by its anchor line but could be suspended at any height above the bottom or raised easily to the surface by the vertical net line. Within the limitations set by the velocities available in the stream, this gear fished well and could be handled and serviced readily, although high winds or heavy floating debris occasionally made it necessary to move the gear to a sheltered position on shore. When not in use, the wire anchor lines were allowed to lie on the bottom with the free ends attached by a light nylon line to a spar buoy at the surface.

The stationary gear was operated regularly from March 2 to May 8 at a position 1500 ft above Bay 8 of Mission bridge (FIGURE 6). The depth of water at this location varied between 25 and 30 ft. By May 8, entrained debris had greatly reduced the efficiency of the net, particularly at the bottom fishing position, and floating logs in the rising river rendered operation in darkness somewhat dangerous. However, by this date sufficient information had been obtained on the distribution of fry at depth.

Sampling Procedures

The basic purpose of the estuarial sampling program was to obtain a quantitative estimate of the total number of pink salmon fry migrating from the Fraser River to the sea. Because of some inherent problems in sampling, it was expected that this estimate would include errors which could not be quantified adequately. However, providing these errors could be assumed to be reasonably constant from year to year, the estimates would represent adequately the relative abundance of succeeding biennial pink fry migrations. A secondary aim of the program was to obtain estimates of daily abundance so that various portions of the migration might be related to the independently estimated timing and abundance of pink fry migrations from some major upstream tributaries. Since the estimate of total abundance could be obtained by summation of daily abundance, the primary data required were considered to be the numbers of pink fry migrating past the sampling site daily.

The gear which could be operated most consistently and with a minimum of interruption was the mobile surface trap (FIGURE 3) and therefore the catches in this gear were used as the basic measure of fry abundance. With the engine speed of the propelling vessel maintained at a constant speed of 800 rpm, the velocity of the water in the trap was also reasonably constant (averaging 2.61 ft/sec during the season — TABLE 1). By increasing the engine speed to 1100 rpm, the same velocity of water could be maintained in the trap when the mobile vertical gear was simultaneously propelled by the vessel. The trap (and vertical gear) was

TABLE 1—Velocity determinations inside the mobile trap mouth and 20 in. below the water surface during 1964.

Date	Velocity (ft/sec)
March 9	2.68
12	2.70
19	2.64
26	2.62
April 2	2.62
9	2.66
16	2.55
23	2.59
30	2.54
May 1	2.62
7	2.57
8	2.59
14	2.62
15	2.65
26	2.57
Mean	2.61
Standard Deviation	$\pm$ 0.05

always started from a point 2,000 ft above Mission bridge (FIGURE 6) and operated for 15 minutes before the catch was recorded and the gear returned to the starting position. Thus, except for minor random fluctuation due to variable wind resistance, the trap retained fish from a constant volume of water in each 15-minute run. Since the effective frontal area of the trap was 13.333 sq ft (48 in. wide and 40 in. deep), the volume of water sampled in each run was (13.333 sq ft x 2.61 ft/sec x 900 sec) or 31,319 cu ft.

To obtain information on variability in the abundance of fry across the width of the river (lateral distribution) the stream channel was divided into three hypothetical longitudinal sections without precise boundaries and designated as Right Bank, Midstream and Left Bank sections. Successive 15-minute runs by the mobile trap were continuously alternated between each of these sections in turn by operating directly upstream from the appropriate bridge piers (FIGURE 6). To provide more detailed information on the lateral distribution of fry within these three main sections, they were further subdivided into four longitudinal subsections by operating the trap upstream from successive bridge piers in turn (e.g., piers 2, 3, 4 and 5 in the Right Bank section — FIGURE 6).

Except for brief interruptions due to high winds, fog or large sub-surface debris, the mobile trap was routinely operated for an 8-hr period between 0500 and 1300 hours daily except on Sundays. The trap was also operated for this 8-hr period on Sundays during the peak of the migration when large day-to-day changes in the abundance of fry might be expected. The standard procedure was to fish for 15 min in each of the main sections in turn, as described above. However, on Tuesday and Friday of each week, the 8-hr period was devoted to fishing the subsections within a single main section in turn; i.e., Tuesday — Left Bank subsections, Friday — Midstream subsections, Tuesday — Right Bank subsections, Friday — Left Bank subsections, etc.

Diurnal changes in the abundance of fry (i.e., changes during 24 hr periods) were monitored by operating the mobile trap continuously for 24 hr periods twice each week. These 24 hr periods began at 0500 on Mondays and Thursdays. Thus the mobile trap was routinely operated for a total of 80 hr each week.

The mobile vertical gear was operated simultaneously with the mobile trap during the routine, twice weekly 24 hr periods beginning at 0500 on Mondays and Thursdays. Thus, on these days, the vertical gear was fished continuously for 15 min periods in each of the main longitudinal river sections in turn. The movable (deep) net was routinely fished with its center at depths of 7.5, 10.5 and 13.5 ft, the procedure being to sample all three sections at each depth in turn. Thus, for example, the net was fished at 7.5 ft for 15 min in each of the three sections (Right Bank, Midstream and Left Bank), then fished at 10.5 ft in each of the three sections and finally at 13.5 ft, before repeating the cycle again. The surface net (with its center at a depth of 1.5 ft) was fished in all 15 min runs. Operated in this manner the mobile vertical gear provided information on the distribution of fry to depths of 13.5 ft, on diurnal changes in this distribution and on differences laterally across the width of the stream.

Supplementary information on the vertical distribution of fry at depths below 13.5 ft was obtained from operation of the stationary gear (Figure 7). This gear was operated for two 24 hr periods each week coincident with the periods of operation of the mobile vertical gear. Depths of 13.5, 19.5 and 25.5 ft were fished successively, each for one-hour periods throughout the day. The upper depth (13.5 ft) coincided with the deepest fishing position of the mobile gear while the lowest depth (25.5 ft) was very near the bottom during the early portion of the season. Fishing time at each depth was reduced from one hour to one-half hour in the latter portion of the season when fibrous debris tended to clog the net and reduce its efficiency. Water velocity at the depth of the net was measured with a current meter at the beginning and end of each fishing period. At least once a week, velocities were also measured inside and outside the net at the beginning and end of a normal fishing period (one hour or one-half hour) with the net in a position one foot below the surface.

The stationary gear was also used as a working platform for obtaining additional information on the influence of tidal swing on the vertical distribution of velocity in the stream channel. From March 4 to May 6 about 8 hours per week were devoted to measuring the velocity and direction of flow at 5 ft intervals between a depth of 2 ft and the bottom. Information on turbidity was also obtained by measuring transparency at least twice a week with a Secchi disk.

PERTINENT FEATURES OF STREAM FLOW AND FRY BEHAVIOR

Certain variable features of the flow of the Fraser River at Mission and some behavioral characteristics of migrating pink fry in this area are either essential to an analysis of fry abundance data or are necessary for interpretation of these data.

Stream Discharge

Due to the difficulties of measuring discharge in a stream section subject to tidal influence, daily discharge records are not available for the Fraser River at Mission. However, gauging stations are maintained by the Water Resources Branch, Department of Northern Affairs and National Resources on the Fraser at Hope (45 miles above Mission) and on the Harrison and Vedder Rivers, the two principal tributaries of the Fraser between Hope and Mission. These gauging stations provide records of daily discharge from over 99% of the Fraser drainage area above Mission. However, the 731 sq miles of drainage area not accounted for are situated in the mild coastal region where precipitation is relatively heavy and, during the early spring months, while the run-off from the interior portion of the Fraser drainage area remains near its winter minimum, the run-off from this local drainage area can contribute significantly to the total discharge at Mission.

Run-off from the local drainage area was estimated from the known discharge of adjacent streams draining similar terrain. The local area included 434 sq miles of mountainous terrain and 297 sq miles of lowland valley bottoms. Run-off characteristics of the mountainous portion were assumed to be similar to those of the Vedder River basin (i.e., daily discharge per sq mile would be the same in both areas). Similarly, run-off characteristics of the lowland portion were assumed to be similar to those of the Sumas River basin (TABLE 2). The total daily discharge from the local drainage area, estimated in this manner, was added to the measured discharge of the Fraser at Hope, the Harrison River and the Vedder River to provide an estimate of the daily discharge at Mission (TABLE 3).

Velocity

A measure of the seasonal changes in velocity of the river at Mission may be derived from data arising from the operation of the mobile gear. During each 15 min run this gear was propelled from a fixed starting line in an upstream direction and at the end of each run the distance travelled by the gear relative to the shore (upstream or downstream) was estimated to the nearest 50 ft by visual alignment with markers set at 100 ft intervals along the left bank. Since the gear was propelled at a constant velocity relative to the water it was possible to estimate surface stream velocity from the distance travelled per 15 min run.

Early in the season, when river levels were low, the semidiurnal tidal swing caused relatively large hour-to-hour changes in velocities at Mission (FIGURE 8). To obtain a measure of seasonal changes in velocity, it was necessary to damp out this short term variability by using the mean distance travelled per 15 min run during 24 hr periods of continuous gear operation. During these 24 hr periods, 20

TABLE 2—Calculation of local run-off in the Mission area in 1964. (Drainage area in square miles is indicated in parentheses.)

Date	Vedder R. (484)	Mountainous Area (434)	Sumas R. (57.6)	Lowland Area (297)	Total (731)
Feb. 22	1,000	897	139	717	1,610
23	1,000	897	131	675	1,570
24	1,000	897	129	665	1,560
25	1,000	897	118	608	1,500
26	1,000	897	114	588	1,490
27	1,000	897	110	567	1,460
28	1,000	897	108	557	1,450
29	1,000	897	108	557	1,450
March 1	1,090	977	125	645	1,620
2	1,090	977	130	670	1,650
3	1,060	950	120	619	1,570
4	1,090	977	140	722	1,700
5	1,280	1,148	436	2,248	3,400
6	1,220	1,094	504	2,599	3,690
7	1,150	1,031	315	1,624	2,660
8	1,110	995	245	1,263	2,260
9	1,090	977	213	1,098	2,070
10	1,070	959	189	974	1,930
11	1,090	977	177	913	1,890
12	1,070	959	168	866	1,830
13	1,110	995	156	804	1,800
14	1,150	1,031	168	866	1,900
15	1,270	1,139	217	1,119	2,260
16	1,230	1,103	217	1,119	2,220
17	1,400	1,255	233	1,201	2,460
18	1,380	1,237	274	1,413	2,650
19	1,350	1,211	222	1,145	2,360
20	1,280	1,148	184	949	2,100
21	1,230	1,103	170	877	1,980
22	1,190	1,067	154	794	1,860
23	1,130	1,013	135	696	1,710
24	1,090	977	122	629	1,610
25	1,080	968	119	614	1,580
26	1,060	950	125	644	1,590
27	1,030	924	117	603	1,530
28	994	891	110	567	1,460
29	1,000	897	105	541	1,440
30	1,170	1,049	103	531	1,580
31	1,500	1,345	121	624	1,970
April 1	1,810	1,623	308	1,588	3,210
2	1,650	1,480	314	1,619	3,100
3	1,530	1,372	200	1,031	2,400
4	1,540	1,381	170	877	2,260
5	1,550	1,390	184	949	2,340
6	1,560	1,400	171	882	2,280
7	1,580	1,417	151	779	2,200
8	1,600	1,435	137	706	2,140
9	1,630	1,462	126	650	2,110
10	1,660	1,489	125	644	2,130
11	1,690	1,515	130	670	2,180
12	1,710	1,533	126	650	2,180

TABLE 2—Continued.

Date		Vedder R. (484)	Mountainous Area (434)	Sumas R. (57.6)	Lowland Area (297)	Total (731)
April	13	1,660	1,489	122	629	2,120
	14	1,800	1,614	138	712	2,330
	15	2,050	1,838	217	1,119	2,960
	16	1,830	1,641	243	1,253	2,890
	17	1,720	1,542	210	1,083	2,630
	18	1,680	1,506	171	882	2,390
	19	1,620	1,453	146	753	2,210
	20	1,500	1,345	130	670	2,020
	21	1,420	1,273	122	619	1,890
	22	1,770	1,587	183	944	2,530
	23	1,570	1,408	206	1,062	2,470
	24	1,510	1,354	160	825	2,180
	25	1,570	1,408	134	691	2,100
	26	1,550	1,390	122	629	2,020
	27	1,520	1,363	113	583	1,950
	28	1,470	1,318	113	583	1,900
	29	1,510	1,354	105	541	1,900
	30	1,450	1,300	101	521	1,820
May	1	1,420	1,273	95	490	1,760
	2	1,390	1,246	93.4	481	1,730
	3	1,350	1,211	89.5	461	1,670
	4	1,420	1,273	85.0	438	1,710
	5	1,420	1,273	85.8	442	1,710
	6	1,390	1,246	82.8	427	1,670
	7	1,420	1,273	77.9	402	1,680
	8	1,570	1,408	74.6	385	1,790
	9	1,920	1,722	77.9	402	2,120
	10	2,320	2,080	95.0	490	2,570
	11	2,050	1,838	85.0	438	2,280
	12	2,140	1,919	80.0	412	2,330
	13	2,150	1,928	96.6	498	2,430
	14	2,000	1,793	90.2	465	2,260
	15	1,980	1,775	77.2	398	2,170
	16	2,050	1,838	72.6	374	2,210
	17	2,600	2,331	70.0	361	2,690
	18	2,920	2,618	67.4	347	2,970
	19	3,670	3,291	66.8	344	3,630
	20	4,460	3,999	64.8	334	4,330
	21	4,410	3,954	77.9	402	4,360
	22	3,960	3,551	107	552	4,100
	23	3,380	3,031	129	665	3,700
	24	3,220	2,887	134	691	3,580
	25	2,840	2,547	132	681	3,230
	26	2,780	2,493	103	531	3,020
	27	3,450	3,094	88.8	458	3,550
	28	4,740	4,250	79.3	409	4,460
	29	5,500	4,932	75.2	388	5,320
	30	6,790	6,089	71.3	368	6,460
	31	7,800	6,994	68.7	354	7,350
June	1	8,570	7,685	64.8	334	8,020
	2	8,550	7,667	68.0	351	8,020
	3	7,570	6,789	66.8	344	7,130
	4	7,710	6,913	68.0	351	7,260
	5	8,620	7,730	77.9	402	8,130

TABLE 3—Estimation of Fraser River discharge at Mission from February 22 to June 5, 1964 (in cfs)[a].

Date		Fraser R. at Hope	Harrison River	Vedder River	Local Runoff	Total at Mission
Feb.	22	28,800	5,920	1,000[b]	1,610	37,330
	23	29,600	5,660	1,000[b]	1,570	37,830
	24	29,200	5,610	1,000[b]	1,560	37,370
	25	29,200	5,360	1,000[b]	1,500	37,060
	26	28,900	5,210	1,000[b]	1,490	36,600
	27	28,700	5,040	1,000[b]	1,460	36,200
	28	28,500	4,830	1,000[b]	1,450	35,780
	29	28,200	4,810	1,000[b]	1,450	35,460
March	1	28,300	4,880	1,090	1,620	35,890
	2	27,900	4,950	1,090	1,650	35,590
	3	27,800	4,880	1,060	1,570	35,310
	4	27,800	4,830	1,090	1,700	35,420
	5	27,600	4,920	1,280	3,400	37,200
	6	27,700	4,920	1,220	3,690	37,530
	7	26,800	4,810	1,150	2,660	35,420
	8	26,800	4,660	1,110	2,260	34,830
	9	26,200	4,680	1,090	2,070	34,040
	10	26,000	4,660	1,070	1,930	33,660
	11	26,200	4,790	1,090	1,890	33,970
	12	26,600	4,900	1,070	1,830	34,400
	13	26,600	4,920	1,110	1,800	34,430
	14	26,600	5,040	1,150	1,900	34,690
	15	26,800	5,180	1,270	2,260	35,510
	16	27,300	5,280	1,230	2,220	36,030
	17	27,500	5,280	1,400	2,460	36,640
	18	27,900	5,160	1,380	2,650	37,090
	19	27,300	5,230	1,350	2,360	36,240
	20	26,800	5,160	1,280	2,100	35,340
	21	26,200	5,040	1,230	1,980	34,450
	22	26,500	4,970	1,190	1,860	34,520
	23	26,000	4,880	1,130	1,710	33,720
	24	25,600	4,590	1,090	1,610	32,890
	25	24,900	4,410	1,080	1,580	31,970
	26	24,800	4,310	1,060	1,590	31,760
	27	25,600	4,260	1,030	1,530	30,890
	28	25,700	4,160	994	1,460	32,310
	29	25,600	4,060	1,000	1,440	32,100
	30	25,600	3,990	1,170	1,580	32,340
	31	27,000	4,100	1,500	1,970	34,570
April	1	30,100	4,330	1,810	3,210	39,450
	2	29,500	4,610	1,650	3,100	38,860
	3	30,600	4,700	1,530	2,400	39,230
	4	32,000	4,770	1,540	2,260	40,570
	5	33,500	4,920	1,550	2,340	42,310
	6	35,200	4,970	1,560	2,280	44,010
	7	38,800	5,040	1,580	2,200	47,620
	8	42,900	5,140	1,600	2,140	51,780
	9	45,800	5,360	1,630	2,110	54,900
	10	47,200	5,480	1,660	2,130	56,470
	11	50,700	5,820	1,690	2,180	60,390
	12	51,600	6,080	1,710	2,180	61,570
	13	54,800	6,240	1,660	2,120	64,820
	14	54,800	6,520	1,800	2,330	65,450
	15	58,700	6,770	2,050	2,960	70,480

TABLE 3—Continued.

Date	Fraser R. at Hope	Harrison River	Vedder River	Local Runoff	Total at Mission
April 16	57,900	7,010	1,830	2,890	69,630
17	56,800	7,040	1,720	2,630	68,190
18	55,600	6,950	1,680	2,390	66,620
19	54,900	6,800	1,620	2,210	65,530
20	54,900	6,740	1,500	2,020	65,160
21	54,000	6,720	1,420	1,890	64,030
22	54,800	6,920	1,770	2,530	66,020
23	55,900	6,980	1,570	2,470	66,920
24	56,600	6,860	1,510	2,180	67,150
25	57,300	6,830	1,570	2,100	67,800
26	58,400	6,830	1,550	2,020	68,800
27	59,600	6,890	1,520	1,950	69,960
28	61,400	6,890	1,470	1,900	71,660
29	61,500	6,800	1,510	1,900	71,710
30	62,100	6,890	1,450	1,820	72,260
May 1	63,200	6,740	1,420	1,760	73,120
2	62,900	6,740	1,390	1,730	72,760
3	64,700	6,600	1,350	1,670	74,320
4	68,600	6,520	1,420	1,710	78,250
5	70,400	6,660	1,420	1,710	80,190
6	75,600	6,660	1,390	1,670	85,320
7	85,000	6,690	1,420	1 680	94,790
8	95,100	6,830	1,570	1,790	105,290
9	114,000	7,190	1,920	2,120	125,230
10	120,000	7,940	2,320	2,570	132,830
11	131,000	8,630	2,050	2,280	143,960
12	147,000	9,260	2,140	2,330	160,730
13	148,000	9,860	2,150	2,430	162,440
14	144,000	10,300	2,000	2,260	158,560
15	143,000	10,500	1,980	2,170	157,650
16	148,000	10,600	2,050	2,210	162,860
17	146,000	10,800	2 600	2,690	162,090
18	144,000	11,600	2,920	2,970	161,490
19	147,000	12,500	3,670	3,630	166,800
20	156,000	13,400	4,460	4,330	178,190
21	168,000	14,500	4,410	4,360	191,270
22	182,000	15,100	3,960	4,100	205,160
23	186,000	15,100	3,380	3,700	208,180
24	193,000	15,000	3,220	3,580	214,800
25	192,000	15,000	2,840	3,230	213,070
26	193,000	14,800	2,780	3,020	213,600
27	192,000	15,100	3,450	3,550	214,100
28	193,000	16,100	4,740	4,460	218,300
29	198,000	17,800	5,500	5,320	226,620
30	208,000	20,300	6,790	6,460	241,550
31	234,000	22,600	7,800	7,350	271,750
June 1	258,000	24,500	8,570	8,020	299,090
2	290,000	31,500	8,550	8,020	338,070
3	312,000	27,700	7,570	7,130	354,400
4	325,000	29,300	7,710	7,260	369,270
5	345,000	30,000	8,620	8,130	391,750

[a] Based on preliminary discharge tabulations kindly provided by the District Engineer, Water Resources Branch, Vancouver, B. C.
[b] Estimated by extrapolation.

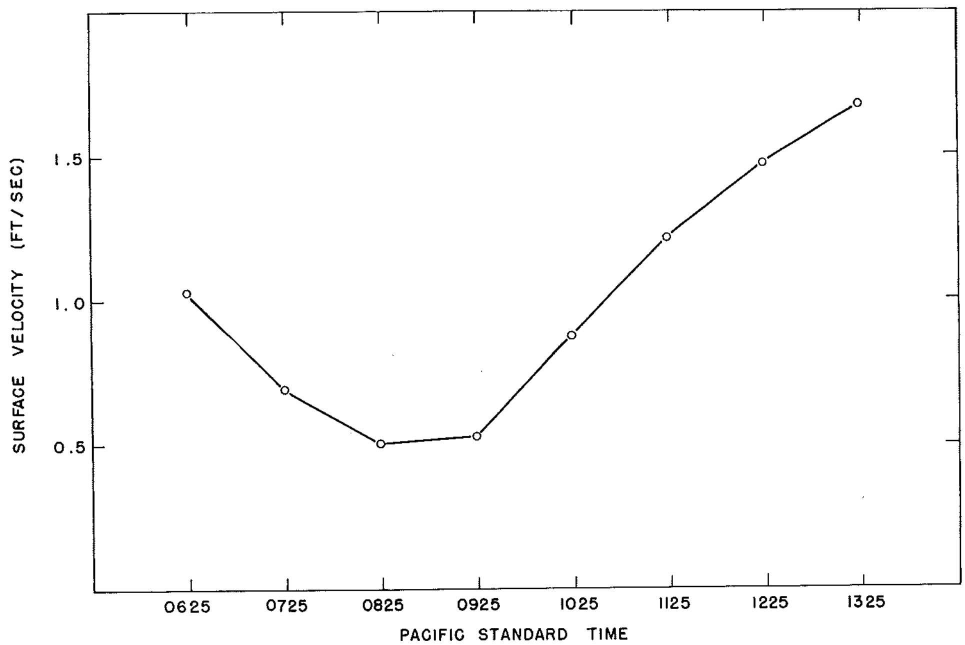

FIGURE 8—Changes in velocity of the Fraser River at Mission as determined with a current meter during a 7-hr period on April 1, 1964. (At the Fraser mouth, high tide occurred at 0720 and low tide at 1413.)

to 25 runs were usually made in each of the three longitudinal sections routinely sampled. Thus velocities estimated on this basis (TABLE 4) can be considered as gross averages for the river surface as a whole.

The relationship of velocity with depth was approximated from weekly series of velocity determinations made with a current meter from the stationary gear between March 4 and May 8. On one day each week several series of determinations were made at intervals of 5 ft between depths of 2 ft and the bottom. For each day, after eliminating those series which were unduly affected by rapid tidal changes, the mean velocity was computed for each depth interval and expressed as a fraction of the velocity at the surface (2 ft). A curve was visually fitted to these composite data (FIGURE 9).

The effects of reverse flow on the velocity profile were investigated during several periods of maximum tidal influence early in the season. During these periods, while making the routine velocity determinations at 5 ft intervals, the direction of flow at these intervals was also determined by observing the set of a small, weighted drogue suspended on a line. These observations indicated that, except for insignificant anomalies resulting from minor turbulence as velocities approached zero, the direction of flow was always consistent from the surface to the bottom, i.e., if surface flow was upstream, flow at all depths was upstream and if surface flow was downstream, flow at all depths was downstream.

TABLE 4—Estimates of mean surface velocity of the Fraser River at Mission at semiweekly intervals from February 24 to June 2 in 1964. (Based in the upstream distance travelled—"D"—by the mobile gear during 15 min at 2.61 ft/sec.)

Date	D Mean Upstream Travel in 15 Minutes (ft)	Mean Velocity $\left(\frac{2349\text{-D}}{2349}\right)$ x 2.61 (ft/sec)
Feb. 24	+1,658	0.77
27	+1,609	0.82
March 2	+1,619	0.81
5	+1,469	0.98
9	+1,553	0.88
12	+1,558	0.88
16	+1,464	0.98
19	+1,365	1.09
23	+1,416	1.04
26	+1,597	0.84
30	+1,472	0.97
April 2	+1,384	1.07
6	+1,256	1.21
9	+1,004	1.49
13	+ 954	1.55
16	+ 840	1.68
20	+ 862	1.65
23	+ 826	1.69
27	+ 982	1.52
30	+ 797	1.72
May 4	+ 944	1.56
7	+ 314	2.26
11	— 485	3.15
14	— 791	3.49
18	— 838	3.54
22	— 752	3.45
26	— 995	3.72
29	—1,087	3.82
June 2	—1,250	4.00

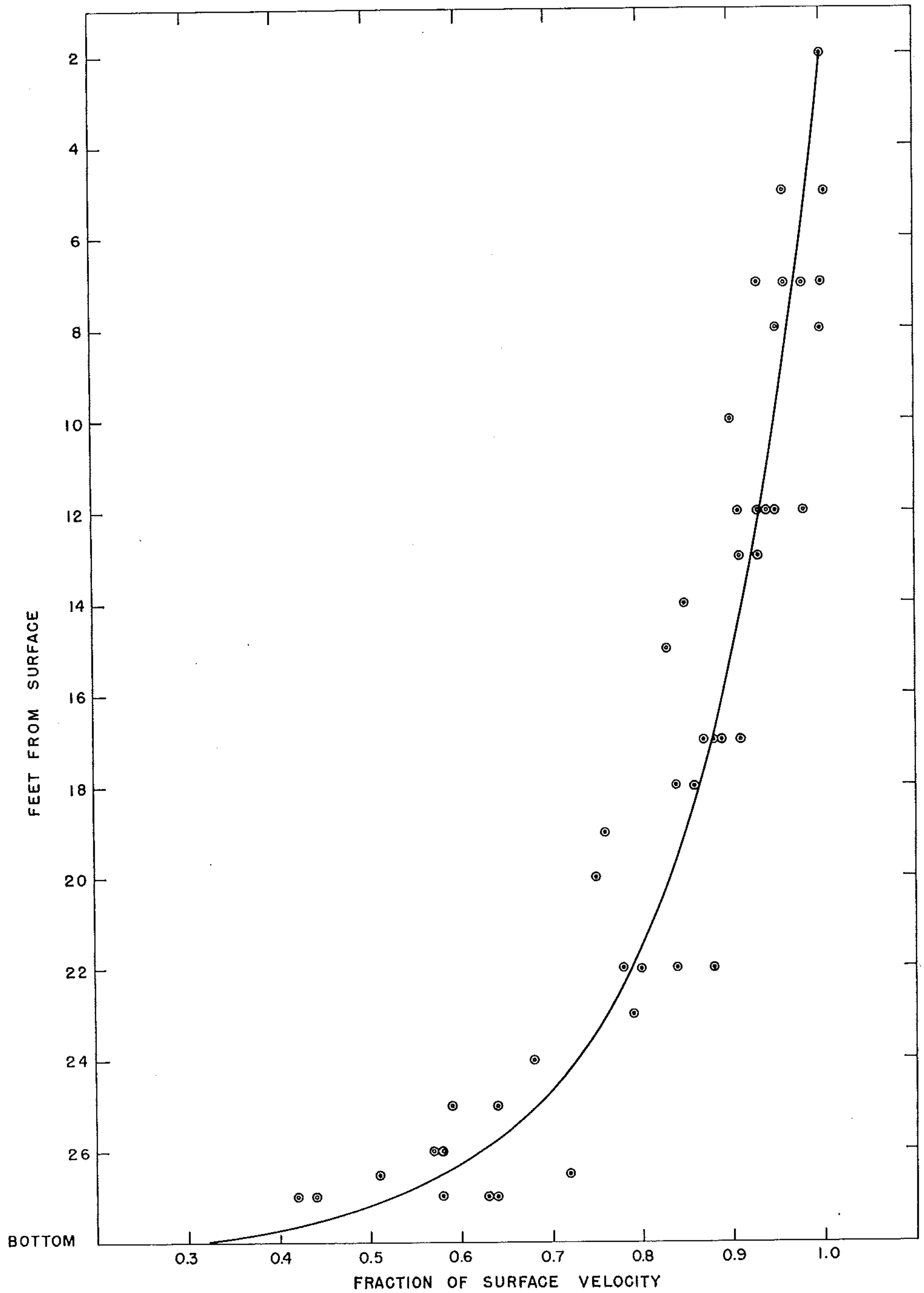

FIGURE 9—Composite velocity profile of Fraser River at Mission during March and April, 1964.

Turbidity

During the early portion of the fry migration in 1964 the water of the Fraser River at Mission was unusually clear as a consequence of persistently low discharge levels (not surpassing 38,000 cfs until April 1 — TABLE 3). Transparency, as measured with a Secchi disk, varied between 30 and 65 in. during the period before April 2 (FIGURE 10). Coincident with increasing discharge and turbidity, transparency declined rapidly from 63 in. on March 30 to 15 in. on April 9 and remained at a low level of 6 to 12 in. for the remainder of the migration period.

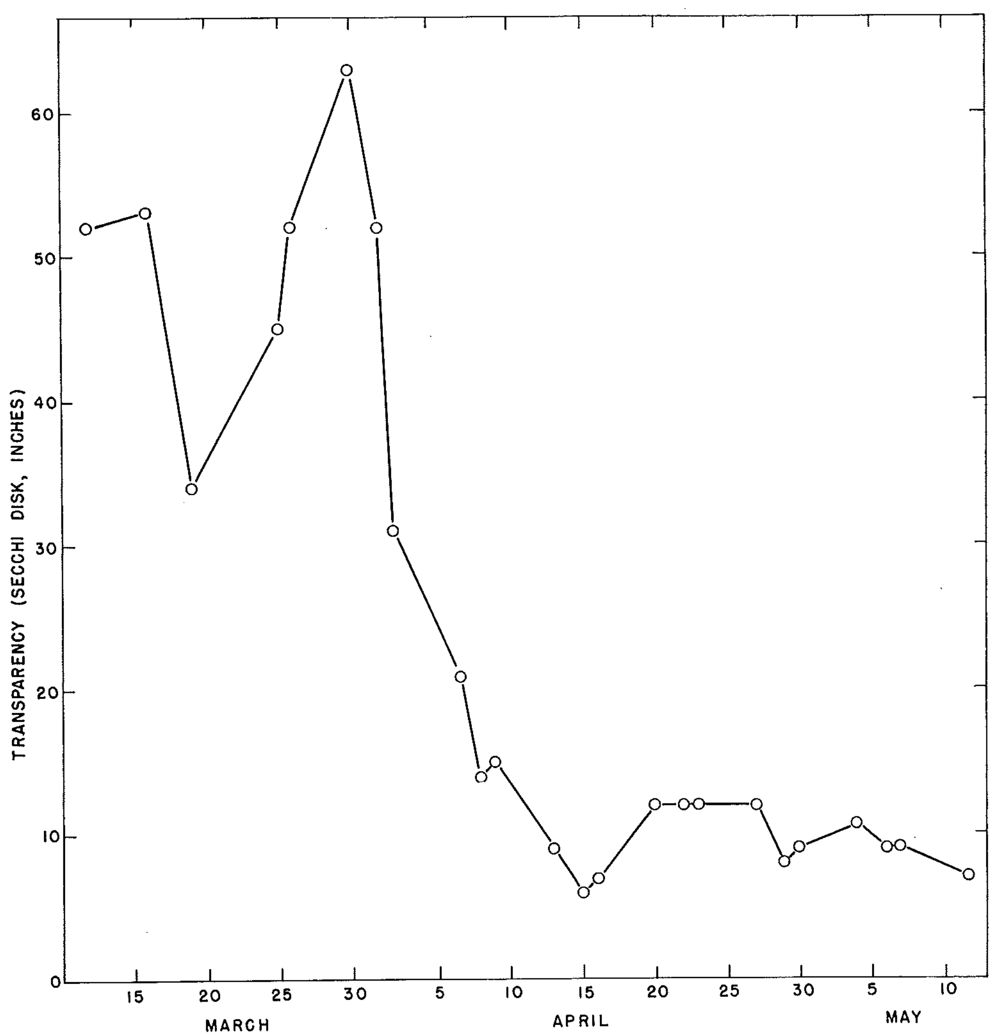

FIGURE 10—Transparency of Fraser River water at Mission during the period March 12-May 12, 1964.

Effects of Turbidity on Schooling of Pink Fry

There was considerable indirect evidence that the spacial distribution of pink fry at Mission was non-random (i.e., discontinuous or contagious) but that the distribution became more random with increasing turbidity of the water.

Examination of data from 8 hr series of 15 min runs by the mobile gear (trap or net) indicated that, early in the season, catches of pink fry tended to fluctuate violently from one 15 min period to the next and that this fluctuation was much reduced later in the season. For example, during the 0500-1300 hr period on March 16, catches per 15 min run in the net ranged from 1 to 548 pinks (FIGURE 11). During a similar 8 hr period on May 4, catches in the net per 15 min run ranged from 6 to 76 pinks. Thus by May 4, although the total catch in the two gears had declined by a factor of 2, the range of fluctuation had declined by a factor of 8.

Early in the season a high degree of variability was also apparent between the number of pink fry caught simultaneously in the surface trap and net (FIGURE 11) although these gears were positioned only 15 ft apart on either side of the same propelling vessel. Again this form of variability was greatly reduced by May 4 (FIGURE 11).

To examine systematically the decline in variability during the season, three measures of variability were developed for 15 representative 8 hr periods between March 16 and May 4 for which trap and net catches were available. These measures were:

1. Coefficient of variation $\left(\frac{S^2}{\bar{x}}\right)$ or the ratio of the variance (S^2) to the mean $(\bar{x})$ for trap catches per 15 min run.

2. Correlation coefficient (r) of simultaneous trap and net catches.

3. Correlation coefficient (r) of catches in successive 15 min runs of the mobile trap.

During the period March 16 to April 6, values for the coefficient of variation were extremely high and fluctuated from 167 to 1,105 (FIGURE 12). After April 6 the coefficient of variation declined to much lower values between 2 and 25. Although fry could not be observed entering the fishing gear, the erratic nature of the catches early in the season strongly suggests that individual fish were not distributed randomly but were aggregated in schools of some size. Thus the very large catches for some 15 min runs could have resulted from the chance interception of one or more large schools of fry. It can be noted (FIGURE 12) that the period of highly variable catches to April 6 coincided with a period of relatively high water transparency and that after April 6, when transparency was consistently low, catches were much less variable. Thus if the high degree of variability was due to schooling of fry then schooling was much reduced by high turbidity (low

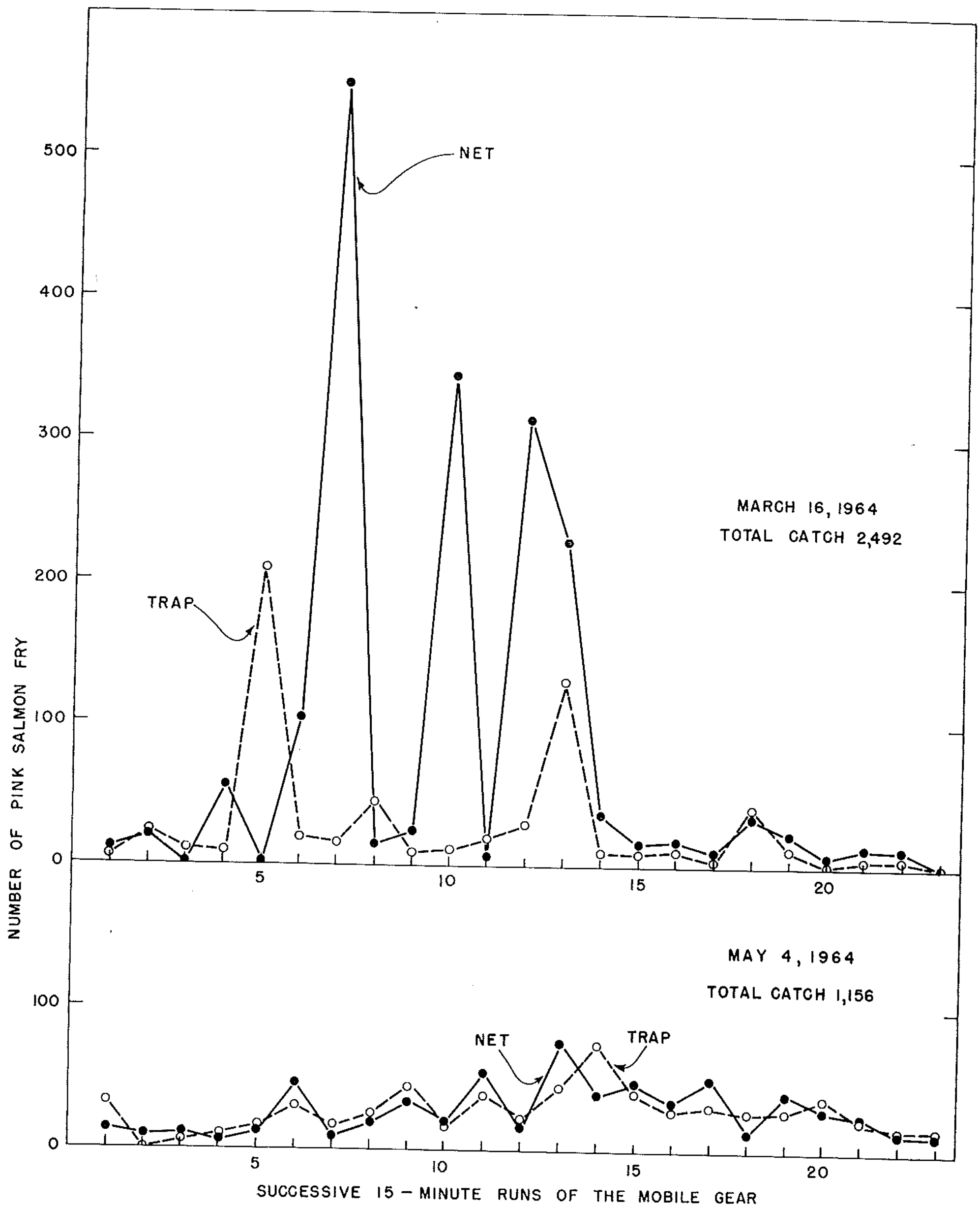

FIGURE 11—Comparison of pink salmon fry catches in 15-min simultaneous runs of the surface trap and surface net during the 0500-1300 hr period on March 16 and on May 4, 1964.

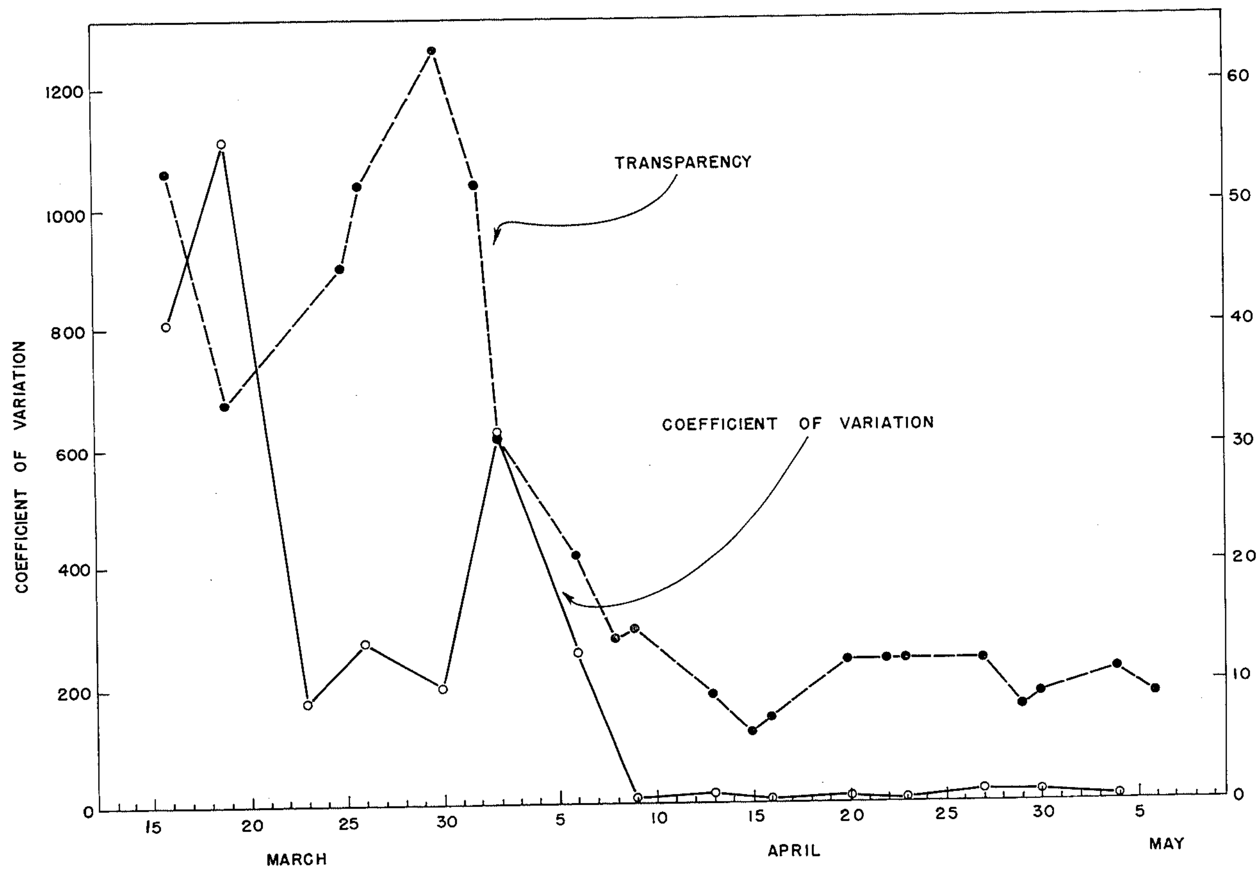

FIGURE 12—Degree of variability of pink salmon catches in 15-min runs during 8-hr sampling periods throughout the season in 1964, as indicated by the ratio of sample variance to sample mean (coefficient of variation). Also shown are Secchi disk transparencies throughout the same period.

transparency). Since maintenance of schools is largely dependent on visual contact between individuals, it appears reasonable to assume that the highly variable catches early in the season were due to the intermittent occurrence of large schools in the relatively clear water which prevailed during this period.

Further evidence that the spacial distribution of pink fry was non-random early in the season and became more uniform with increasing turbidity is provided by a correlation analysis of simultaneous trap and net catches. These catches represent fish present near the surface in parallel horizontal columns of water 2,350 ft long and 15 ft apart. The correlation coefficient (r) for these catches was low and non-significant early in the season but was much higher during the latter part of the season (FIGURE 13).

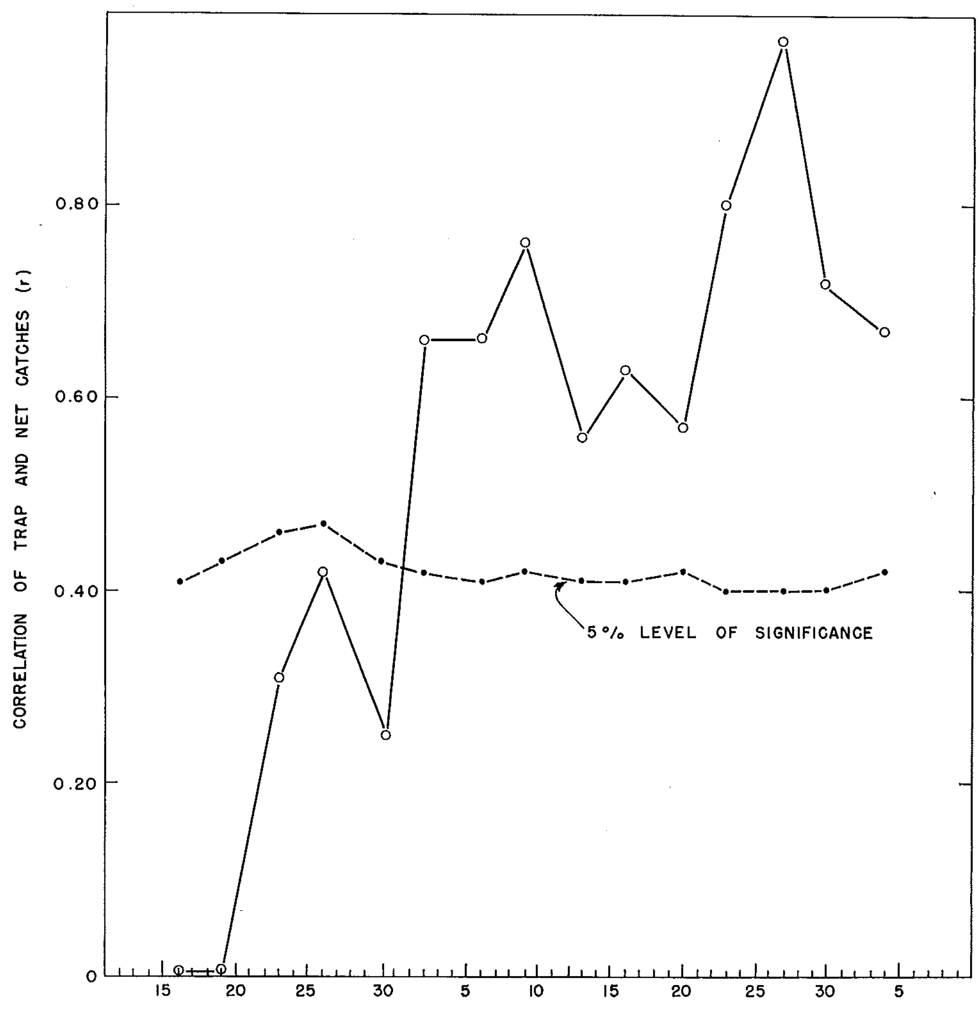

FIGURE 13—Degree of correlation between 15-min catches of pink fry in the surface trap and simultaneous 15-min catches of pink fry in the surface net during 8-hr periods between March 16 and May 4, 1964.

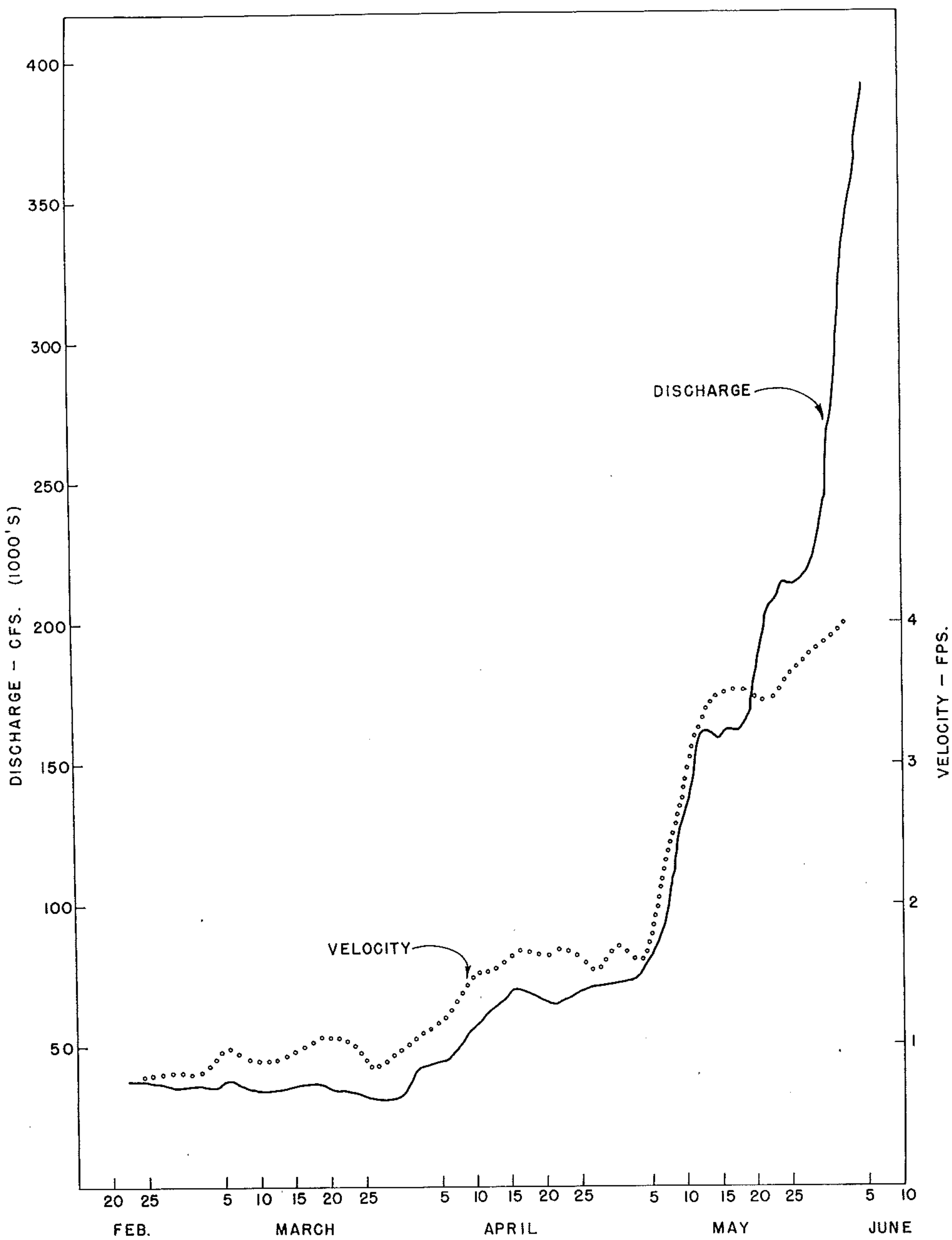

FIGURE 14—Estimated discharge and surface velocity of the Fraser River at Mission during the pink salmon outmigration in 1964. (From Tables 3 and 4.)

A third measure of reduced variability in catches after April 6 was developed from correlation analyses of successive 15 min catches in the mobile trap. For the analysis of any 8 hr period with n consecutive 15 min runs, the X_1 variates consisted of catches in runs 1, 2, 3, ..., n-1 and the X_2 variates consisted of catches in runs 2, 3, 4, ..., n. Although the correlation coefficients (r) calculated in this manner tended to vary considerably from day to day, the overall value of r for the period March 16 to April 6 was low (0.193, $p>0.05$) while the overall value of r for the period April 9 to May 4 was much higher (0.612, $p<0.01$). This again indicated that a high degree of variability between successive catches was associated with high water transparency.

Since turbidity is generally associated with stream discharge, it was possible that the more uniform distribution of fry as the season progressed may have been the result of the turbulent mixing action of the stream as discharge increased. However, the gear was operated in a straight reach of the stream, which was reasonably uniform in cross section and which had no obvious turbulence of flow. Moreover, the variability of fry catches decreased markedly between April 2 and April 9 (FIGURE 12) when increases in discharge and velocity had only just begun (FIGURE 14).

On the basis of these various lines of evidence it was concluded that pink salmon fry in the lower Fraser River tended to form schools when the water was relatively clear (Secchi disk of 2-5 ft) but that these schools broke up or were greatly reduced in size when the water was turbid (Secchi disk of one foot or less).

Orientation of Fry

In developing methods of estimating the total daily abundance of seaward migrant fry it was considered necessary to obtain information on the movements of fry relative to the water. Although pink fry have been observed to migrate actively seaward in small, clear streams, their behavior and orientation in large, relatively slow-moving and turbid bodies of water such as the lower Fraser were unknown.

Direct observations of pink fry in the turbid water at Mission were seldom possible because of their protective coloration and small size (average length 33.5 mm, range 31-37 mm). During periods of calm weather however, schools of fry could be observed occasionally in the mobile trap as they took violently evasive action on encountering the inclined plane. From these observations it was apparent that, in daylight, few fry were present in the upper few inches of water. Thus, even slight turbidity was sufficient to render them invisible from above the surface and it was necessary to devise indirect methods to obtain information on their movements and orientation.

If fry were actively migrating seaward, they would constantly enter the horizontal column of water sampled by the mobile trap in the course of a normal upstream run at constant velocity. Conversely, if the trap were operated similarly in a downstream direction, actively migrating fry would constantly leave the column of water and catches would be proportionately smaller than those made in an upstream direction. To examine possible differences in upstream and downstream catches, paired runs in both directions were made periodically throughout the season.

Two or three successive paired runs were generally made during that portion of the tidal cycle when current was at a minimum so that excessive displacement of the gear during the downstream runs could be avoided. For each test the gear was first operated in the standard manner (upstream at 2.61 ft/sec for 15 min) and, immediately after removal of the captured fry, was propelled downstream over the same course for 15 min at the same engine speed. In all, 47 pairs of upstream and downstream runs were made between March 2 and May 5. A total of 1,707 pink fry were captured during upstream runs and 1,888 fry during downstream runs. Although these totals suggest that fry were actively swimming upstream against the current, catches in individual runs varied widely (between 1 and 198 fry) and were not consistently higher in the downstream direction. Since more than half the catches consisted of less than 25 fry, a transformation to logarithms was necessary to obtain a reasonably normal distribution of values. A statistical comparison of means on this basis indicated that the difference between downstream and upstream catches was not greater than that which might be expected as a result of random variations ($t = 0.639$). No consistent or significant differences were apparent between upstream and downstream catches made in daylight and darkness, inflow and outflow conditions or low and high turbidity periods.

On only two occasions during the season were large numbers of pink fry seen in the Mission area. At the confluence of the Vedder River, about 10 miles above Mission, a plume of clear Vedder River water extended downstream along the left bank of the Fraser. In this clear water, schools of 200 pinks or less were seen in daylight swimming in all directions apparently at random. On the night of April 6, during a period of slack current and flat calm, pink fry were seen in numbers on the surface near the stationary gear at Mission. Using a flashlight from a slowly moving power boat, fry were observed singly and in schools at the surface across the full width of the river. These fry were also swimming in all directions, apparently at random.

On the basis of the similarity of catches made in upstream and downstream directions by the mobile gear and of the direct observations, it was concluded that, in the lower reaches of the Fraser River, migrating pink fry were not oriented with respect to the stream channel but were moved passively seaward by the current. Observations of pink fry in the tidal portion of the Skeena River by McDonald (1960) also support this conclusion.

ESTIMATION OF PINK FRY ABUNDANCE IN 1964

The primary information on pink fry abundance was in the form of catches per run in the mobile trap. A constant, known volume of water passed through the trap on each run and therefore the catches were measures of fry density or concentration in terms of fry per unit volume of water. Since the total daily volume of river discharge was known, the number of fry migrating daily could be computed readily from estimates of the daily average concentration of fry throughout the channel section at Mission.

The basic data consisted of catches at the surface during the 0500-1300 hr period. To estimate the average daily concentration (catch per run) in the channel section as a whole, it was necessary to examine the spacial distribution of fry concentration in both vertical and lateral dimensions as well as the temporal distribution over 24 hr periods. If there was evidence of significant departure from random distribution in any of these dimensions, then the basic data would require adjustment so that this variability was accounted for.

For two reasons, it was desirable to combine data from more than one section or period whenever possible:

(a) Since catches consisted of very small samples of the fry present in the river, great variability due to sampling error was to be expected and greater confidence could be placed on estimates based on large series of samples.

(b) Computation of fry abundance could be greatly simplified if unnecessary subdivisions of data were avoided. Thus data from several river sections or time periods were combined to provide overall measures of relative abundance wherever possible.

In the search for coherent patterns of practical value in the extremely variable data, it was usually necessary to utilize mean values or percentages. Since these procedures masked some of the inherent variability, the 0.01 level of confidence was chosen for statistical comparisons of grouped data.

Vertical Distribution of Fry

Information on the vertical distribution of pink salmon fry was chiefly in the form of catches per run in the mobile vertical gear. These samples were taken at a series of depths between the surface and 13.5 ft, in the three river sections during twice weekly 24 hr periods. For most of the season supplementary information was also available from catches by the stationary gear at depths of 13.5, 19.5 and 25.5 ft during the same twice weekly 24 hr periods.

DISTRIBUTION BETWEEN SURFACE AND 13.5 FEET

For an initial examination of vertical distribution data, mean pink salmon fry catches per run in the mobile gear at 1.5, 7.5, 10.5 and 13.5 ft were grouped by day and by 8 hr period (TABLE 5). Seasonal variation in the pattern of vertical distribution was indicated by the changing proportion of the total catch which was taken in the surface stratum, i.e., catch at 1.5 ft expressed as a percentage of total catch between 1.5 and 13.5 ft (TABLE 6 and FIGURE 15). It can be noted (FIGURE 15) that early in the season (prior to April 8) there were

TABLE 5—Mean catch of pink fry per 15-minute run[a] in the mobile vertical gear by 8-hour period and by depth stratum at Mission in 1964.

8-HOUR PERIOD	0500-1300 HOURS				1300-2100 HOURS				2100-0500 HOURS			
Depth in Feet	1.5	7.5	10.5	13.5	1.5	7.5	10.5	13.5	1.5	7.5	10.5	13.5
Feb. 24	1.75	0.0	0.33	0.0	—	—	—	—	—	—	—	—
27	2.28	0.56	0.0	0.17	7.33	1.00	0.44	0.17	0.68	0.0	0.67	0.33
March 2	2.83	0.17	0.0	0.0	5.87	0.22	0.38	0.50	0.50	0.33	0.43	1.43
5	11.84	0.0	0.33	0.33	10.55	1.00	2.00	1.00	0.75	0.0	0.0	0.33
9	18.95	0.67	0.0	0.0	81.75	0.50	0.25	0.33	1.29	0.17	0.50	0.33
12	16.78	0.33	0.17	0.33	81.05	4.75	2.50	4.17	1.86	0.71	2.22	3.00
16	11.53	0.29	0.17	0.17	80.57	8.88	44.33	4.17	2.50	2.17	2.17	7.38
19	11.95	0.86	0.83	0.50	69.00	6.12	62.50	5.50	3.94	0.83	0.83	2.50
23	41.48	0.56	0.33	1.33	70.00	0.0	69.00	3.00	—	—	—	—
26	59.78	2.00	0.0	0.0	144.32	1.57	31.17	6.50	23.29	3.50	4.00	9.17
30	20.74	0.14	0.0	0.17	65.95	2.75	4.43	1.17	6.52	0.50	3.25	3.14
April 2	97.90	17.12	31.67	2.67	263.18	46.14	10.22	9.33	3.33	2.83	8.00	8.17
6	89.18	41.89	5.86	13.17	132.13	18.50	58.00	13.11	5.86	9.44	8.00	9.17
9	38.05	18.89	23.71	2.05	14.77	13.83	16.62	2.02	25.71	24.62	14.67	15.14
13	17.89	16.14	42.00	32.83	18.04	16.88	24.78	20.17	31.86	22.71	19.67	15.67
16	9.22	11.56	16.38	23.50	9.12	13.75	13.71	19.11	19.27	27.28	25.89	24.33
20	7.87	7.56	14.50	18.50	9.70	10.14	12.86	17.56	19.94	30.14	31.17	28.50
23	11.95	4.11	11.00	11.33	10.92	8.00	14.22	16.00	18.83	20.00	28.62	20.50
27	6.86	10.00	19.17	22.33	10.58	15.50	19.11	20.78	15.95	22.71	13.67	15.83
30	18.30	15.00	21.12	30.17	16.83	17.50	16.14	16.00	28.79	22.57	18.67	16.33
May 4	28.18	5.78	9.75	18.00	21.00	—	11.00	19.50	—	—	—	—
7	4.00	4.44	7.88	14.33	4.83	4.14	8.57	8.33	3.90	4.50	2.67	3.83
11	3.33	4.50	5.83	6.50	1.53	2.00	3.17	2.83	2.44	3.50	1.00	1.67
14	1.37	1.43	1.83	2.67	0.81	1.50	1.00	0.50	1.56	1.17	1.67	0.83
18	6.20	1.25	1.67	0.33	0.50	0.33	0.0	0.17	0.16	0.17	0.50	0.83

[a] In each 8 hr period, 6 to 8 runs were usually made at each depth below the surface and 18 to 24 runs on the surface (1.5 ft).

considerable differences between 8 hr periods in the percentage at the surface. Comparisons of mean percentages for this portion of the season indicated that the proportion on the surface during the 2100-0500 hr period was significantly lower than that during the 0500-1300 or the 1300-2100 hr periods ($p<0.01$). After April 8 the differences were greatly reduced and were not statistically significant. Thus, before April 8, data for the three 8 hr periods cannot be combined without bias while, after this date, these data can be grouped into 24 hr periods.

To determine whether the pattern of vertical distribution varied laterally across the width of the channel section at Mission, 24 hr catch data from the mobile vertical gear after April 8 were grouped by river section. Surface catches (1.5 ft) expressed as a percentage of the total catch in the vertical gear were plotted separately for each river section (FIGURE 16). It can be noted that the proportion of fry near the surface followed similar trends in all stream sections and that day-to-day fluctuations in this proportion were much greater than the

TABLE 6—Mean catch of pink fry per run[a] in the mobile vertical gear and the percentage of this catch taken at the surface (1.5 ft) at Mission in 1964.

DATE	8-HOUR PERIOD					
	0500-1300		1300-2100		2100-0500	
	Total Catch	% at 1.5 ft	Total Catch	% at 1.5 ft	Total Catch	% at 1.5 ft
Feb. 27	3.01	75.8	8.94	82.1	1.68	40.5
March 2	3.00	94.3	6.97	84.1	2.69	18.6
5	12.50	94.8	14.55	72.7	1.08	69.4
9	19.62	96.6	82.83	98.7	2.29	56.4
12	17.61	95.3	92.47	87.7	7.79	23.9
16	12.16	94.8	137.95	58.5	14.22	17.6
19	14.14	84.5	143.12	48.2	8.10	48.7
23	43.70	94.9	142.00	49.3	—	—
26	61.78	96.8	183.56	78.6	39.96	58.3
30	21.05	98.5	74.30	88.8	13.41	48.7
April 2	149.36	65.5	328.87	80.0	22.33	14.9
6	150.10	59.4	221.74	59.6	32.47	18.0
9	82.70	46.0	47.24	31.3	80.14	32.1
13	108.86	16.4	79.87	22.6	89.91	35.4
16	60.66	15.2	55.69	16.4	96.77	19.9
20	48.43	16.3	50.26	19.3	109.75	18.2
23	38.39	31.1	49.14	22.2	87.95	21.4
27	120.07	11.8	58.36	16.0	68.16	23.4
30	84.59	21.6	66.47	25.3	86.36	33.3
May 4	61.71	45.7	61.50	34.1	—	—
7	30.65	13.0	25.87	18.7	14.90	26.2
11	20.16	16.5	9.53	16.1	8.61	28.3
14	7.30	18.8	3.81	21.3	5.23	29.8
18	9.45	65.6	1.00	50.0	1.66	9.6
Season Total	1,181.00 (24 days)	45.6	1,946.04 (24 days)	58.1	795.46 (22 days)	27.5

[a] Sum of the mean catches at 1.5, 7.5, 10.5 and 13.5 ft (TABLE 5).

differences between sections. The mean percentages during the 35-day period were 24.5 in the right bank section, 24.3 in midstream and 26.2 on the left bank. The differences between these means were not statistically significant. Although further evidence of the uniformity of vertical distribution patterns would have been desirable, the great variability of the data precluded more detailed analyses and it was concluded that the pattern of vertical distribution of pink fry was essentially the same across the full width of the river. On the basis of this evidence it was also concluded that catch data from the stationary gear, situated between the left bank and midstream sections (FIGURE 6), could be considered representative of pink fry abundance at depth across the width of the river.

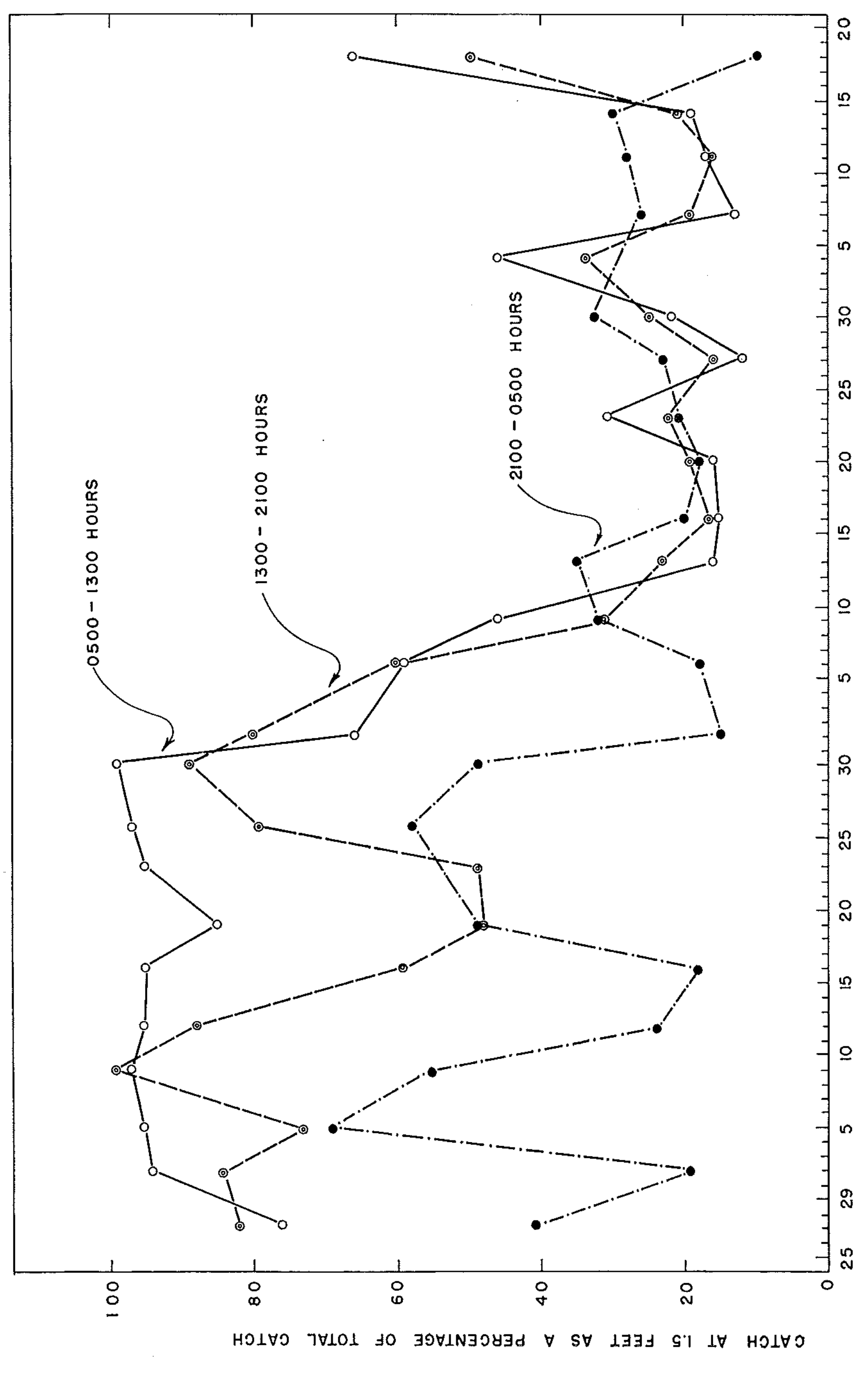

FIGURE 15—Surface catch of pink fry per run as a percentage of the total catch per run in the mobile vertical gear during each 8-hr period of the day in 1964.

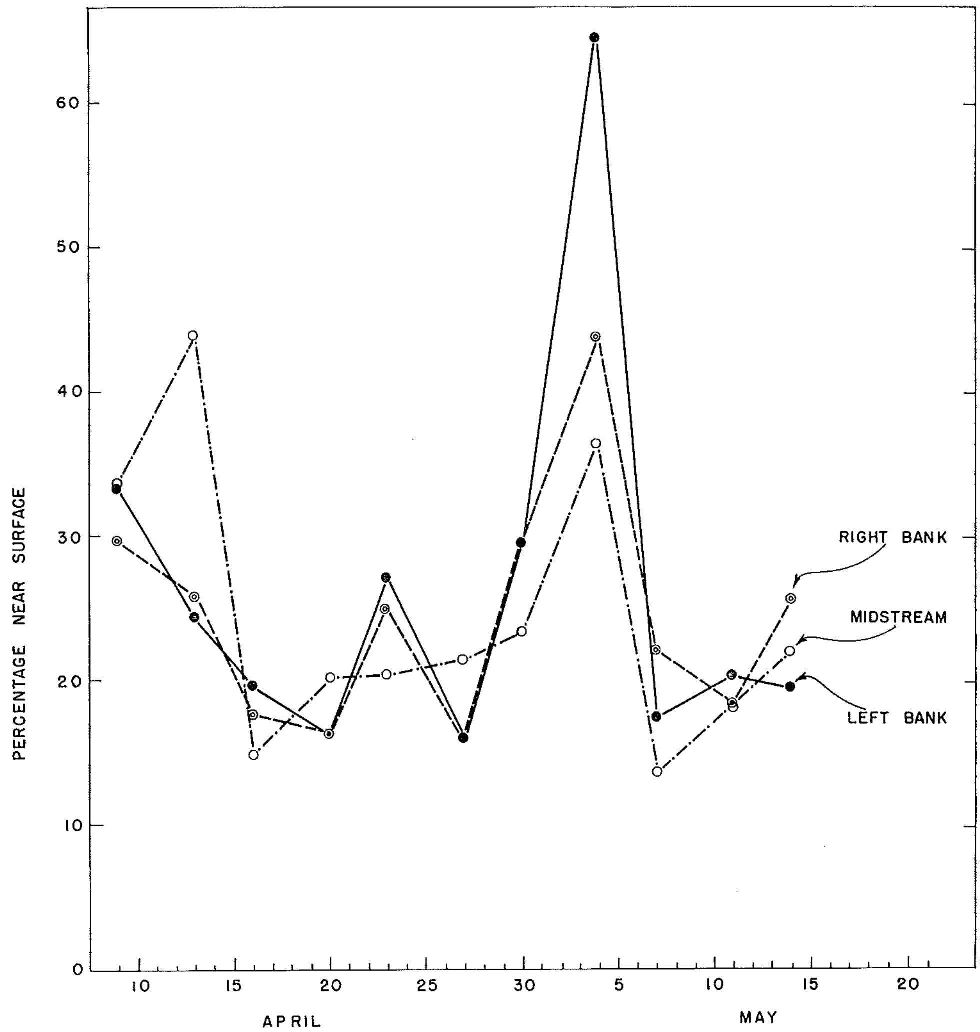

FIGURE 16—Catch of pink fry at 1.5 ft as a percentage of the total catch in the mobile vertical gear. Data for Left Bank, Midstream and Right Bank sections plotted separately for the period April 9-May 14, 1964.

Since there was evidence for lateral uniformity in the pattern of vertical distribution of pink fry, the combined data from all three stream sections (Table 6 and Figure 15) were examined in more detail. During the early portion of the season before April 8, it can be noted (Figure 15) that, for the 0500-1300 hr and the 1300-2100 hr periods, a large proportion of the pink fry were near the surface and that for the 2100-0500 hr period, except for a few erratically high values, this proportion was much lower. The 0500-1300 hr and 1300-2100 hr periods together approximately encompassed the hours of daylight. During this early season period, the difference between these two 8 hr periods in the proportion on the surface was not statistically significant at the 0.01 level of confidence. Therefore data for these two periods (0500-1300 and 1300-2100) were combined and compared with those for the remaining 8 hr period of darkness (FIGURE 17). Also plotted in FIGURE 17 are values of water transparency (Secchi disk determinations) and it can be noted that, during daylight, the proportion of pink fry near the surface was closely related to transparency ($r = 0.948$). On the other hand, during darkness the proportion of fry near the surface tended to vary erratically throughout the season and had no significant association with transparency ($r = 0.346$).

After April 8, when transparency was consistently low, the proportion of fry near the surface showed no temporal trend (FIGURES 15 and 17) and a comparison of means indicated no statistically significant differences between 8 hr periods in the proportion of fry near the surface. Thus after April 8, data for all three 8 hr periods were combined and the catches at 1.5, 7.5, 10.5 and 13.5 ft were compared by expressing each as a percentage of the total 24 hr catch in the mobile vertical gear (FIGURE 18). It can be noted that the proportion of pink fry at any one depth zone was not consistently different from that in any other. A comparison of the mean percentages during this period also indicated that, at the 0.01 level of probability, differences between them were not statistically significant. On this basis it was assumed that, from April 8 to the end of the migration period pink salmon fry were randomly distributed from the surface to a depth of 13.5 ft throughout all periods of the day.

It was apparent that, during daylight hours (0500-2100), the vertical distribution of pink fry before April 8 differed considerably from that later in the season (FIGURE 17). However, during darkness (2100-0500 hr), a comparison of mean percentages indicated that the proportion near the surface before April 9 did not differ significantly from that thereafter. To examine the distribution during darkness in more detail, the catches at each depth zone were expressed as percentages of the total 8 hr catch in the mobile vertical gear (FIGURE 19). It can be noted that even during the early portion of the season, there was no consistent difference between the proportions taken at the two extremes of depth (1.5 ft and 13.5 ft). The apparent low proportion of fry at 7.5 ft early in the season was largely due to interference by the surface net (see below). Since the chief difference between early season and late season periods was that the day-to-day variability was much greater before April 5 than after, it was concluded that, throughout the season during darkness, pink fry were randomly distributed from the surface to depths of 13.5 ft.

To varying degrees, pink fry tended to be concentrated near the surface during daylight hours early in the season (FIGURE 17) and therefore it was necessary to develop reliable estimates of their relative abundance in the various depth strata to 13.5 ft. To reduce the variability caused by sporadic catches of large schools of fry during this portion of the season and to reduce the number of computations involved, data were combined for those periods within which day-to-day variability was at a minimum (TABLE 7).

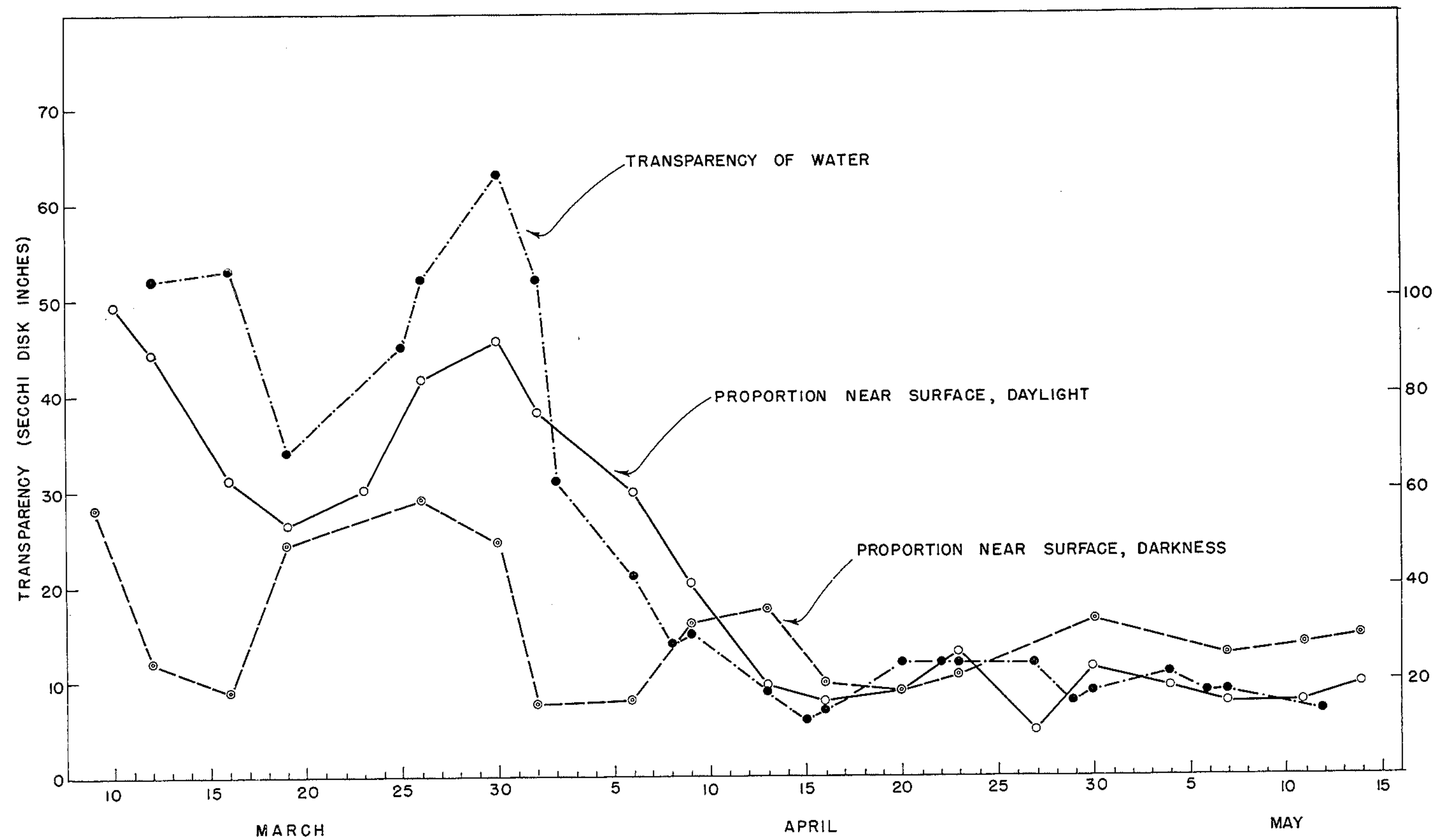

FIGURE 17—Relationship of the proportion of fry taken near the surface during daylight (0500-2100 hrs) and darkness (2100-0500 hrs) to transparency of the stream (Secchi disk inches).

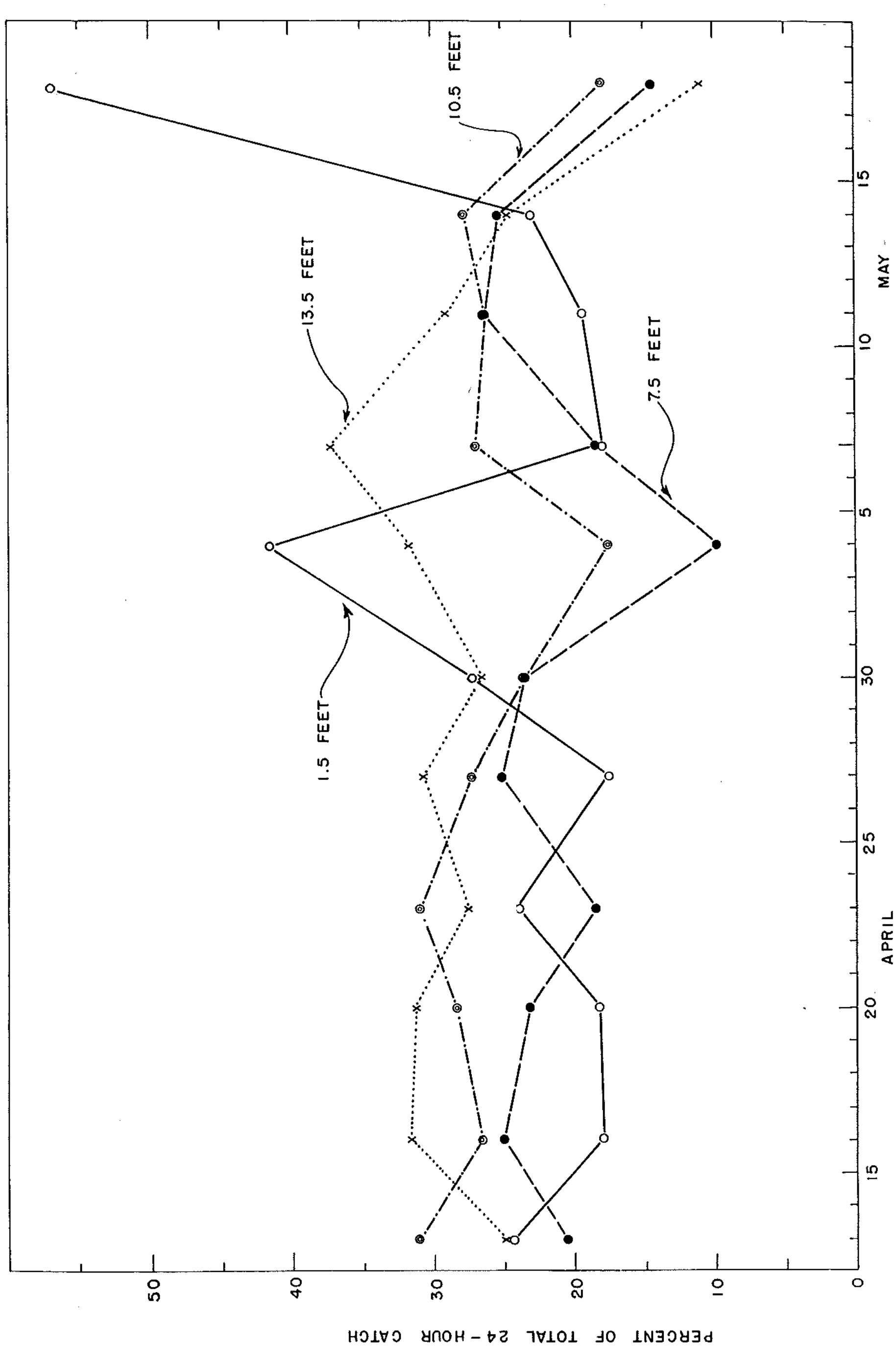

FIGURE 18—Catches of pink fry at 1.5, 7.5, 10.5 and 13.5 ft as percentages of the total catch each day at all of these depths during the period April 13-May 18, 1964.

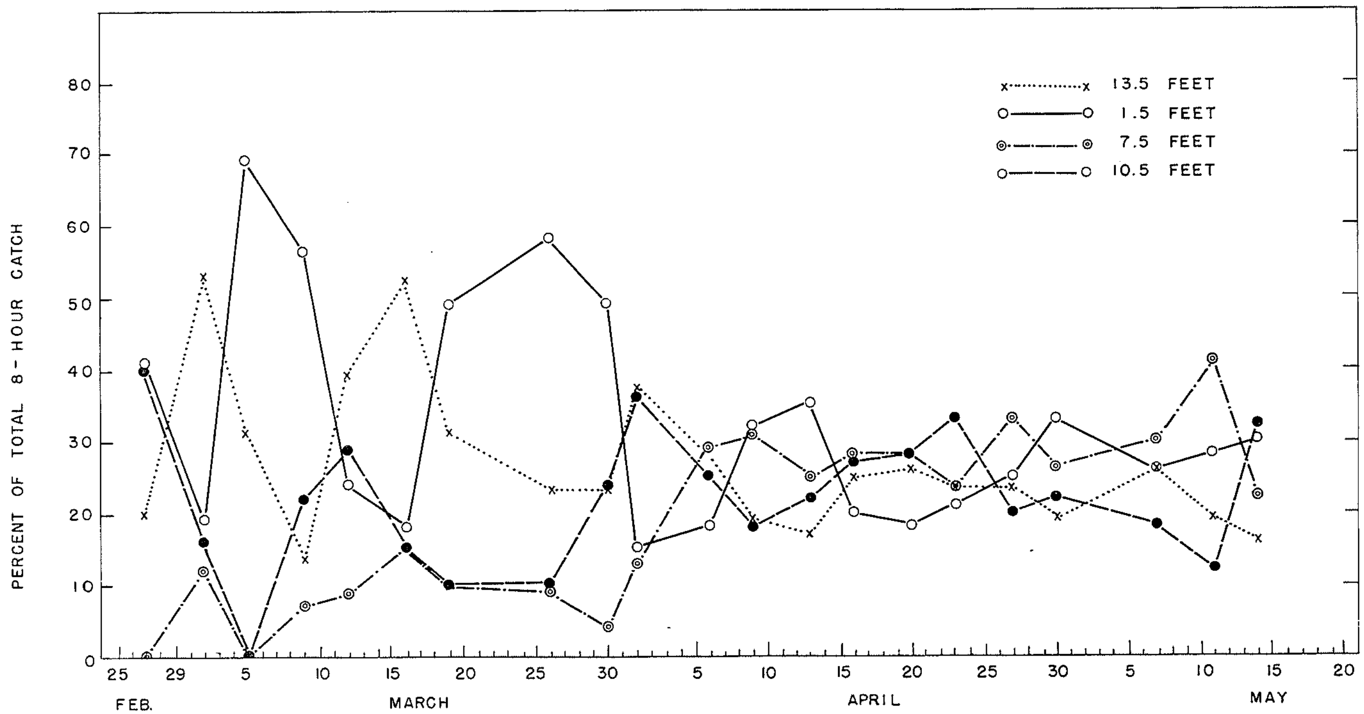

FIGURE 19—Catches of pink fry in the mobile vertical gear during darkness (2100-0500 hrs) at Mission in 1964. For each depth interval, catches are expressed as a percentage of the combined catch at all intervals.

TABLE 7—Mean catches of pink fry per run[a] in the mobile vertical gear during daylight hours (0500-2100 hr) from February 24 to April 9, 1964 at Mission.

DATE	DEPTH IN FEET			
	1.5	7.5	10.5	13.5
Feb. 24	1.75	0.0	0.33	0.0
27	4.81	0.78	0.22	0.17
March 2	4.35	0.20	0.19	0.25
5	11.20	0.50	1.17	0.67
9	50.35	0.59	0.13	0.17
12	48.92	2.54	1.34	2.25
Mean, Feb. 24-March 12	20.23	0.77	0.56	0.58
March 16	46.05	4.59	22.25	2.17
19	40.48	3.49	31.67	3.00
23	55.74	0.28	34.67	2.17
Mean, March 16-23	47.42	2.79	29.53	2.45
March 26	102.05	1.79	15.59	3.25
30	43.35	1.45	2.22	0.67
April 2	180.54	31.63	20.95	6.00
Mean, March 26-April 2	103.65	11.62	12.92	3.31
April 6	110.66	30.20	31.93	13.14
9	26.41	16.36	20.17	2.04
Mean, April 6-9	63.54	23.28	26.05	7.59

[a] One half the sum of the mean catches in the 0500-1300 and 1300-2100 hr periods (from TABLE 4).

From February 24 to March 12 pink fry were consistently confined almost entirely to the surface (TABLE 7) and therefore data for this period were combined. During a period of reduced water transparency from March 16 to March 23 (FIGURE 17), catches at depth increased substantially and therefore data for this period were also combined and treated separately.

Water transparency was again high from March 26 to April 2 and, since catches at depth were again reduced, data for this period were also treated separately. Between April 6 and April 9 water transparency was decreasing rapidly to the uniformly low level characteristic of the latter part of the season. Catches at depth increased during this transition period and consequently were also treated separately. For these four discrete periods the mean catch per run was plotted against depth (FIGURES 20-23). Smooth curves were drawn visually through the plotted points. Catches in the 7.5 ft stratum were consistently lower than expected, in most cases being lower than those at 1.5 ft or 10.5 ft. This anomaly apparently resulted from interference by the net at 1.5 ft which fished constantly ahead and above that at 7.5 ft. Consequently it was necessary to ignore the data obtained at 7.5 ft and derive interpolated values for this stratum as well as for the 4.5 ft stratum.

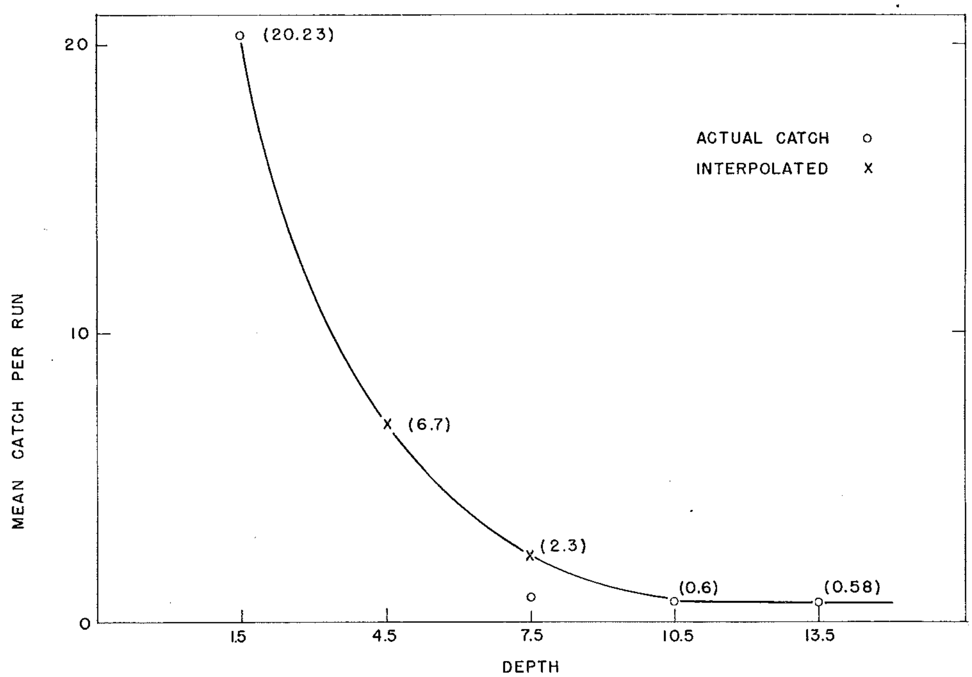

FIGURE 20—Mean catch per run in the mobile vertical gear during daylight hours (0500-2100) for the period February 24-March 12, 1964. (From Table 7.)

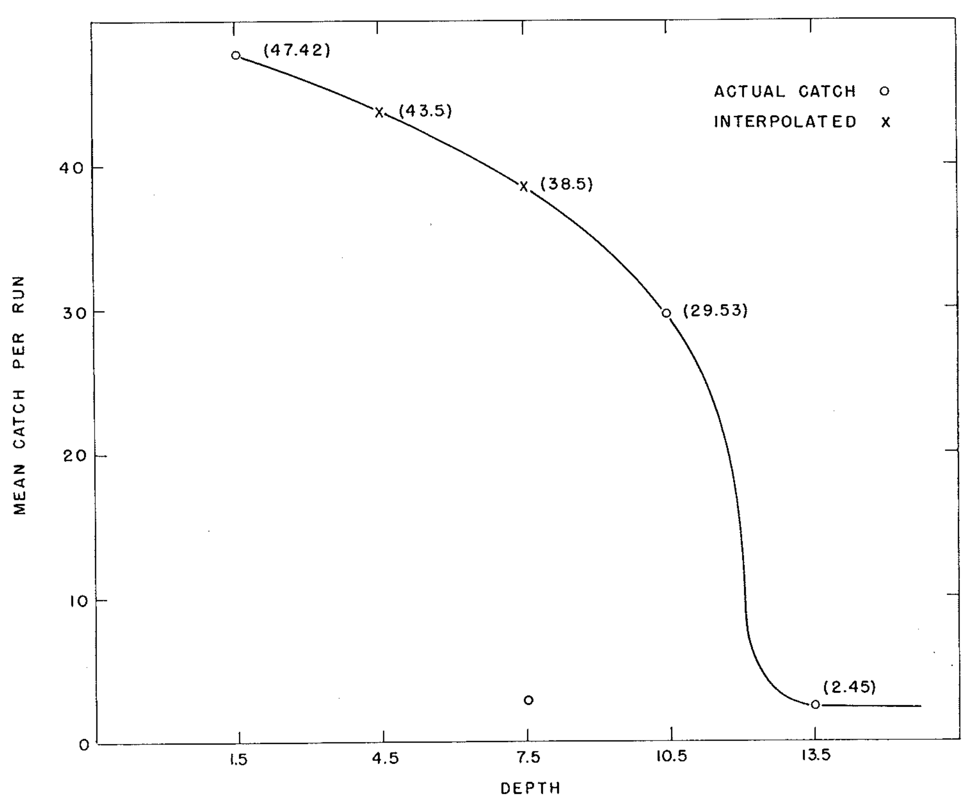

FIGURE 21—Mean catch per run in the mobile vertical gear during daylight hours (0500-2100) for the period March 16-23, 1964. (From Table 7.)

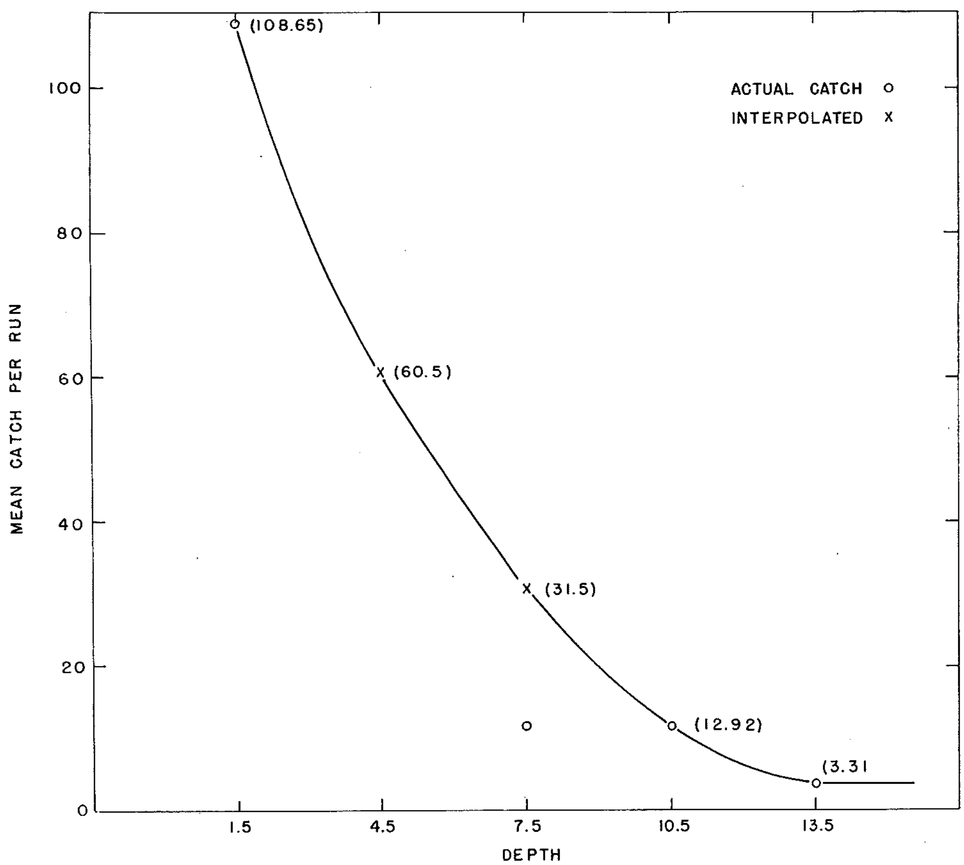

FIGURE 22—Mean catch per run in the mobile vertical gear during daylight hours (0500-2100) for the period March 26-April 2, 1964. (From Table 7.)

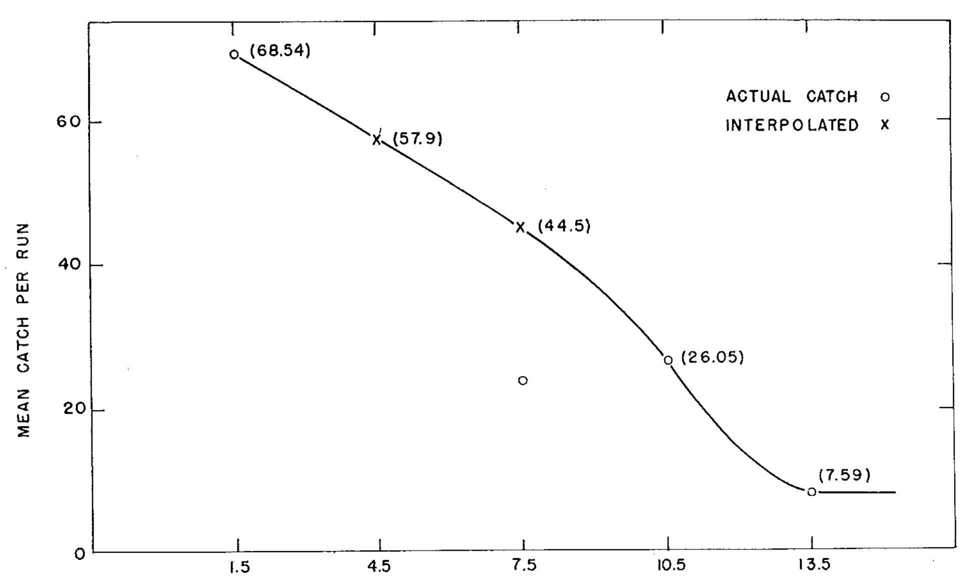

FIGURE 23—Mean catch per run in the mobile vertical gear during daylight hours (0500-2100) for the period April 6-9, 1964. (From Table 7.)

DISTRIBUTION BELOW 13.5 FEET

Below the depth reached by the mobile gear, pink salmon fry were sampled regularly from March 2 to May 7 by the stationary gear fishing at depths of 13.5, 19.5 and 25.5 ft. Stream velocity, which fluctuated constantly from slightly over one ft/sec early in the season to about two ft/sec later in the season, was measured at the depth of the net at the beginning and end of each hour of fishing. To obtain data which were in terms of fry concentration (catches per unit volume of water) and which therefore would be comparable for all depths and periods, catches were weighted to a velocity of one ft/sec. For an analysis of diurnal and seasonal changes in the pattern of vertical distribution, the data were grouped by 8 hr periods and the mean catches per hour at each depth were summed to compute a percentage of the total which were present at 13.5 ft (TABLES 8-10).

TABLE 8—Catch of pink salmon fry per hour in the stationary vertical gear during the 0500-1300 hour period at Mission in 1964. (Catches weighted to constant velocity of one ft/sec.)

DATE	DEPTH 13.5′ Catch/Hour	13.5′ Hrs.	19.5′ Catch/Hour	19.5′ Hrs.	25.5′ Catch/Hour	25.5′ Hrs.	TOTAL CATCH	PER CENT AT 13.5′
March 2	0	1	0	1	—	0	0	—
3	0	1	—	0	—	0	0	—
9	0	2	0	2	0	2	0	—
12	0	2	0	1	0	1	0	—
16	0.48	2	0	1	0	1	0.48	100.0
19	0	3	0.96	1	0	1	0.96	0
26	0	2	0	1	0	1	0	—
30	0	1	0	1	—	0	0	—
April 2	0	3	0.54	2	0.67	2	1.21	0
6	0.47	3	1.31	2	0	2	1.78	26.4
8	39.33	1	28.86	1	24.74	1	92.93	42.3
9	15.54	3	19.95	3	25.96	2	61.45	25.3
13	9.73	3	5.98	2	9.42	2	25.13	38.7
15	9.55	1	16.57	1	—	0	—	—
16	12.56	3	16.67	2	11.87	2	41.10	30.6
20	11.81	3	23.02	3	24.26	2	59.09	20.0
22	13.44	1	26.14	1	27.21	1	66.79	20.1
23	7.77	3	14.56	3	33.31	2	55.64	14.0
27	9.57	3	11.23	3	13.13	2	33.93	28.2
29	22.63	1	12.43	1	23.08	1	58.14	38.9
30	12.86	3	21.02	3	31.01	2	64.89	19.8
May 4	15.32	3	21.15	3	17.26	2	53.73	28.5
6	16.67	1	19.63	1	16.17	1	52.47	31.8
7	10.97	3	10.86	3	7.04	2	28.87	38.0
Mean, April 6 to May 7	13.88		16.63		18.89			28.8

TABLE 9—Catch of pink salmon fry per hour in the stationary vertical gear during the 1300-2100 hour period at Mission in 1964. (Catches weighted to constant velocity of one ft/sec.)

DATE	DEPTH						TOTAL CATCH	PER CENT AT 13.5′
	13.5′		19.5′		25.5′			
	Catch/Hour	Hrs.	Catch/Hour	Hrs.	Catch/Hour	Hrs.		
March 2	0	1	0	1	0	1	0	—
3	0.82	2	0	2	0	2	0.82	100.0
5	0.56	3	0.46	2	0.47	2	1.49	37.6
6	0.83	3	0.83	3	1.84	2	3.50	23.7
9	0	3	0.28	3	0	2	0.28	0
12	0	2	0.36	3	0	3	0.36	0
16	0	2	0	2	0	2	0	—
19	6.20	2	3.82	2	2.57	2	12.59	49.2
26	0	2	0.71	3	0	1	0.71	0
30	0	2	0	2	0	2	0	—
April 2	3.46	2	0.56	3	2.71	2	6.73	51.4
6	8.98	2	9.09	3	9.72	3	27.79	32.3
8	22.76	1	55.00	1	38.54	1	116.30	19.6
9	10.28	2	9.05	2	4.46	3	23.79	43.2
13	7.79	2	5.42	3	6.14	2	19.35	40.3
15	19.70	1	9.88	1	25.95	1	55.53	35.5
16	12.97	2	17.23	3	8.76	3	38.96	33.3
20	13.28	2	24.71	2	32.26	3	70.25	18.9
22	20.83	1	41.38	1	—	0	—	—
23	15.70	2	21.26	2	23.64	3	60.60	25.9
27	12.36	2	18.33	2	18.61	3	49.30	25.1
29	23.33	1	30.49	1	20.83	1	74.65	31.3
30	18.30	2	19.74	2	24.86	3	62.90	29.1
May 4	14.07	2	15.52	2	10.68	3	40.27	34.9
6	7.44	1	19.19	1	20.83	1	47.46	15.7
7	8.37	2	9.78	2	0.89	3	19.04	44.0
Mean, April 2 to May 7	13.73		19.16		16.59			32.0

During the 0500-1300 hr and 1300-2100 hr periods, which extended through the daylight hours, catches at 13.5 ft or deeper were erratic and insignificant before April 2-6 (TABLES 7 and 8). Later in the season the pattern of vertical distribution, as indicated by the proportion taken at 13.5 ft, fluctuated considerably from day to day, due largely to the small size of the samples, but there was no apparent difference between the 0500-1300 hr and the 1300-2100 hr periods in this pattern, nor was there any evidence of a consistent change in the pattern throughout the season (FIGURE 24).

During the 2100-0500 hr period, reasonably consistent catches were made after March 9, some three weeks earlier than during the daylight periods (FIGURE 24). This confirmed the information derived from the mobile gear that, during darkness, pink fry were present at depth even while water trans-

TABLE 10—Catch of pink salmon fry per hour in the stationary vertical gear during the 2100-0500 hour period at Mission in 1964. (Catches weighted to constant velocity of one ft/sec.)

DATE	DEPTH						TOTAL CATCH	PER CENT AT 13.5′
	13.5′		19.5′		25.5′			
	Catch/Hour	Hrs.	Catch/Hour	Hrs.	Catch/Hour	Hrs.		
March 6	—	0	1.59	1	—	0	—	—
9	0.41	2	0	1	0.46	2	0.87	47.1
12	1.68	3	1.91	2	0.48	2	4.07	41.3
16	2.09	3	2.14	2	1.60	1	5.83	35.8
19	2.15	1	1.00	1	—	0	—	—
23	7.83	2	3.50	2	7.14	1	18.47	42.4
26	2.60	2	2.71	2	0.85	3	6.16	42.2
30	1.54	2	3.11	2	5.43	1	10.08	15.3
April 2	1.09	1	6.80	1	0	1	7.89	13.8
6	6.34	1	0.82	2	—	0	—	—
9	3.64	3	5.92	2	3.06	2	12.62	28.8
13	5.40	3	7.73	2	3.78	3	16.91	31.9
16	13.15	3	5.88	2	3.19	2	22.22	59.2
20	11.83	3	13.81	2	7.61	2	33.25	35.6
23	10.82	3	13.00	2	11.62	2	35.44	30.5
27	8.13	3	6.10	2	6.24	2	20.47	39.7
30	6.49	3	5.40	3	0	2	11.89	54.6
May 4	3.72	3	1.54	2	1.31	2	6.57	56.6
7	4.37	2	2.93	2	0	1	7.30	59.9
Mean, March 9 to May 7	5.18		4.68		3.30			39.7

parency was high. Due to the general low abundance of fry during darkness, samples were small and as a consequence the percentage taken at 13.5 ft fluctuated considerably from day to day. High values for this proportion near the end of the season were more apparent than real because at this time considerable quantities of fibrous debris, which increased with depth, reduced the efficiency of the net in the bottom position. Thus there was no evidence for a consistent seasonal change in the pattern of vertical distribution during the 2100-0500 hr period.

For each of the 8 hr periods, mean percentages at 13.5 ft were computed for that part of the season during which reasonably consistent values were obtained, i.e., erratic early-season values were excluded (TABLES 8-10). A comparison of these means indicated that differences between 8 hr periods in the pattern of vertical distribution were not statistically significant at the 0.01 level of probability. For each 8 hr period the pattern of vertical distribution was also examined by comparing the season mean catches at 13.5, 19.5 and 25.5 ft — again excluding erratic early-season catches (TABLES 8-10). Again, differences between depths showed no consistent pattern and were not statistically significant. Similarly, combined data for all 8 hr periods showed no statistically significant differences between catches at the three depths.

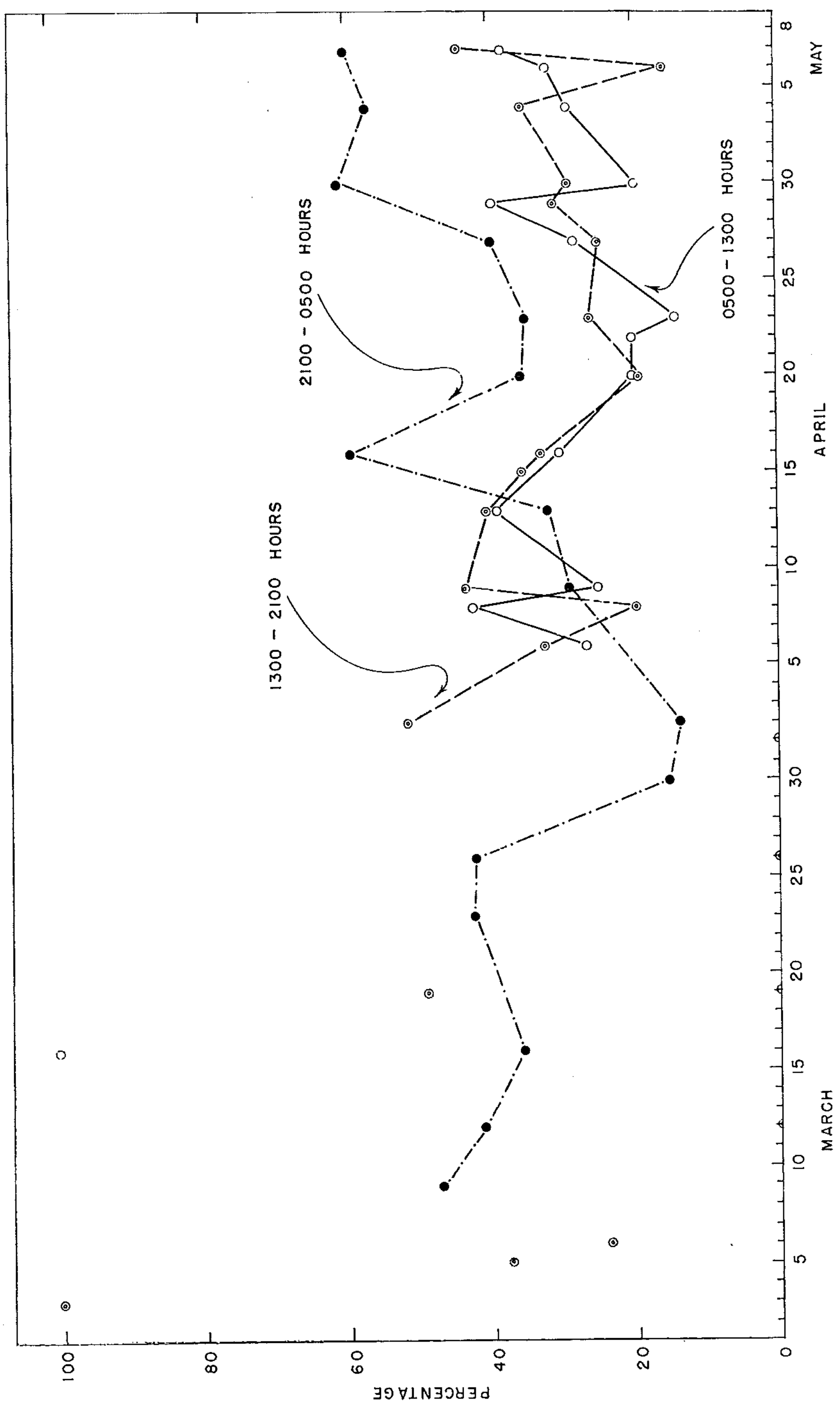

FIGURE 24—Catches of pink fry at 13.5 ft expressed as a percentage of the combined catch at 13.5, 19.5 and 25.5 ft in the stationary vertical gear in 1964. Data for each 8-hr period are plotted separately.

On this basis it was concluded that, although catches of pink salmon fry were extremely variable at depths below 13.5 ft, there was no evidence of trends in their relative abundance which were consistently associated with depth or time of day. Thus it was assumed that below depths of 13.5 ft pink salmon fry were distributed at random and that samples taken at 13.5 ft by the mobile vertical gear would be representative of fry abundance in the deeper strata.

CALCULATION OF WEIGHTING FACTORS

As outlined above, basic data for the estimation of daily fry abundance at Mission are in the form of fry per unit volume (concentration) at the surface during the 0500-1300 hr period (TABLE 22). Since pink salmon fry were not at all times distributed uniformly from the surface to the bottom of the stream, these basic data must be weighted to account for the non-random distribution. It has been shown that a uniform vertical distribution of fry could be assumed except for the strata above 13.5 ft during daylight hours (0500-2100) before April 9. Suitable measures of the changing distribution during this period may be derived from mean catches in the mobile vertical gear (FIGURES 20-23).

In calculating weighting factors to account for the non-random vertical distribution of pink fry it is also worthwhile to anticipate the final step in the calculation of daily abundance of fry at Mission. In this operation, daily fry abundance will be estimated by the product of the mean daily fry concentration in the channel section and the daily volume of flow or discharge at Mission. However, the vertical distribution of flow is not uniform in the channel section but decreases with depth in proportion to velocity. Thus a unit of fry concentration near the bottom represents less fry per day than the same unit near the surface. To account for the effect of decreasing flow with depth, weighting factors for various strata may be derived from the average velocity profile (FIGURE 9). (In this procedure, the river banks at Mission are considered sufficiently steep to assume a rectangular channel cross-section.) For each depth stratum, at intervals of 3 ft from the surface to the bottom, the mean velocity relative to the surface velocity was estimated (TABLE 11) from the velocity profile.

To calculate appropriate weighting factors for surface catches during daylight in the period up to April 9, the values of relative velocity were first entered into line 1 of TABLE 12 under the corresponding vertical strata. For the four separate periods to April 9, catches of fry in the various strata were interpolated from the corresponding curves (FIGURES 20-23). These catches were weighted by the velocity factor in line 1 and totalled to give a mean catch in the 9 strata. This mean catch (column 12) was divided by the surface catch (column 1) to provide an overall weighting factor (column 13) for surface catches during daylight (0500-2100 hr) in each of the four periods to April 9.

During darkness (2100-0500 hr) up to April 9 and at all periods of the day thereafter, surface catches require adjustment only to account for decreasing velocity with depth. The appropriate weighting factor for these periods is the mean relative velocity (0.876 — TABLE 11). In addition, since surface catches

TABLE 11—Calculation of mean relative velocities at 3-foot intervals of depth at Mission in 1964.

DEPTH IN FEET		FRACTION OF SURFACE VELOCITY		
Stratum	Interval	Upper Limit of Interval[a]	Lower Limit of Interval[a]	Mean Relative Velocity[b]
1.5	0-3	1.00	1.00	1.00
4.5	3-6	1.00	0.980	0.99
7.5	6-9	0.980	0.960	0.97
10.5	9-12	0.960	0.940	0.95
13.5	12-15	0.940	0.905	0.92
16.5	15-18	0.905	0.865	0.89
19.5	18-21	0.865	0.815	0.84
22.5	21-24	0.815	0.730	0.77
25.5	24-bottom	0.730	0.000	0.55
Mean, surface to bottom				0.876

[a] Values interpolated from velocity profile (FIGURE 9).

[b] Values estimated by assuming a linear relationship within each 3 ft interval except that at the bottom, where it was necessary to subdivide into one foot intervals because of the rapid rate of change.

during the 0500-1300 hr period must be weighted so that they are representative of fry concentration throughout the day, the changing vertical distribution of fry in daylight and darkness up to April 9 must be accounted for. This is readily accomplished by a weighted mean of the factors already calculated for daylight hours (TABLE 12) and for darkness (TABLE 11). Thus weighting factors for surface catches of fry have been estimated (TABLE 13, Column C) which take account of all appreciable variables in the vertical dimension during the migration period in 1964.

Lateral Distribution of Fry

Routine sampling by surface gear was carried out at constant positions (lines) within each main longitudinal section of the stream channel (Right Bank, Midstream and Left Bank — FIGURE 6). Before these samples could be combined to estimate the mean daily surface concentration of pink fry (catch per run), it was necessary to examine the distribution of fry within each of the stream sections as well as the distribution across the full width of the channel.

DISTRIBUTION WITHIN STREAM SECTIONS

Information on the distribution of pink fry within each stream section was obtained during regular 8 hr periods in which the surface trap was operated consecutively in four separate positions (including the standard position) within each section. Two sections were fished in this manner each week and, throughout the season, a series of 8 tests was obtained for each section.

TABLE 12—Calculation of weighting factors for surface abundance to account for declining abundance of fry with depth during daylight for the period up to April 9, and to account for reduced discharge with depth[c] at Mission in 1964.

VELOCITY FACTOR[a]	VERTICAL STRATA									TOTAL WEIGHTED CATCH	NO. STRATA	MEAN CATCH	RATIO OF MEAN TO CATCH AT 1.5 FT
	1.5	4.5	7.5	10.5	13.5	16.5	19.5	22.5	25.5				
	1.00	0.99	0.97	0.95	0.92	0.89	0.84	0.77	0.55				
To March 12													
Catch[b]	20.1	6.7	2.3	0.6	0.6	0.6	0.6	0.6	0.6				
Weighted Catch	20.1	6.6	2.2	0.57	0.55	0.53	0.50	0.46	0.33	31.84	9	3.54	0.176
March 16-23													
Catch[b]	47.4	43.5	38.5	29.5	2.5	2.5	2.5	2.5	2.5				
Weighted Catch	47.4	43.1	37.3	28.0	2.3	2.2	2.1	1.9	1.4	165.7	9	18.4	0.388
March 26-April 2													
Catch[b]	108.7	60.5	31.5	12.9	3.3	3.3	3.3	3.3	3.3				
Weighted Catch	108.7	59.9	30.6	12.3	3.0	2.9	2.8	2.5	1.8	224.5	9	24.9	0.229
April 6-9													
Catch[b]	68.5	57.9	44.5	26.1	7.6	7.6	7.6	7.6	7.6				
Weighted Catch	68.5	57.3	43.2	24.8	7.0	6.8	6.4	5.9	4.2	224.1	9	24.9	0.306

[a] From TABLE 10.

[b] From FIGURES 20 to 23 for strata from 1.5 ft to 13.5 ft. Below 13.5 ft, catch assumed to be constant.

[c] In effect, this procedure assumes that the velocity of the net below the surface to 13.5 ft was equivalent to that at the surface. Such an assumption is not strictly true but this has been ignored for the sake of simplicity and because the resulting degree of underestimation is small (in the order of 1% of the fry abundance). Below 13.5 ft, this error does not apply since catch data were weighted to a constant velocity.

TABLE 13—Calculation of overall weighting factors for surface catches of pink fry in the 0500-1300 hr period to account for variable vertical distribution in 1964.

PERIOD	WEIGHTING FACTORS, VERTICAL		
	(A) Daylight[a] (16 hours)	(B) Darkness[b] (8 hours)	(C) 24 Hours $\left[\frac{2A + B}{3}\right]$
To March 12	0.176	0.876	0.409
March 16-23	0.388	0.876	0.551
March 26 - April 2	0.229	0.876	0.445
April 6-9	0.306	0.876	0.496
After April 9	0.876	0.876	0.876

[a] From TABLE 11.
[b] From TABLE 10.

TABLE 14—Comparison of surface catches of pink fry in the standard position (2) and catches in positions 2, 3, 4 and 5 in the Right Bank section at Mission in 1964.

DATE	STANDARD POSITION (2)			ALL POSITIONS (2, 3, 4 & 5)		
	Catch	Runs	Catch/Run (X)	Catch	Runs	Catch/Run (Y)
Feb. 28	24	6	4.00	82	22	3.73
March 10	8	5	1.60	79	21	3.76
20	4	6	0.67	186	24	7.75
31	45	6	7.50	96	23	4.17
April 10	207	6	34.50	648	23	28.17
21	56	7	8.00	319	25	12.76
May 1	307	7	43.86	1,148	25	45.96
21	19	6	3.17	87	23	3.78
Mean			12.91			13.76

Regression coefficient = 0.900
Standard error = 0.0968

By means of a regression analysis, catches per run in the standard position were compared with the combined catch per run in all four positions within each stream section. For example, in the Right Bank section, the regression of catch per run in positions 2, 3, 4 and 5 on catch per run in the standard position (2) indicated a coefficient (slope) of 0.900 (TABLE 14). Since this coefficient did not differ significantly from unity ($p<0.4$), it was concluded that samples taken in the standard position would be representative of fry concentration in the section as a whole. Using similar analyses it was evident that samples taken in the standard positions in the Midstream and Left Bank sections would also be representative of fry concentration within these sections (TABLES 15 and 16). On this basis it was concluded that adjustments of surface catch data for lateral variability within stream sections were not required.

TABLE 15—Comparison of surface catches of pink fry in the standard position (6) and catches in positions 5, 6, 7 & 8 in the Midstream section at Mission in 1964.

DATE	STANDARD POSITION (6)			ALL POSITIONS (5, 6, 7 & 8)		
	Catch	Runs	Catch/Run (X)	Catch	Runs	Catch/Run (Y)
March 3	8	6	1.33	35	24	1.46
13	27	6	4.50	78	22	3.55
24	12	6	2.00	194	22	8.82
April 3	249	6	41.50	829	22	37.68
14	40	6	6.67	121	24	5.04
24	101	6	16.83	406	25	16.24
May 5	154	6	25.67	644	23	28.00
15	10	6	1.67	27	22	1.23
Mean			12.52			12.75

Regression coefficient = 0.910
Standard error = 0.0808

TABLE 16—Comparison of surface catches of pink fry in the standard position (11) and catches in positions 8, 9, 10 & 11 in the Left Bank section at Mission in 1964.

DATE	STANDARD POSITION (11)			ALL POSITIONS (8, 9, 10 & 11)		
	Catch	Runs	Catch/Run (X)	Catch	Runs	Catch/Run (Y)
March 6	7	5	1.40	43	21	2.05
17	6	6	1.00	35	24	1.46
27	19	5	3.80	133	22	6.05
April 7	208	6	34.67	743	25	29.72
17	54	6	9.00	142	25	5.68
28	63	6	10.50	278	26	10.69
May 8	28	6	4.67	95	26	3.65
19	14	5	2.80	99	23	4.30
Mean			8.48			7.95

Regression coefficient = 0.770
Standard error = 0.129

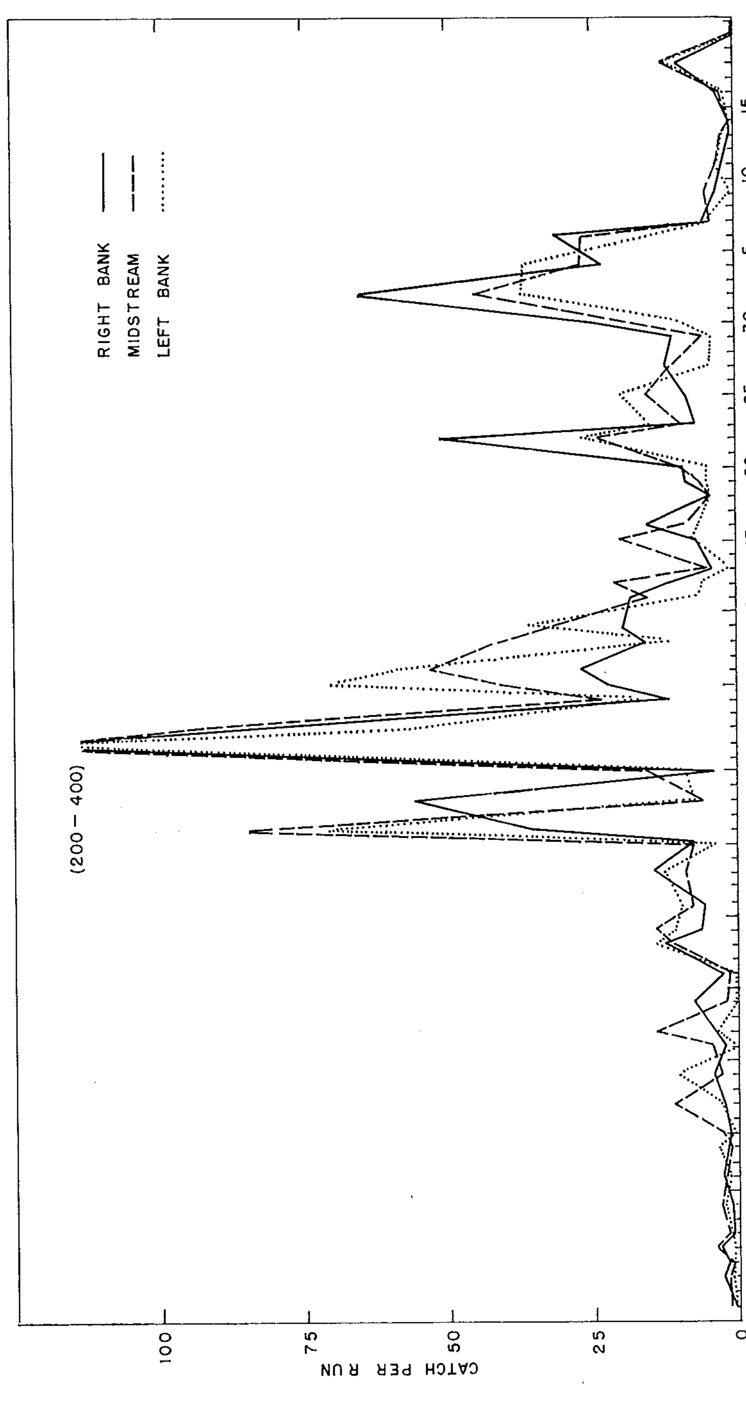

FIGURE 25—Pink fry catches per run in the mobile surface trap during the 0500-1300 hr period at Mission in 1964. Data for each stream section are plotted separately.

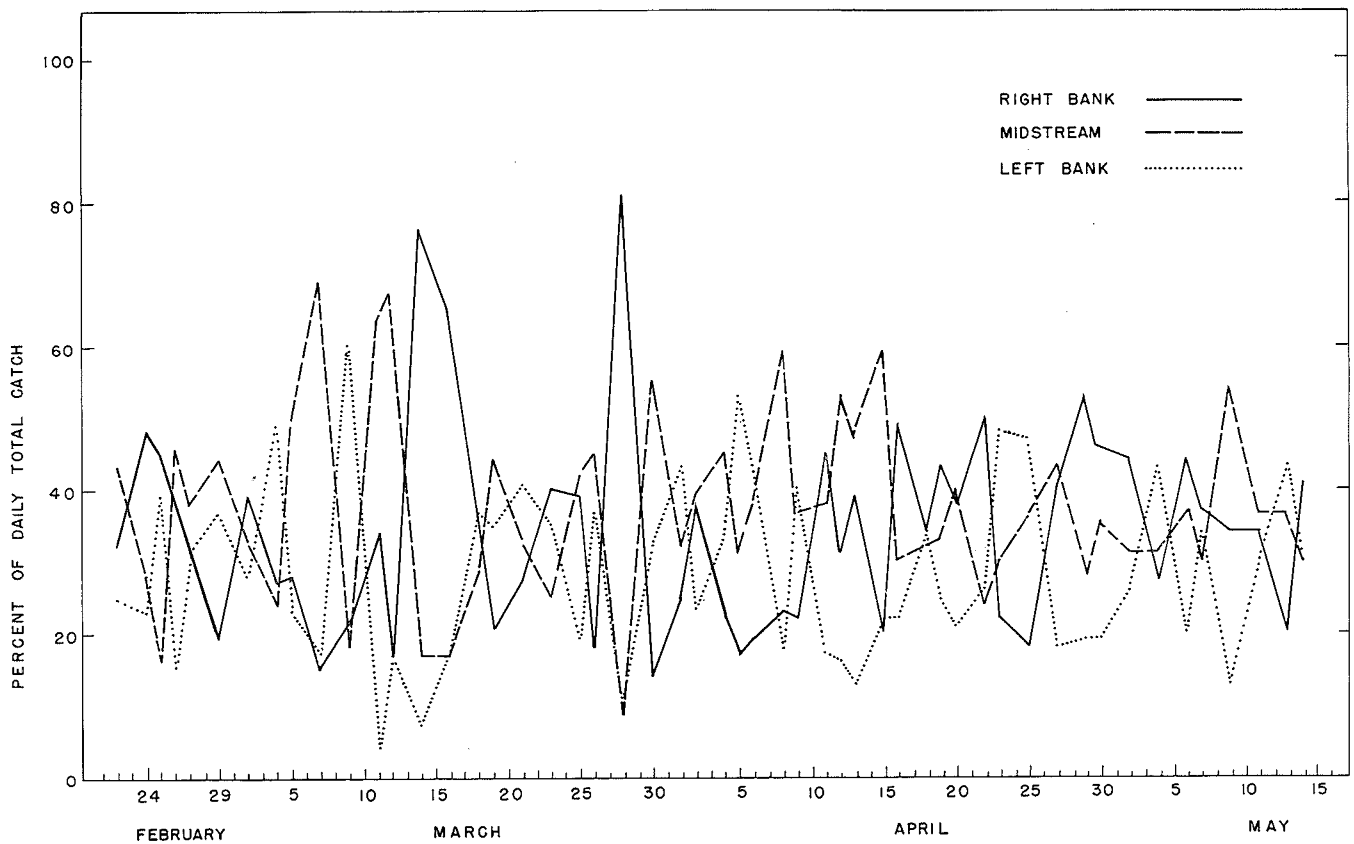

FIGURE 26—Pink fry catches per run in the mobile surface trap during the 0500-1300 hr period at Mission in 1964. Catches in each stream section are expressed as percentages of the combined catch in all sections.

DISTRIBUTION ACROSS THE STREAM CHANNEL

To a large extent, variations in fry concentration throughout the season were similar in each stream section (FIGURE 25). However, because of the great seasonal changes in the abundance of fry, it was difficult to make reliable statistical comparisons of these data between stream sections. To remove the effects of changing abundance, the daily catch per run in each section was expressed as a percentage of the combined (summed) daily catches per run in all sections (FIGURE 26). It can be noted that there are no consistent seasonal trends in the proportions taken in any of the stream sections but that the proportion taken in the Left Bank section appears generally lower than that for the other two sections. A statistical comparison of mean percentages confirmed that the proportion taken in the Left Bank section (28.3%) was significantly lower than that in the Right Bank or Midstream sections (34.3% and 37.4% respectively). On this basis it was concluded that pink fry concentration in the Left Bank section was lower than that in the remainder of the channel and that fry concentrations in the Right Bank and Midstream sections were similar.

As outlined previously, daily fry abundance will be estimated by the product of the mean daily fry concentration in the channel section as a whole and the daily discharge of the river at Mission. Since fry concentration was not uniform across the channel section, the data on concentration (catches per run) in the three sections cannot be combined to provide an unbiased overall daily average concentration unless it can be shown that equivalent volumes of water passed through each of these sections.

For the purpose of this analysis the three channel sections (Right Bank, Midstream and Left Bank) will be considered to be equal in cross-section and approximately equal in shape. (The sections were actually very similar and the boundaries between them were indeterminate.) Thus the fraction of the total daily discharge passing through each section will be proportional to the relative velocity in each section. Using the procedures outlined previously (TABLE 4) surface velocities in the three sections were estimated from the mean distance travelled in 15 min by the mobile gear during the 0500-1300 hr period (TABLE 17). Since fry concentration was similar in the Right Bank and Midstream sections, velocity data for these sections were combined. It can be noted that, early in the season, velocity (and thus relative discharge) was lower in the Left Bank section than in the other two sections but that by the end of the season velocity in the Left Bank section was similar to that in the remainder of the channel. To define this change in more convenient terms the velocity in the Left Bank section was expressed as a fraction of the summed velocities in all three sections (TABLE 17). A seasonal plot of this fraction appeared linear (FIGURE 27) and indicated a highly significant correlation with time ($r = 0.658$). The regression of this fraction (Y) on time (X) was $Y = 0.258 + 0.000892 X$ and this relationship was used to calculate the fraction (Y^1) of the total daily discharge which passed through the Left Bank section. Since the remaining discharge passed through the combined Right Bank and Midstream sections, the

TABLE 17—1964 surface velocities at Mission in the combined Right Bank and Midstream sections and in the Left Bank section as estimated from the mean distance travelled in 15 minutes by the mobile gear during the 0500-1300 hour period. Also shown are the fractions of the total discharge estimated to have passed through the Left Bank section.

DATE	VELOCITY (FT/SEC)		DISCHARGE[a]	DATE	VELOCITY (FT/SEC)		DISCHARGE[a]
	Right Bank & Midstream	Left Bank	Fraction in Left Bank		Right Bank & Midstream	Left Bank	Fraction in Left Bank
Feb. 22	0.89	0.69	0.280	April 16	1.64	1.47	0.310
24	0.81	0.72	0.308	18	1.42	1.21	0.300
26	0.33	0.18	0.214	19	1.39	1.06	0.276
27	0.66	0.56	0.298	20	1.68	1.54	0.315
				22	1.29	1.26	0.327
March 2	0.48	0.37	0.278	23	1.80	1.76	0.329
4	0.49	0.28	0.222	25	1.07	1.12	0.343
5	1.05	0.79	0.274	27	1.44	1.19	0.292
7	0.80	0.65	0.237	29	1.34	1.08	0.287
9	0.82	0.80	0.329	30	1.75	1.51	0.301
12	0.50	0.57	0.363				
16	0.63	0.45	0.262	May 2	1.43	1.41	0.331
19	0.92	0.62	0.252	4	1.77	1.59	0.310
21	0.63	0.42	0.249	6	1.54	1.65	0.349
23	1.46	1.32	0.311	7	2.21	2.03	0.314
26	0.55	0.44	0.288	9	2.31	2.16	0.319
28	0.39	0.29	0.274	11	2.68	2.97	0.356
30	1.00	0.86	0.301	13	2.48	2.94	0.373
				14	3.41	3.75	0.354
April 1	0.59	0.42	0.262	16	2.94	3.21	0.354
2	1.02	0.83	0.288	18	3.30	3.93	0.373
4	0.68	0.56	0.293	20	2.96	3.22	0.352
5	0.88	0.73	0.294	21	3.10	3.24	0.344
6	1.28	1.13	0.306	22	3.48	3.38	0.327
8	0.91	0.79	0.303	23	3.33	3.39	0.338
9	1.40	1.45	0.341	25	3.71	3.81	0.340
11	0.93	0.56	0.232	26	3.70	3.83	0.341
12	0.69	0.53	0.277	27	3.61	3.78	0.344
13	1.40	1.10	0.283	28	3.72	3.55	0.323
15	1.19	0.83	0.258	29	3.83	3.79	0.331

[a] Velocity in the Left Bank section divided by the sum of velocities in all three sections.

TABLE 18—Weighting of surface catches of pink fry during the 0500-1300 hour period at Mission for changes in the lateral distribution of discharge in 1964.

DATE		CATCH PER RUN				WEIGHTING FACTOR		WEIGHTED CATCHES		
		Left Bank	Right Bank	Mid-stream	Mean R. B. & Midstream	L.B.	R.B. & M.	Left Bank	Right Bank & Midstream	Total
Feb.	22	0.57	0.75	1.00	0.88	0.259	0.741	0.15	0.65	0.80
	24	1.29	2.67	1.57	2.12	0.261	0.739	0.34	1.57	1.91
	25	1.25	1.43	0.50	0.97	0.262	0.738	0.33	0.72	1.05
	26	1.12	2.88	3.38	3.13	0.262	0.738	0.29	2.31	2.60
	27	1.29	1.29	1.57	1.43	0.263	0.737	0.34	1.05	1.39
	29	2.43	1.25	2.86	2.05	0.265	0.735	0.64	1.51	2.15
March	2	1.67	2.33	2.00	2.17	0.267	0.733	0.45	1.59	2.04
	4	3.38	1.88	1.62	1.75	0.269	0.731	0.91	1.28	2.19
	5	1.17	1.43	2.50	1.97	0.270	0.730	0.32	1.44	1.76
	7	2.75	2.38	11.12	6.75	0.271	0.729	0.74	4.92	5.66
	9	10.83	4.00	3.33	3.67	0.273	0.727	2.96	2.67	5.63
	11	0.25	2.40	4.50	3.45	0.275	0.725	0.07	2.50	2.57
	12	3.53	3.50	14.00	8.75	0.276	0.724	0.97	6.34	7.31
	14	0.71	7.75	1.71	4.73	0.278	0.722	0.20	3.41	3.61
	16	0.83	3.14	0.83	1.99	0.279	0.721	0.23	1.43	1.66
	18	14.43	13.00	11.29	12.15	0.281	0.719	4.05	8.74	12.79
	19	11.00	6.71	14.17	10.44	0.282	0.718	3.10	7.50	10.60
	21	9.50	6.25	7.62	6.94	0.284	0.716	2.70	4.97	7.67
	23	12.71	14.57	9.00	11.78	0.286	0.714	3.64	8.41	12.05
	25	3.57	7.25	7.71	7.48	0.287	0.713	1.02	5.33	6.35
	26	70.83	34.83	84.67	59.75	0.288	0.712	20.40	42.54	62.94
	28	7.29	55.50	6.12	30.81	0.290	0.710	2.11	21.88	23.99
	30	9.17	4.00	15.83	9.92	0.292	0.708	2.68	7.02	9.70
April	1	406.28	239.28	309.28	274.28	0.293	0.707	119.04	193.39	312.43
	2	54.17	90.43	92.43	91.43	0.294	0.706	15.93	64.55	80.48
	4	17.57	11.53	23.62	17.58	0.295	0.705	5.18	12.39	17.57
	5	70.00	22.00	41.25	31.62	0.296	0.704	20.72	22.26	42.98
	6	59.14	26.88	53.14	40.01	0.297	0.703	17.56	28.13	45.69
	8	12.29	15.88	41.00	28.44	0.299	0.701	3.67	19.94	23.61
	9	35.86	19.88	33.00	26.44	0.300	0.700	10.76	18.51	29.27
	11	6.71	18.12	15.25	16.69	0.302	0.698	2.03	11.65	13.68
	12	6.33	11.86	20.67	16.27	0.303	0.697	1.92	11.34	13.26

TABLE 18—Continued.

DATE		CATCH PER RUN				WEIGHTING FACTOR		WEIGHTED CATCHES		
		Left Bank	Right Bank	Mid-stream	Mean R. B. & Midstream	L.B.	R.B. & M.	Left Bank	Right Bank & Midstream	Total
April	13	1.50	4.43	5.33	4.88	0.303	0.697	0.45	3.40	3.85
	15	7.43	6.75	20.12	13.44	0.305	0.695	2.26	9.34	11.60
	16	6.71	15.25	9.25	12.25	0.306	0.694	2.05	8.50	10.55
	18	4.88	4.88	4.62	4.75	0.303	0.692	1.50	3.29	4.79
	19	5.00	8.62	6.62	7.62	0.309	0.691	1.55	5.27	6.82
	20	5.00	9.00	9.50	9.25	0.310	0.690	1.55	6.38	7.93
	22	26.88	51.00	24.12	37.56	0.312	0.688	8.39	25.84	34.23
	23	15.00	6.86	9.50	8.18	0.312	0.688	4.68	5.63	10.31
	25	19.75	7.50	15.25	11.37	0.314	0.686	6.20	7.80	14.00
	27	4.71	10.71	11.43	11.07	0.316	0.684	1.49	7.57	9.06
	29	4.00	11.25	6.00	8.63	0.318	0.682	1.27	5.89	7.16
	30	10.14	25.25	19.12	22.18	0.319	0.681	3.23	15.10	18.33
May	2	37.75	65.25	45.13	55.19	0.320	0.680	12.08	37.53	49.61
	4	37.43	23.75	27.00	25.38	0.322	0.678	12.05	17.21	29.26
	6	14.14	31.50	26.63	29.06	0.324	0.676	4.58	19.64	24.22
	7	5.29	5.75	4.63	5.19	0.325	0.675	1.72	3.50	5.22
	9	1.25	3.38	5.38	4.38	0.327	0.673	0.41	2.95	3.36
	11	2.67	3.00	3.29	3.15	0.328	0.672	0.88	2.12	3.00
	13	2.14	1.00	1.86	1.43	0.330	0.670	0.71	0.96	1.67
	14	0.83	1.14	0.83	0.99	0.331	0.669	0.27	0.66	0.93
	16	1.86	3.00	1.88	2.44	0.333	0.667	0.62	1.63	2.25
	18	11.83	10.14	13.29	11.71	0.335	0.665	3.96	7.79	11.75
	20	0.50	0.38	0.13	0.25	0.336	0.664	0.17	0.17	0.34
	21	0.63	0.12	0.63	0.38	0.337	0.663	0.21	0.25	0.46
	22	0.29	0.00	0.37	0.19	0.338	0.662	0.10	0.13	0.23
	23	0.00	0.00	0.13	0.06	0.339	0.661	0.00	0.04	0.04
	25	0.14	0.13	0.00	0.07	0.341	0.659	0.05	0.05	0.10
	26	0.00	0.00	0.28	0.14	0.342	0.658	0.00	0.09	0.09
	27	0.00	0.25	0.00	0.13	0.343	0.657	0.00	0.08	0.08
	28	0.00	0.12	0.13	0.12	0.344	0.656	0.00	0.08	0.08
	29	0.14	0.13	0.00	0.07	0.345	0.655	0.05	0.05	0.10

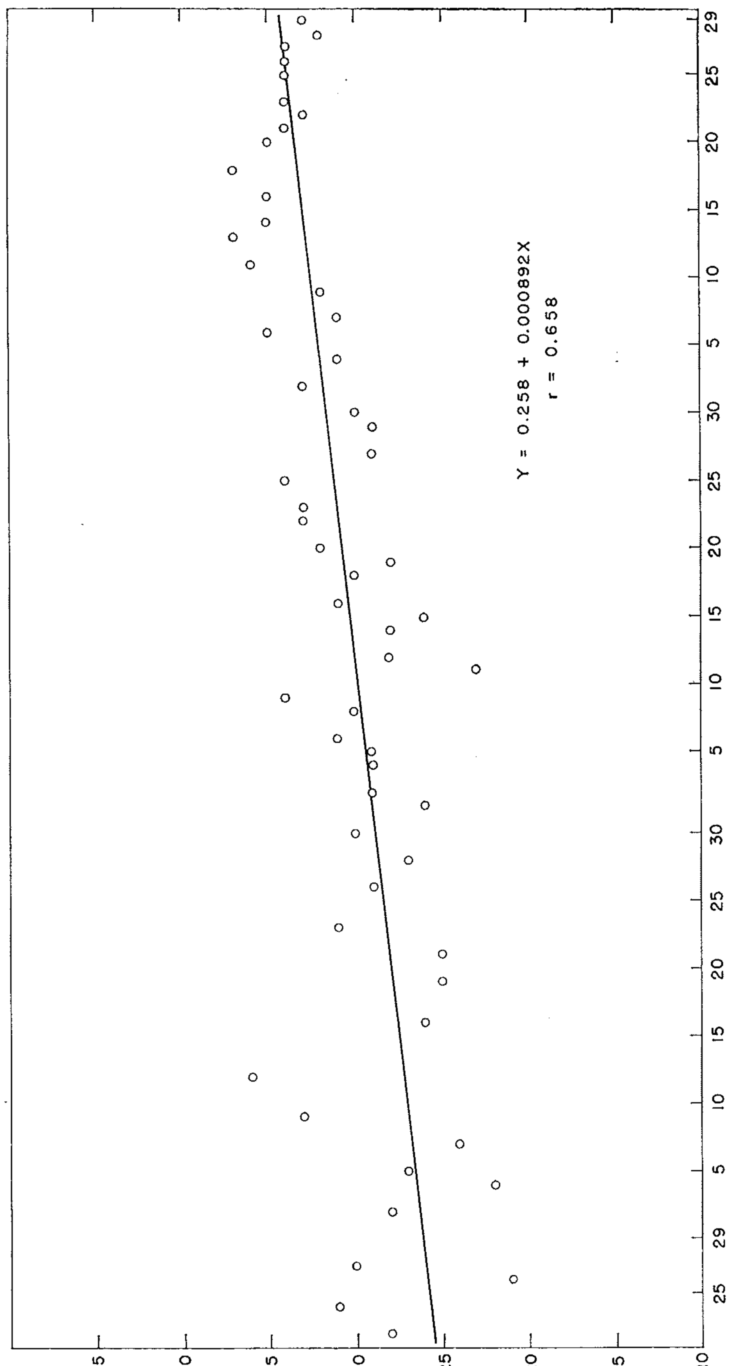

FIGURE 27—Seasonal change in the fraction of the total discharge which passed through the Left Bank section of the channel at Mission in 1964 as estimated by a comparison of the velocities in the three stream sections. (From Table 16.)

daily fraction of the discharge passing through these sections was estimated by $1\text{-}Y^1$. These fractions were used to weight the surface catches in the respective sections (TABLE 18) before they were combined. Thus the lack of lateral uniformity in fry concentration and in stream flow were accounted for in estimating the mean daily surface concentration of fry during the 0500-1300 hr period.

Diurnal Variability of Fry Abundance

Since it was apparent that marked changes in the abundance of pink fry occurred during any one day, to estimate the mean daily fry concentration it was necessary to weight the mean catch per run during the standard sampling period (0500-1300 hr) so that it would be representative of fry concentration over a full 24 hr period. For this purpose the pertinent statistic is the ratio of the mean catch per run during the 0500-1300 hr period to the mean catch per run during the corresponding 24 hr period. (Catch-per-run data during the early season period to April 9 were first weighted to remove the effects of diurnal variation in vertical distribution, using the information previously developed in TABLE 12.) This ratio was computed for each of the twice weekly, 24 hr fishing period throughout the season (FIGURE 28).

It can be noted (FIGURE 28) that very large fluctuations in the ratio occurred, particularly during the early portion of the season when catches tended to be erratic because of the schooling behavior of fry in the prevailing clear water. Although they were not significantly correlated one with another ($p>0.05$), the ratios in the three stream sections tended to vary together. Since there was no evidence for consistent seasonal trends in the ratios and, since the mean seasonal ratios did not differ significantly between stream sections, data for all three sections were combined to provide an overall mean daily ratio.

Values for the mean ratio ranged from 0.17 to 1.72 and, although much of this variability was obviously the result of sampling error, it was possible that a portion of the variability was due to real day-to-day differences in the proportion of fry migrating during the 0500-1300 hr period. Since the individual spawning areas were situated at varying distances upstream it was possible that the changing relative abundance of fry emanating from these areas could influence the hourly abundance of fry at Mission because of differences in daily arrival times. However no relationship was evident between the daily abundance of pink fry migrating from either Harrison or Vedder River spawning areas (which together contributed about one-third of the total fry at Mission) and the fluctuating values of the ratio. Similarly, no relationship was apparent with mean daily stream discharge or velocity.

A more detailed examination of day-to-day variability of the ratio (using catches per run in each stream section as the bases of independent estimates of the daily ratio) indicated that all daily estimates of the ratio had fiducial limits (0.05 level) which overlapped the mean seasonal ratio of 0.830. It was concluded that the day-to-day variability was entirely due to vagaries of sampling and that the overall mean value of 0.830 provided the best estimate of the ratio through-

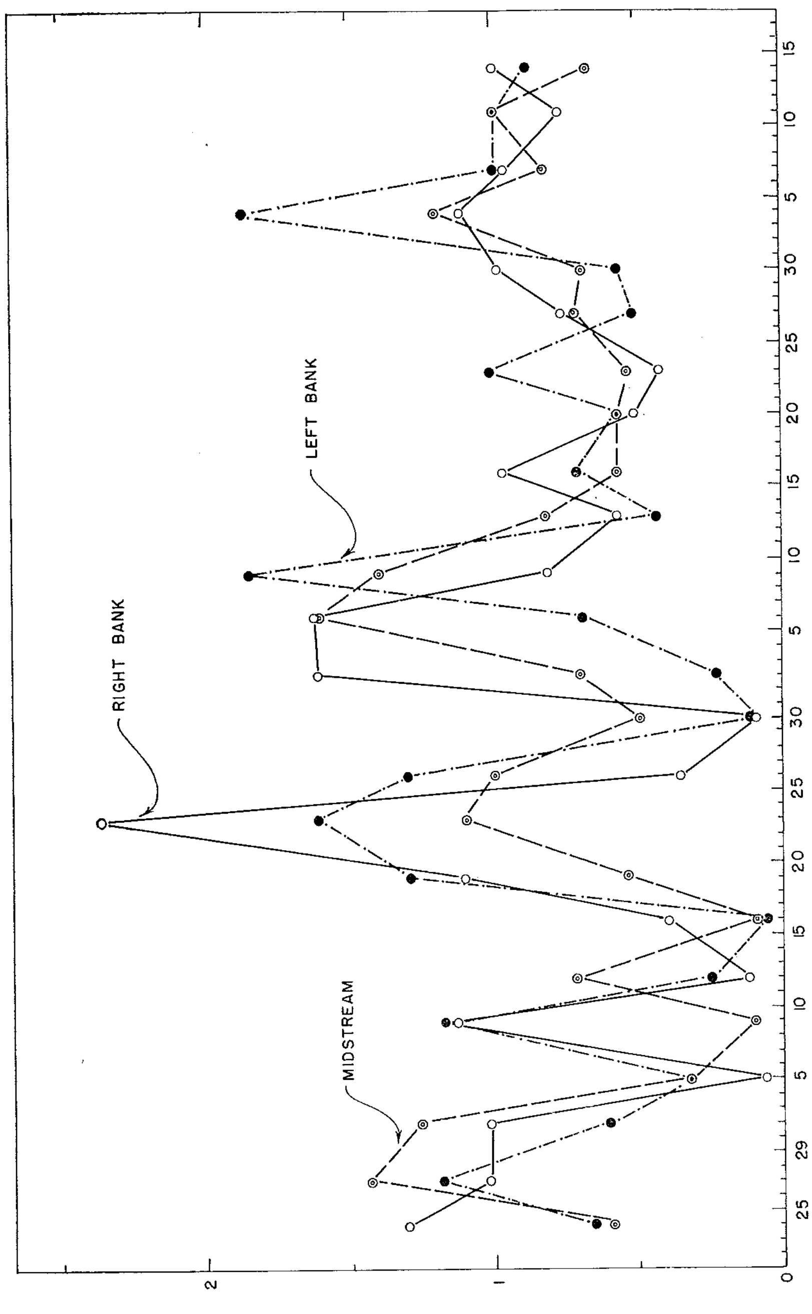

FIGURE 28—Pink fry catch per run in the surface trap during the 0500-1300 hr period at Mission in 1964 expressed in ratio to catch per run in the corresponding 24-hr period. Data for each stream section plotted separately.

out the season. Thus the concentration of pink fry during 0500-1300 hr periods must be multiplied by the reciprocal of this ratio (1.205) to estimate surface concentration during corresponding 24 hr periods.

Estimation of Daily Abundance

In the previous sections the relative abundance of pink fry in the stream channel at Mission was examined in the vertical, lateral and temporal planes and suitable factors computed to account for their non-random distribution in each of these dimensions. However, before proceeding to apply these factors in estimating daily abundance, it was necessary to examine evidence that basic catch data required adjustment for loss of intercepted pink fry through the meshes of the inclined plane in the mobile trap.

During twice weekly 24 hr periods the surface net of the mobile vertical gear (FIGURE 4) and the mobile surface trap were operated simultaneously on opposite sides of the propelling vessel (FIGURE 5). Since the surface net consisted of closely woven bobbinet, it could be assumed that all fry intercepted by this gear would be retained and therefore a comparison of simultaneous catches in the net and trap provided a means of accounting for any loss of fry from the trap during the standard 0500-1300 hr sampling period.

Since the effective cross-sectional area of the mobile trap was 13.33 sq ft and that of the net was 10 sq ft, pink fry catches in the surface net during the 0500-1300 hr period were adjusted upward by a factor of 1.333 (TABLE 19). The ratio of these adjusted catches to the catches in the mobile trap were plotted (FIGURE 29). Although there was no significant linear trend with time ($r = 0.301$), it was apparent that variability was extremely high during the early portion of the season to April 13, when fry tended to be schooled, and was much less variable during the remainder of the season. The mean ratio for the early period (2.89) was significantly higher ($p<0.01$) than that for the later period (1.27). Consequently separate adjustment factors were computed for these two periods from the total catches by each gear (TABLE 19). Thus, to account for loss of pink fry through the inclined plane of the mobile trap, catches in this gear must be increased by a factor of 2.04 during the period up to April 13 and by a factor of 1.22 thereafter.

The volume of river discharge at Mission varied from day to day (TABLE 3) and consequently the constant volume sampled in the standard 15 min run by the mobile trap constituted a variable fraction of the total river discharge. Thus, in estimating the daily abundance of pink salmon fry it was necessary to account for the fluctuating relationship between the volume of water sampled and the volume of river discharge. To simplify the computation, the amount of water which was passed through the mobile trap during the standard 15 min run was retained as the unit of volume.

TABLE 19—Comparison of simultaneous pink fry catches in the mobile surface net and in the mobile trap during the 0500-1300 hour period at Mission in 1964.

DATE		A SURFACE NET CATCH	B ADJUSTED NET CATCH (A x 1.333)	C TRAP CATCH	RATIO B/C
Feb.	27	48	64	29	2.21
March	2	51	68	36	1.89
	5	99	132	32	4.13
	9	360	480	113	4.25
	12	302	403	317	1.27
	16	100	133	32	4.16
	19	227	303	198	1.53
	23	871	1,161	254	4.57
	26	1,076	1,435	1,142	1.26
	30	394	525	178	2.95
April	2	1,958	2,611	1,605	1.63
	6	1,961	2,615	1,001	2.61
	9	837	1,116	641	1.74
	13	340	453	72	6.29
Subtotal			11,499	5,650	2.04
April	16	212	283	236	1.20
	20	191	255	183	1.39
	23	251	335	219	1.53
	27	144	192	188	1.02
	30	421	561	426	1.32
May	4	620	827	668	1.24
	7	92	123	120	1.03
	11	60	80	60	1.33
	14	26	35	18	1.94
	18	128	171	235	0.73
Subtotal			2,862	2,353	1.22
GRAND TOTAL			14,361	8,003	1.79

The effective frontal area of the mobile trap (FIGURE 3) was 13.333 sq ft, the duration of a run was 15 min (900 sec) and the average velocity inside the trap mouth was 2.61 ft/sec (TABLE 1). Thus the volume sampled per run was:

$$(13.333 \text{ sq ft} \times 2.61 \text{ ft/sec} \times 900 \text{ sec}) = 31{,}319 \text{ cu ft.}$$

In any one day, the number of pink fry (N) which passed through the channel at Mission was given by:

$$N = (C/31{,}319)\ 86{,}400Q = C(2.7587Q) \quad \ldots \quad (1);$$

where C = mean catch of pink fry per run,

Q = river discharge in cu ft/sec (TABLE 3) and

86,400 = number of seconds in one day.

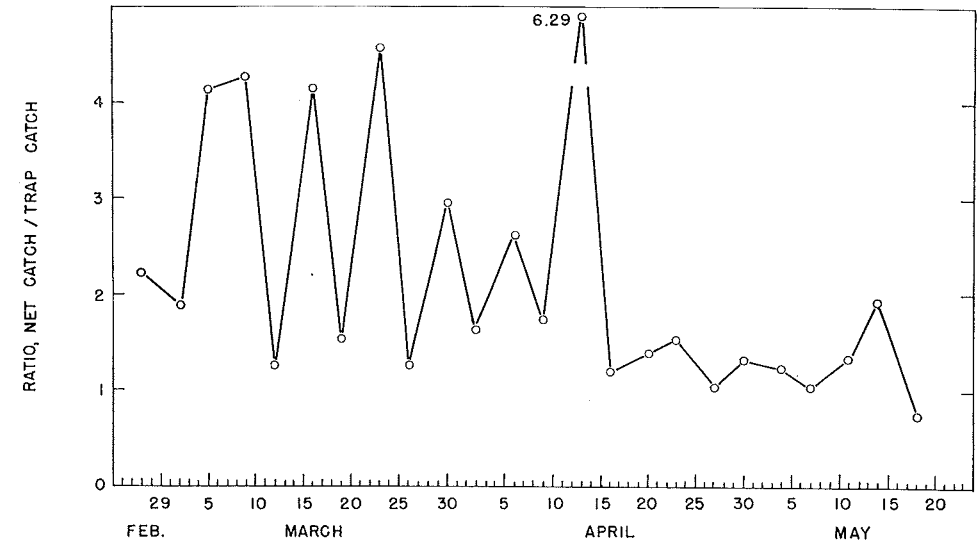

FIGURE 29—Ratio of pink fry catches in the mobile surface net to catches taken simultaneously in the mobile trap during the 0500-1300 hr period at Mission in 1964.

Steps in the calculation of daily fry abundance are given in TABLE 20. The mean numbers of fry per run in the mobile trap during the 0500-1300 hr period (taken from TABLE 18, where adjustments were made for non-random lateral distribution) are given in Column 1. These data are adjusted by factors for loss of fry in the trap and for non-random vertical and diurnal distribution (Columns 2-4) to provide estimates of the average daily concentration (catch per run) throughout the channel section. In turn, these estimates (not listed) are multiplied, as shown in Equation 1, by 2.7587 Q (Column 5) to give estimates of daily abundance (Column 6). A smooth curve was drawn visually through a plot of these data (FIGURE 30) and interpolations were made on this curve for days in which catch per run data were not available. The total number of pink salmon fry migrating from the Fraser at Mission in 1964 was estimated to be 284.2 million (TABLE 20).

ESTIMATION OF FRY ABUNDANCE IN 1962

In 1962 daily samples of pink fry were taken with the mobile trap between 0500 hr and 1300 hr during the period March 9 to May 25. In addition, pink fry were sampled with the mobile trap and to depths of 10.5 ft with a mobile vertical gear (see above) during a series of eleven 24 hr periods between April 5 and May 14. With the methods developed for the 1964 data, the more restricted information on the 1962 migration was examined and an estimate made of the abundance of fry in that year.

TABLE 20—Calculation of daily abundance of pink fry migrating downstream in the Fraser River at Mission in 1964.

DATE	1	2	3	4	5	6
		ADJUSTMENT FACTORS				
	MEAN FRY PER RUN[a]	Trap Loss	Vertical[b]	Diurnal	Discharge[c] (2.7587 Q)	FRY ABUNDANCE[d]
Feb. 22	0.80	2.04	0.409	1.205	102,982	82,828
23	—	—	—	—	—	110,000
24	1.91	2.04	0.409	1.205	103,093	197,958
25	1.05	2.04	0.409	1.205	102,265	107,959
26	2.60	2.04	0.409	1.205	100,968	263,935
27	1.39	2.04	0.409	1.205	99,865	139,562
28	—	—	—	—	—	180,000
29	2.15	2.04	0.409	1.205	97,824	211,456
March 1	—	—	—	—	—	205,000
2	2.04	2.04	0.409	1.205	98,182	201,373
3	—	—	—	—	—	207,000
4	2.19	2.04	0.409	1.205	97,713	215,147
5	1.76	2.04	0.409	1.205	102,624	181,594
6	—	—	—	—	—	350,000
7	5.66	2.04	0.409	1.205	97,713	556,042
8	—	—	—	—	—	550,000
9	5.63	2.04	0.409	1.205	93,906	531,546
10	—	—	—	—	—	400,000
11	2.57	2.04	0.409	1.205	93,713	242,143
12	7.31	2.04	0.409	1.205	94,899	697,457
13	—	—	—	—	—	650,000
14	3.61	2.04	0.551	1.205	95,699	347,339
15	—	—	—	—	—	180,000
16	1.66	2.04	0.551	1.205	99,396	165,888
17	—	—	—	—	—	900,000
18	12.79	2.04	0.551	1.205	102,320	1,315,740
19	10.60	2.04	0.551	1.205	99,975	1,065,454
20	—	—	—	—	—	875,000
21	7.67	2.04	0.551	1.205	95,037	732,870
22	—	—	—	—	—	900,000
23	12.05	2.04	0.551	1.205	93,023	1,126,980
24	—	—	—	—	—	900,000
25	6.35	2.04	0.445	1.205	88,196	626,130
26	62.94	2.04	0.445	1.205	87,616	6,165,266
27	—	—	—	—	—	4,400,000
28	23.99	2.04	0.445	1.205	89,134	2,390,645
29	—	—	—	—	—	1,180,000
30	9.70	2.04	0.445	1.205	89,216	967,512
31	—	—	—	—	—	23,000,000
April 1	312.43	2.04	0.445	1.205	108,831	38,014,309
2	80.48	2.04	0.445	1.205	107,203	9,645,766
3	—	—	—	—	—	3,800,000
4	17.57	2.04	0.471	1.205	111,920	2,276,738
5	42.98	2.04	0.496	1.205	116,721	6,116,673
6	45.69	2.04	0.496	1.205	121,410	6,763,563
7	—	—	—	—	—	5,200,000
8	23.61	2.04	0.496	1.205	142,845	4,112,073
9	29.27	2.04	0.496	1.205	151,453	5,405,059
10	—	—	—	—	—	5,300,000
11	13.68	2.04	0.876	1.205	166,598	4,907,684
12	13.26	2.04	0.876	1.205	169,853	4,849,952
13	3.85	2.04	0.876	1.205	178,819	1,482,501
14	—	—	—	—	—	2,500,000
15	11.60	1.22	0.876	1.205	194,433	2,904,556
16	10.55	1.22	0.876	1.205	192,088	2,609,782

TABLE 20—Continued.

	1	2	3	4	5	6
DATE		ADJUSTMENT FACTORS				
	MEAN FRY PER RUN[a]	Trap Loss	Vertical[b]	Diurnal	Discharge[c] (2.7587 Q)	FRY ABUNDANCE[d]
April 17	—	—	—	—	—	1,650,000
18	4.79	1.22	0.876	1.205	182,626	1,126,549
19	6.82	1.22	0.876	1.205	180,778	1,587,749
20	7.93	1.22	0.876	1.205	179,757	1,835,738
21	—	—	—	—	—	4,200,000
22	34.23	1.22	0.876	1.205	182,129	8,028,563
23	10.31	1.22	0.876	1.205	184,612	2,451,153
24	—	—	—	—	—	2,850,000
25	14.00	1.22	0.876	1.205	187,040	3,372,208
26	—	—	—	—	—	2,900,000
27	9.06	1.22	0.876	1.205	192,999	2,251,827
28	—	—	—	—	—	1,900,000
29	7.16	1.22	0.876	1.205	197,826	1,824,098
30	18.33	1.22	0.876	1.205	199,344	4,705,626
May 1	—	—	—	—	—	9,600,000
2	49.61	1.22	0.876	1.205	200,723	12,823,842
3	—	—	—	—	—	11,000,000
4	29.26	1.22	0.876	1.205	215,868	8,134,191
5	—	—	—	—	—	7,700,000
6	24.22	1.22	0.876	1.205	235,372	7,341,431
7	5.22	1.22	0.876	1.205	261,497	1,757,879
8	—	—	—	—	—	1,500,000
9	3.36	1.22	0.876	1.205	345,472	1,494,872
10	—	—	—	—	—	1,500,000
11	3.00	1.22	0.876	1.205	397,142	1,534,330
12	—	—	—	—	—	1,450,000
13	1.67	1.22	0.876	1.205	448,123	963,752
14	0.93	1.22	0.876	1.205	437,419	523,881
15	—	—	—	—	—	530,000
16	2.25	1.22	0.876	1.205	449,282	1,301,827
17	—	—	—	—	—	4,300,000
18	11.75	1.22	0.876	1.205	445,502	6,741,233
19	—	—	—	—	—	2,700,000
20	0.34	1.22	0.876	1.205	491,573	215,238
21	0.46	1.22	0.876	1.205	527,657	312,580
22	0.23	1.22	0.876	1.205	565,975	167,640
23	0.04	1.22	0.876	1.205	574,306	29,584
24	—	—	—	—	—	50,000
25	0.10	1.22	0.876	1.205	587,796	75,697
26	0.09	1.22	0.876	1.205	589,258	68,297
27	0.08	1.22	0.876	1.205	590 638	60,850
28	0.08	1.22	0.876	1.205	602,224	62,044
29	0.10	1.22	0.876	1.205	625,177	80,511
30	—	—	—	—	—	60,000
31	—	—	—	—	—	40,000
June 1	—	—	—	—	—	20,000
Total						284,231,670

[a] Adjusted for non-random lateral distribution (TABLE 18).

[b] From TABLE 13.

[c] From TABLE 3.

[d] Interpolated from abundance curve (FIGURE 30) for days in which catch per run data were not available.

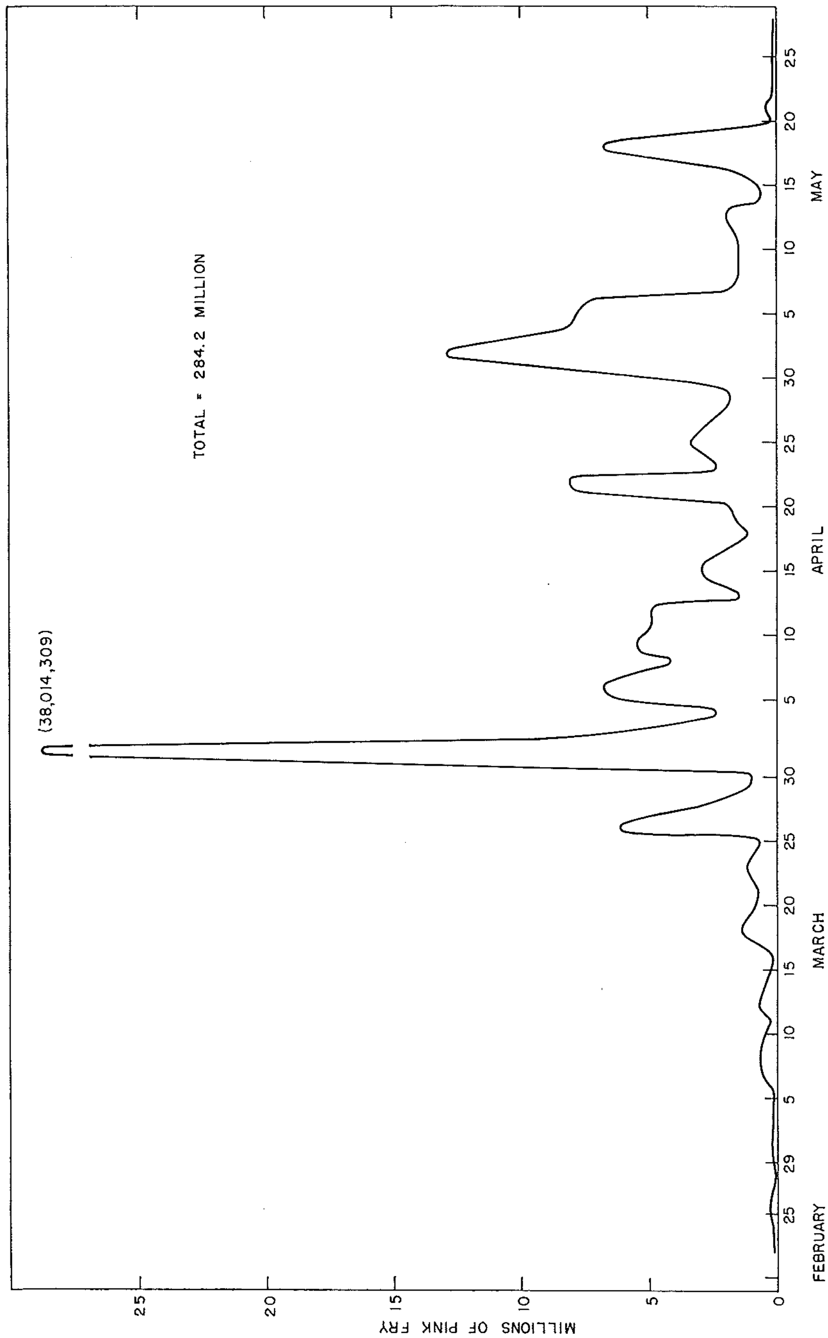

FIGURE 30—Numbers of pink salmon fry migrating from the Fraser River in 1964 as estimated from samples taken at Mission.

Vertical Distribution of Fry

In 1962 the mean catches per run at 1.5, 4.5, 7.5 and 10.5 ft depths showed no consistent seasonal trends in any of the three daily 8 hr periods. An examination of catches per run at the surface (1.5 ft), expressed as percentages of the summed catches per run at all depths (as in 1964), indicated no statistically significant differences between 8 hr periods in the pattern of vertical distribution. Consequently, data for the three 8 hr periods were combined (TABLE 21) and the seasonal mean catches at each depth compared. Although considerable variation occurred, no statistically significant differences between depth strata were apparent and it was concluded that, between April 5 and May 14 in 1962, pink fry were distributed at random from the surface to depths of 10.5 ft.

TABLE 21—Mean catch of pink fry per 15-minute run[a] in the mobile vertical gear during 24-hour periods at Mission in 1962.

DATE	DEPTH STRATUM			
	1.5′	4.5′	7.5′	10.5′
April 5	14.2	22.5	15.2	14.0
9	5.6	9.5	9.6	7.0
12	5.0	6.5	7.2	5.6
16	5.8	7.3	7.3	6.1
19	6.4	11.1	8.5	6.9
23	3.2	7.9	7.1	6.5
26	4.7	6.0	7.2	5.8
30	2.8	4.1	4.3	4.2
May 3	3.3	5.1	6.4	6.4
7	6.7	2.7	3.7	4.1
14	7.0	1.9	2.7	3.0
Mean	5.88	7.69	7.20	6.33

[a] In each 24 hr period, 15 to 20 runs were usually made at each depth below the surface and 50 to 60 runs on the surface (1.5 ft).

Water transparency was not measured in 1962 but field observations indicated that, in contrast to conditions in 1964 (FIGURE 10), no extended period of clear water occurred early in the season. Thus it appeared unlikely that fry were concentrated near the surface during a significant period in 1962. Moreover, since the 1964 sampling program indicated that fry were distributed at random at all times below depths of 13.5 ft, a random distribution of fry concentration from the surface to the bottom could be assumed throughout the season in 1962. Thus, to be representative of pink fry abundance in the vertical dimension, surface catches per run in 1962 required adjustment only for decreasing discharge with depth (by a factor of 0.876 — TABLE 13).

Lateral Distribution of Fry

As in 1964, surface fry concentration was sampled with the mobile trap, operated successively in the Right Bank, Midstream and Left Bank sections during the 0500-1300 hr period daily. Since no lateral sampling was conducted within individual sections in 1962, the basic surface data were more continuous than in 1964. The daily catch per run in each section was again expressed as a percentage of the summed catches per run in all sections. A comparison of mean seasonal percentages indicated statistically significant differences between the proportion taken in the Right Bank section (41.4%), the Midstream section (32.7%) and the Left Bank section (25.9%). Thus, before these estimates of fry concentration could be grouped to provide a basis for the calculation of average abundance, it was necessary to weight these data by the fraction of the total daily discharge which passed through each section, using procedures similar to those used in 1964.

The proportion of the discharge passing through each section was estimated from the relative velocity in each section which in turn was computed from the mean distance per run travelled by the mobile gear during the 0500-1300 hr period. In each stream section, discharge fractions were significantly correlated with time and therefore regression equations were calculated (FIGURES 31 to 33). Daily discharge fractions computed from the regression equations were used to weight the catch data in each section and thence to estimate the mean weighted surface concentration (catch per run) of pink fry in 1962 (TABLE 22).

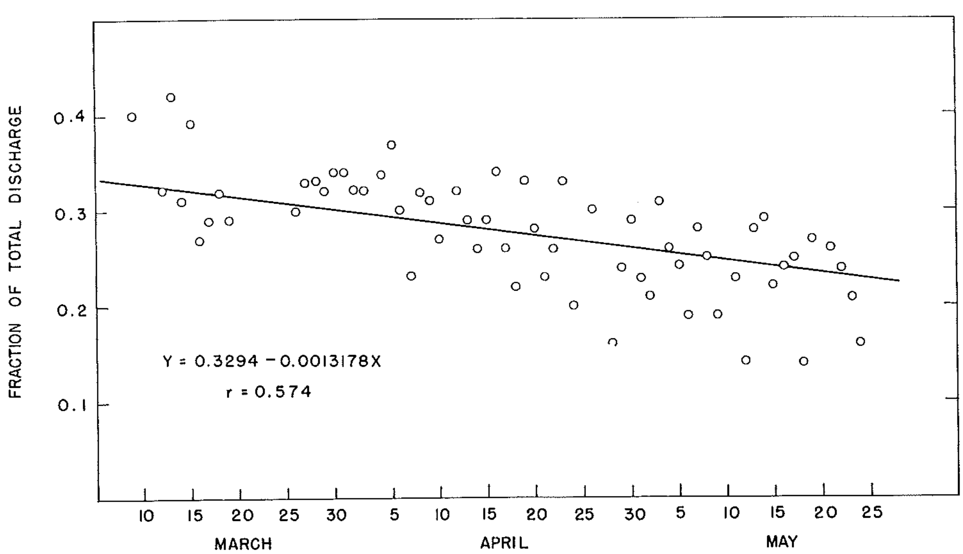

FIGURE 31—Seasonal change in the fraction of the total discharge which passed through the Right Bank section at Mission in 1962 as estimated by a comparison of the velocities in the three stream sections.

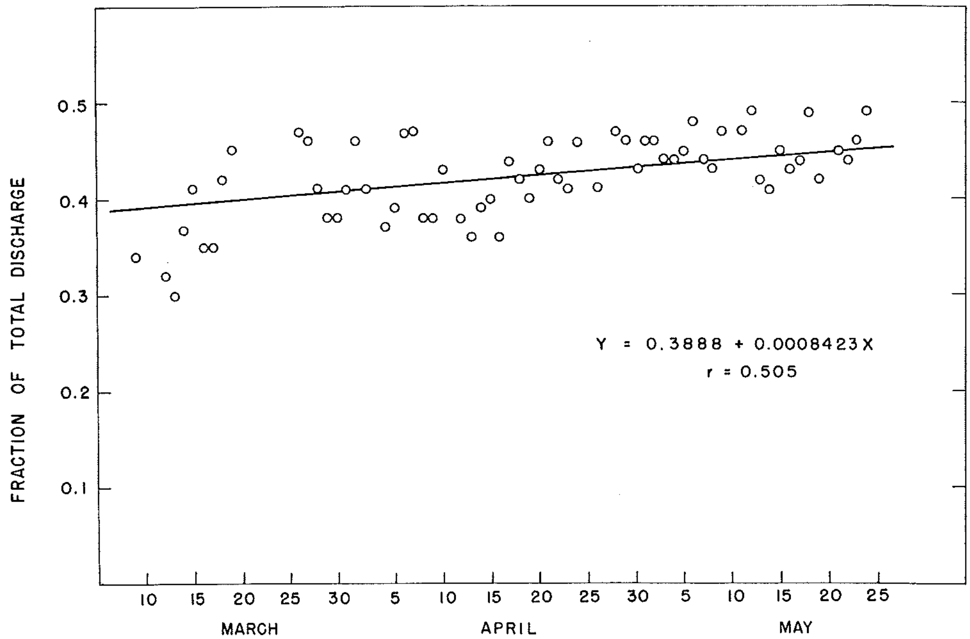

FIGURE 32—Seasonal change in the fraction of the total discharge which passed through the Midstream section at Mission in 1962 as estimated by a comparison of the velocities in the three stream sections.

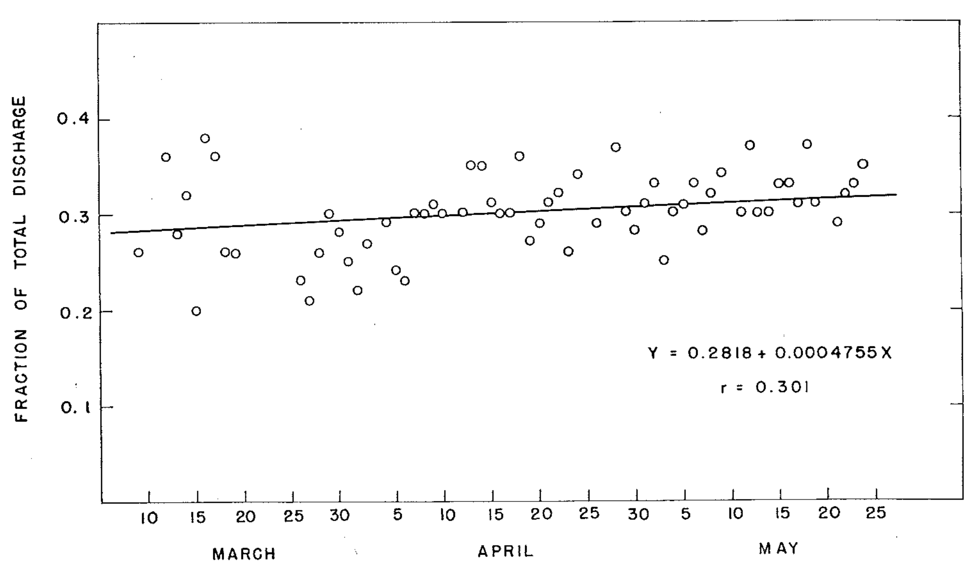

FIGURE 33—Seasonal change in the fraction of the total discharge which passed through the Left Bank section at Mission in 1962 as estimated by a comparison of the velocities in the three stream sections.

TABLE 22—Weighting of surface catches of pink fry during the 0500-1300 hr period at Mission for changes in the lateral distribution of discharge in 1962. (Weighting factors calculated from regression equations shown in FIGURES 30-32.)

DATE	RIGHT BANK			MIDSTREAM			LEFT BANK			TOTAL
	Wtg. Factor	Catch[a]	Wtd. Catch	Wtg. Factor	Catch[a]	Wtd. Catch	Wtg. Factor	Catch[a]	Wtd. Catch	Weighted Mean
March 9	0.328	2.00	0.66	0.390	0.40	0.16	0.282	0.40	0.11	0.93
12	0.325	2.00	0.65	0.392	0.60	0.24	0.283	0.17	0.05	0.94
13	0.324	1.00	0.32	0.392	0.50	0.20	0.284	0.50	0.14	0.66
14	0.323	5.50	1.78	0.393	1.43	0.56	0.284	1.67	0.47	2.81
15	0.322	3.50	1.13	0.394	0.50	0.20	0.284	0.57	0.16	1.49
16	0.320	2.14	0.68	0.395	0.67	0.26	0.285	1.67	0.48	1.42
17	0.319	3.80	1.21	0.396	1.33	0.53	0.285	1.50	0.43	2.17
18	0.318	5.50	1.75	0.396	16.83	6.66	0.286	2.33	0.67	9.08
19	0.316	7.67	2.42	0.397	6.33	2.51	0.287	6.00	1.72	6.65
20	0.315	17.80	5.61	0.398	5.33	2.12	0.287	4.67	1.34	9.07
21	0.314	11.50	3.61	0.399	8.20	3.27	0.287	3.83	1.10	7.98
22	0.312	5.33	1.66	0.400	2.83	1.13	0.288	2.17	0.62	3.41
23	0.311	3.40	1.06	0.401	0.60	0.24	0.288	0.20	0.06	1.36
24	0.310	11.17	3.46	0.401	4.50	1.80	0.289	1.40	0.40	5.66
25	0.309	7.00	2.16	0.402	4.33	1.74	0.289	4.83	1.40	5.30
26	0.308	7.00	2.16	0.403	6.17	2.49	0.289	3.17	0.92	5.57
27	0.306	7.50	2.30	0.404	8.17	3.30	0.290	5.57	1.62	7.22
28	0.304	2.83	0.86	0.405	5.33	2.16	0.291	5.67	1.65	4.67
29	0.303	0.86	0.26	0.406	1.57	0.64	0.291	1.67	0.49	1.39
30	0.302	1.14	0.34	0.406	2.57	1.04	0.292	1.33	0.39	1.77
31	0.300	3.33	1.00	0.407	3.67	1.49	0.293	1.17	0.34	2.83
April 1	0.299	21.83	6.53	0.408	17.83	7.27	0.293	7.00	2.05	15.85
2	0.298	8.33	2.48	0.409	12.83	5.25	0.293	6.83	2.00	9.73
3	0.297	10.40	3.09	0.410	9.20	3.77	0.293	3.60	1.05	7.91
4	0.295	4.60	1.36	0.411	12.00	4.93	0.294	1.67	0.49	6.78
5	0.294	7.75	2.28	0.412	6.25	2.58	0.294	2.60	0.76	5.62
6	0.293	2.83	0.83	0.412	11.00	4.53	0.295	2.17	0.64	6.00
7	0.291	32.83	9.55	0.413	32.50	13.42	0.296	10.80	3.20	26.17
8	0.290	1.83	0.53	0.414	8.50	3.52	0.296	2.00	0.59	4.64
9	0.289	9.17	2.65	0.415	10.50	4.36	0.296	2.67	0.79	7.80
10	0.288	6.83	1.97	0.416	6.29	2.62	0.296	1.57	0.46	5.05
11	0.287	5.80	1.66	0.416	3.00	1.25	0.297	2.40	0.71	3.62
12	0.286	6.43	1.84	0.417	3.33	1.39	0.297	3.00	0.89	4.12
13	0.285	3.57	1.02	0.417	2.29	0.95	0.298	0.86	0.26	2.23
14	0.283	11.40	3.23	0.418	4.29	1.79	0.299	4.50	1.34	6.36
15	0.282	8.67	2.44	0.419	5.50	2.30	0.299	1.86	0.56	5.30
16	0.281	18.71	5.26	0.420	5.43	2.28	0.299	5.83	1.74	9.28
17	0.279	1.71	0.48	0.421	11.00	4.63	0.300	1.83	0.55	5.66
18	0.278	2.17	0.60	0.422	6.33	2.67	0.300	2.17	0.65	3.92
19	0.277	9.50	2.63	0.422	13.33	5.63	0.301	2.33	0.70	8.96
20	0.275	12.43	3.42	0.423	11.71	4.95	0.302	5.50	1.66	10.03
21	0.274	6.50	1.78	0.424	3.71	1.57	0.302	2.83	0.85	4.20
22	0.273	6.33	1.73	0.425	7.67	3.26	0.302	6.50	1.96	6.95
23	0.271	4.17	1.13	0.426	4.33	1.84	0.303	6.60	2.00	4.97
24	0.270	6.00	1.62	0.427	6.67	2.85	0.303	9.00	2.73	7.20
25	0.269	10.40	2.80	0.428	4.83	2.07	0.303	7.33	2.22	7.09
26	0.268	10.17	2.73	0.428	6.20	2.65	0.304	8.83	2.68	8.06
27	0.266	11.75	3.13	0.429	4.75	2.04	0.305	3.40	1.04	6.21
28	0.265	7.00	1.86	0.430	4.20	1.81	0.305	5.40	1.65	5.32
29	0.264	4.00	1.06	0.431	4.17	1.80	0.305	4.17	1.27	4.13
30	0.262	2.25	0.59	0.432	1.20	0.52	0.306	1.67	0.51	1.62
May 1	0.261	1.67	0.44	0.433	3.00	1.30	0.306	4.43	1.36	3.10
2	0.260	4.17	1.08	0.433	3.20	1.39	0.307	3.00	0.92	3.39
3	0.258	4.80	1.24	0.434	2.50	1.09	0.308	1.67	0.51	2.84
4	0.257	6.33	1.63	0.435	5.86	2.55	0.308	5.67	1.75	5.93
5	0.256	7.80	2.00	0.436	11.20	4.88	0.308	8.83	2.72	9.60
6	0.254	18.80	4.78	0.437	7.40	3.23	0.309	10.50	3.24	11.25

TABLE 22—Continued.

DATE	RIGHT BANK			MIDSTREAM			LEFT BANK			TOTAL
	Wtg. Factor	Catch[a]	Wtd. Catch	Wtg. Factor	Catch[a]	Wtd. Catch	Wtg. Factor	Catch[a]	Wtd. Catch	Weighted Mean
May 7	0.253	10.33	2.61	0.438	10.71	4.69	0.309	14.00	4.33	11.63
8	0.251	13.33	3.35	0.439	14.67	6.44	0.310	16.33	5.06	14.85
9	0.250	29.83	7.46	0.439	11.83	5.19	0.311	10.83	3.37	16.02
10	0.249	7.00	1.74	0.440	7.67	3.37	0.311	13.00	4.04	9.15
11	0.248	14.17	3.51	0.441	17.00	7.50	0.311	32.83	10.21	21.22
12	0.246	38.67	9.51	0.442	39.17	17.31	0.312	65.40	20.40	47.22
13	0.245	50.00	12.25	0.443	42.33	18.75	0.312	11.83	3.69	34.69
14	0.244	30.33	7.40	0.443	17.67	7.83	0.313	51.57	16.14	31.37
15	0.242	9.57	2.32	0.444	16.67	7.40	0.314	27.83	8.74	18.46
16	0.241	14.67	3.53	0.445	7.00	3.12	0.314	14.67	4.61	11.26
17	0.240	2.33	0.56	0.446	8.83	3.94	0.314	12.43	3.90	8.40
18	0.239	5.00	1.20	0.447	5.83	2.61	0.314	9.67	3.04	6.85
19	0.237	16.25	3.85	0.448	2.80	1.25	0.315	5.40	1.70	6.80
20	0.236	1.50	0.35	0.449	0.60	0.27	0.315	1.00	0.32	0.94
21	0.235	3.50	0.82	0.449	1.83	0.82	0.316	2.50	0.79	2.43
22	0.233	0.80	0.19	0.450	0.33	0.15	0.317	0.17	0.05	0.39
23	0.232	0.20	0.05	0.451	0.40	0.18	0.317	0.67	0.21	0.44
24	0.231	0.00	0.00	0.452	0.00	0.00	0.317	0.20	0.06	0.06
25	0.229	0.00	0.00	0.453	0.25	0.11	0.318	0.40	0.13	0.24

[a] Mean catch in 5 to 7 runs of the mobile trap during an 8 hr period.

TABLE 23—Comparison of the catch of pink fry per run in the 0500-1300 hour period with that for the corresponding 24-hour period in the mobile trap at Mission in 1962 (all stream sections combined).

DATE	A	B	C	D
	CATCH PER RUN		RATIO	TIME
	0500-1300 hrs	0500-0500 hrs	B/A	(Days)
March 22	3.44	5.32	1.55	1
26	5.44	13.45	2.47	5
29[a]	1.35	11.36	8.41	8
April 2	9.33	30.00	3.22	12
5	5.31	18.81	3.54	15
9	8.56	7.39	0.86	19
12	4.37	6.02	1.38	22
16	10.20	7.90	0.77	26
19	8.39	7.16	0.85	29
23	4.94	4.10	0.83	33
26	8.53	7.08	0.83	36
30	1.67	3.11	1.86	40
May 3	2.88	3.07	1.07	43
7	11.63	6.96	0.60	47
14	34.16	16.85	0.49	54

[a] The very low catch per run in the 0500-1300 hr period was not representative of the catches early in the season and therefore the ratio was excluded from the regression analysis.

Diurnal Variability of Fry

The standard daily sampling period in 1962 was from 0500 hr to 1300 hr as in 1964. Thus it was necessary to weight the daily estimates of fry concentration so that they would be representative of the concentration during full 24 hr periods. The ratio of catch per run during the standard period to that during the corresponding 24 hr period (TABLE 23) was found to decrease significantly (FIGURE 34) over that portion of the season for which 24 hr data were available (March 22-May 14). Thus, over this portion of the season, daily working values for the ratio (TABLE 24) were estimated from the regression equation. Since extrapolation of the regression line beyond the period for which data were available would have given unreasonable values of the ratio, the ratio computed for March 22 was applied to days prior to this date and the ratio computed for May 14 was applied to subsequent days (TABLE 24).

TABLE 24—Weighting factors for catches during the 0500-1300 hour period to account for diurnal changes in pink fry abundance at Mission in 1962 (estimated from the regression equation—FIGURE 34).

Date	Factor	Date	Factor
Before March 22	2.47	April 18	1.42
March 22	2.47	19	1.38
23	2.43	20	1.34
24	2.39	21	1.30
25	2.35	22	1.26
26	2.32	23	1.22
27	2.28	24	1.19
28	2.24	25	1.15
29	2.20	26	1.11
30	2.16	27	1.07
31	2.12	28	1.03
April 1	2.08	29	0.99
2	2.04	30	0.95
3	2.00	May 1	0.91
4	1.96	2	0.87
5	1.93	3	0.84
6	1.89	4	0.80
7	1.85	5	0.76
8	1.81	6	0.72
9	1.77	7	0.68
10	1.73	8	0.64
11	1.69	9	0.60
12	1.65	10	0.56
13	1.61	11	0.52
14	1.58	12	0.49
15	1.54	13	0.45
16	1.50	14	0.41
17	1.46	After May 14	0.41

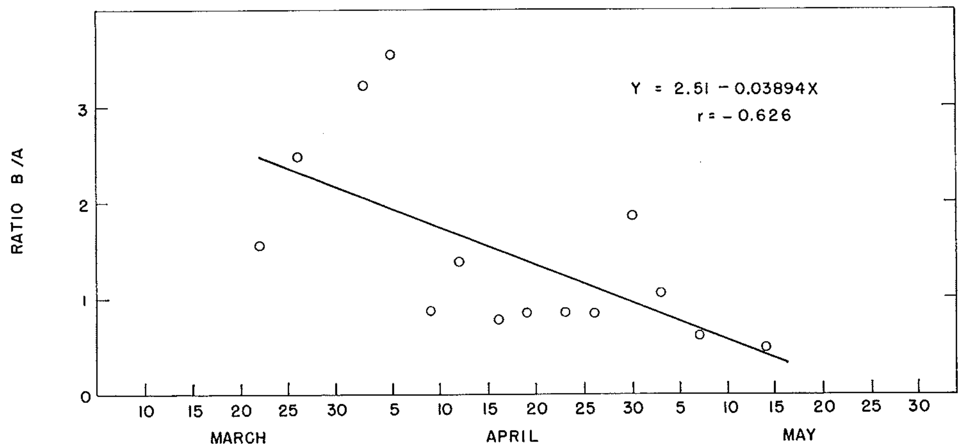

FIGURE 34—Ratio (B/A) of the pink fry catch per run in the 0500-1300 hr period (A) to that in the corresponding 24-hr period (B) in the mobile trap at Mission in 1962.

Trap Efficiency

A comparison of simultaneous pink fry catches in the mobile surface net and in the mobile trap indicated that, as in 1964, some pink fry were being lost through the meshes of the inclined plane in the mobile trap (TABLE 25). Although the ratio of trap catch to net catch fluctuated considerably from day to day, there was no evidence of significant seasonal trends and the best estimate of trap efficiency in 1962 was considered to be a ratio computed from the total catches in the two gears.

TABLE 25—Comparison of simultaneous pink fry catches in the mobile surface net and in the mobile trap during the 0500-1300 hour period at Mission in 1962.

Date	A Net Catch[a]	B Trap Catch	C Ratio A/B
April 3	122	91	1.34
5	92	69	1.33
9	210	154	1.36
12	160	83	1.93
16	243	204	1.19
19	268	151	1.77
23	99	84	1.18
26	205	145	1.41
30	59	25	2.36
May 3	121	49	2.47
7	376	221	1.70
14	326	649	0.50
21	11	47	0.23
Total	2,292	1,972	1.16

[a] Adjusted upward by a factor of 2.0 (April 3-April 9) and 1.8 (April 12-May 21) to account for the smaller effective frontal area of the net relative to that of the trap.

TABLE 26—Calculation of daily abundance of pink fry migrating downstream in the Fraser River at Mission in 1962.

	1	2	3	4	5	6
DATE	MEAN FRY PER RUN[a]	ADJUSTMENT FACTORS				FRY ABUNDANCE
		Trap Loss	Vertical	Diurnal[b]	Discharge (2.9538 Q)	
March 1	—	—	—	—	—	15,000
2	—	—	—	—	—	30,000
3	—	—	—	—	—	60,000
4	—	—	—	—	—	90,000
5	—	—	—	—	—	120,000
6	—	—	—	—	—	150,000
7	—	—	—	—	—	180,000
8	—	—	—	—	—	209,672
9	0.93	1.16	0.876	2.47	102,674	239,672
10	—	—	—	—	—	241,003
11	—	—	—	—	—	242,334
12	0.94	1.16	0.876	2.47	103,274	243,665
13	0.66	1.16	0.876	2.47	106,071	175,717
14	2.81	1.16	0.876	2.47	103,206	727,922
15	1.49	1.16	0.876	2.47	99,927	373,717
16	1.42	1.16	0.876	2.47	98,037	349,423
17	2.17	1.16	0.876	2.47	95,644	520,944
18	9.08	1.16	0.876	2.47	94,433	2,152,204
19	6.65	1.16	0.876	2.47	93,222	1,556,015
20	9.07	1.16	0.876	2.47	92,838	2,113,522
21	7.98	1.16	0.876	2.47	97,298	1,948,859
22	3.41	1.16	0.876	2.47	94,551	809,271
23	1.36	1.16	0.876	2.43	94,433	317,219
24	5.66	1.16	0.876	2.39	95,644	1,314,732
25	5.30	1.16	0.876	2.35	95,083	1,203,389
26	5.57	1.16	0.876	2.32	101,315	1,330,388
27	7.22	1.16	0.876	2.28	101,581	1,699,206
28	4.67	1.16	0.876	2.24	98,923	1,051,542
29	1.39	1.16	0.876	2.20	95,969	298,224
30	1.77	1.16	0.876	2.16	94,728	368,016
31	2.83	1.16	0.876	2.12	94,344	575,173
April 1	15.85	1.16	0.876	2.08	94,522	3,166,553
2	9.73	1.16	0.876	2.04	94,403	1,904,099
3	7.91	1.16	0.876	2.00	99,898	1,605,920
4	6.78	1.16	0.876	1.96	99,927	1,349,364
5	5.62	1.16	0.876	1.93	103,383	1,139,475
6	6.00	1.16	0.876	1.89	122,908	1,416,300
7	26.17	1.16	0.876	1.85	162,164	7,977,961
8	4.64	1.16	0.876	1.81	162,193	1,384,174
9	7.80	1.16	0.876	1.77	169,696	2,380,684
10	5.05	1.16	0.876	1.73	176,135	1,563,671
11	3.62	1.16	0.876	1.69	184,672	1,148,043
12	4.12	1.16	0.876	1.65	187,980	1,298,539
13	2.23	1.16	0.876	1.61	192,292	725,182
14	6.36	1.16	0.876	1.58	196,398	2,000,337
15	5.30	1.16	0.876	1.54	163,375	1,355,016
16	9.28	1.16	0.876	1.50	239,258	3,384,290
17	5.66	1.16	0.876	1.46	262,563	2,204,781
18	3.92	1.16	0.876	1.42	270,627	1,530,764
19	8.96	1.16	0.876	1.38	325,125	4,085,069
20	10.03	1.16	0.876	1.34	358,266	4,892,939
21	4.20	1.16	0.876	1.30	388,070	2,153,102
22	6.95	1.16	0.876	1.26	380,538	3,386,222
23	4.97	1.16	0.876	1.22	396,636	2,443,829
24	7.20	1.16	0.876	1.19	402,367	3,503,192
25	7.09	1.16	0.876	1.15	413,089	3,422,546
26	8.06	1.16	0.876	1.11	418,051	3,800,576

TABLE 26—Continued.

DATE	1	2	3	4	5	6
	MEAN FRY PER RUN[a]	ADJUSTMENT FACTORS				FRY ABUNDANCE
		Trap Loss	Vertical	Diurnal[b]	Discharge (2.9538 Q)	
April 27	6.21	1.16	0.876	1.07	437,842	2,956,342
28	5.32	1.16	0.876	1.03	465,991	2,594,708
29	4.13	1.16	0.876	0.99	445,138	1,849,447
30	1.62	1.16	0.876	0.95	416,013	650,591
May 1	3.10	1.16	0.876	0.91	415,718	1,191,693
2	3.39	1.16	0.876	0.87	403,725	1,209,947
3	2.84	1.16	0.876	0.84	399,029	967,303
4	5.93	1.16	0.876	0.80	383,285	1,847,688
5	9.60	1.16	0.876	0.76	369,343	2,738,273
6	11.25	1.16	0.876	0.72	340,160	2,799,822
7	11.63	1.16	0.876	0.68	330,707	2,657,627
8	14.85	1.16	0.876	0.64	324,741	3,136,214
9	16.02	1.16	0.876	0.60	307,343	3,001,920
10	9.15	1.16	0.876	0.56	306,309	1,594,891
11	21.22	1.16	0.876	0.52	302,203	3,388,516
12	47.22	1.16	0.876	0.49	299,515	7,042,109
13	34.69	1.16	0.876	0.45	310,444	4,924,500
14	31.37	1.16	0.876	0.41	322,909	4,220,274
15	18.46	1.16	0.876	0.41	339,096	2,607,956
16	11.26	1.16	0.876	0.41	366,596	1,719,777
17	8.40	1.16	0.876	0.41	371,440	1,299,912
18	6.85	1.16	0.876	0.41	389,754	1,112,313
19	6.80	1.16	0.876	0.41	408,363	1,156,914
20	0.94	1.16	0.876	0.41	432,938	169,551
21	2.43	1.16	0.876	0.41	448,948	454,515
22	0.39	1.16	0.876	0.41	471,486	76,609
23	0.44	1.16	0.876	0.41	493,934	90,546
24	0.06	1.16	0.876	0.41	537,857	13,445
25	0.24	1.16	0.876	0.41	595,250	59,519
26	—	—	—	—	—	50,000
27	—	—	—	—	—	40,000
28	—	—	—	—	—	30,000
29	—	—	—	—	—	20,000
30	—	—	—	—	—	10,000
Total						143,612,379

[a] From TABLE 22.
[b] From TABLE 24.

Thus a weighting factor of 1.16 (TABLE 25) was applied to catches in the trap to compensate for loss of fry from this gear. It can be noted that this value is similar to that estimated for the latter part of the 1964 season (1.22), when stream conditions (turbidity) were similar to those prevailing throughout the 1962 season.

Stream Discharge and Daily Abundance

Daily discharge (Q) of the Fraser River at Mission was estimated using the same procedures as in 1964. The mobile trap was operated in a position somewhat higher in the water and at a slightly lower velocity (2.5 ft/sec) and therefore the volume sampled in each 15 min run was somewhat less than that in 1964. In estimating daily fry abundance (N) from the mean catch per run (C) the volume sampled per run (29,250 sq ft) was substituted in Equation 1:

$$N = (C/29{,}250)\ 86{,}400\ Q = C\ (2.9538\ Q).$$

The various adjustment factors are assembled in TABLE 26 (Columns 2-5) and applied to the mean surface catches per run (Column 1) to estimate the abundance of fry (Column 6). Daily estimates of abundance were plotted (FIGURE 35) and extrapolations and interpolations were made for days when sampling was not conducted. A total of 143.6 million pink fry were estimated to have migrated from the Fraser River at Mission in 1962 (TABLE 26).

DISCUSSION

Although the daily estimates of fry concentration were generally based on 18 to 20 replicate samples taken in the mobile trap, the individual samples consisted of exceedingly small fractions of the total daily volume of river flow. The daily "discharge adjustment factors" listed in Columns 5 of TABLES 20 and 26 are reciprocals of these fractions for the 1964 and 1962 seasons respectively. In 1964 these fractions ranged from 1/88,000 early in the season to 1/625,000 on the last day of sampling. In 1962 these fractions ranged from 1/93,000 to 1/595,000. Adjustments to account for non-uniform distribution of fry were based on even smaller and fewer samples, although weighting factors were estimated from grouped data to reduce the effects of chance error.

Because of the small size of the samples and the vagaries of fry distribution, estimates of daily fry concentration were undoubtedly subject to considerable chance error. Thus some of the violent fluctuations in the estimates of daily fry abundance (FIGURES 30 and 35) are probably more apparent than real. Much of the error would cancel out in estimates of abundance over periods of several weeks or over the season. Because of the multiplicity of computational steps involved, measures of statistical error would have little meaning and have not been attempted.

Errors due to the vagaries of sampling are to some extent self-cancelling but can lead to either high or low estimates of true abundance. Another type of error is involved in the implicit assumption that fry cannot avoid capture by the mobile trap. The swimming speed of pink fry, even for short periods, is in the order of 1.5 ft/sec and therefore, once having entered the trap, they could not escape the routine operating velocities of 2.5 to 2.6 ft/sec. However it is possible that some fry near the perimeter of the water column sampled by the trap were able to sense its approach and avoid capture. To the extent that avoidance of the trap occurred, abundance of fry would have been underestimated although it is considered that such error would have amounted to less than 10 per cent.

In the long run, the adequacy of the enumeration methods will be judged by the degree to which estimates of fry abundance increase the understanding of the dynamics of Fraser River pinks and aid in forecasting the abundance of returning adult runs. With this in mind, it is well to examine the 1962 and 1964 abundance

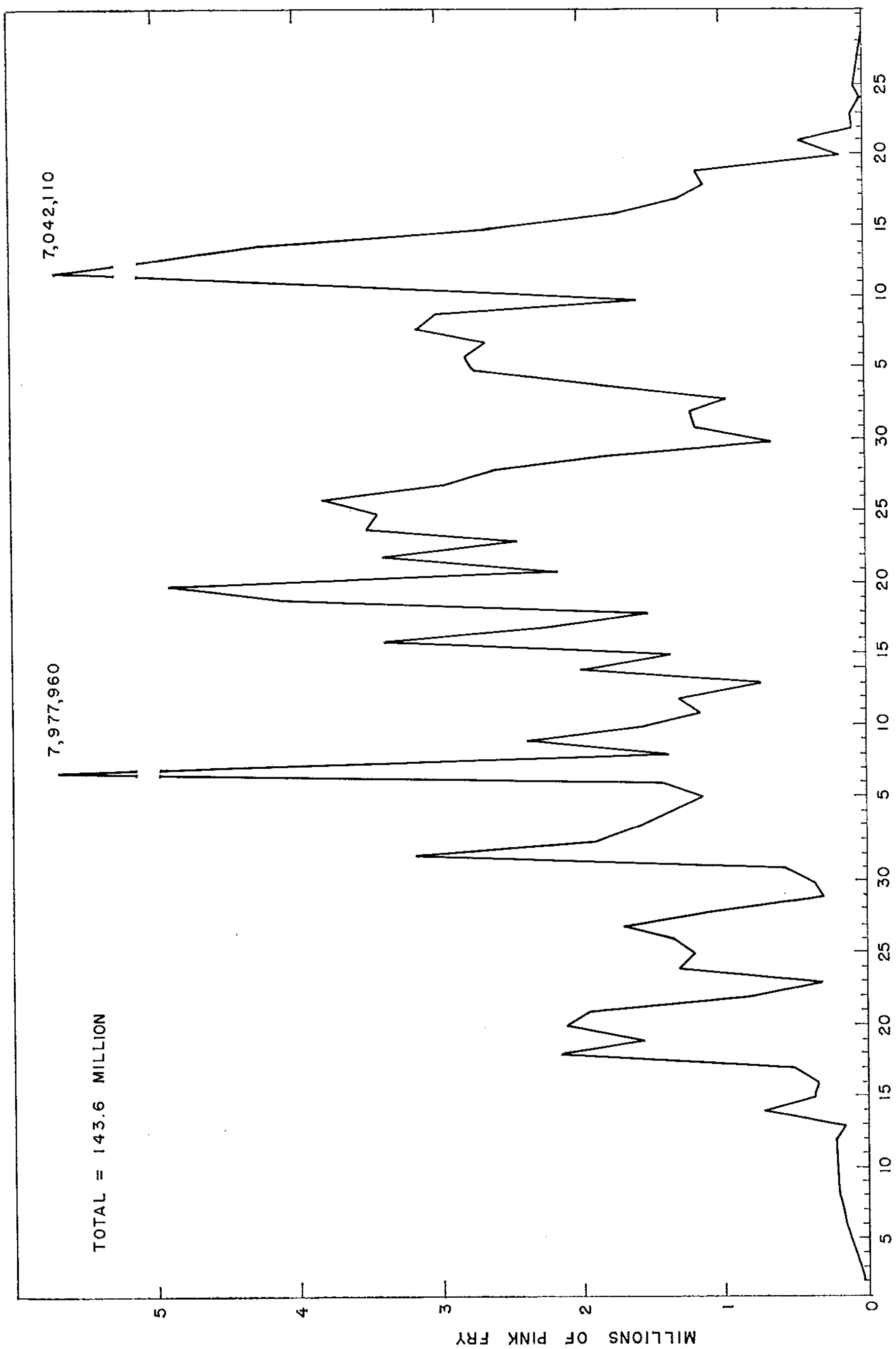

FIGURE 35—Numbers of pink salmon fry migrating from the Fraser River in 1962 as estimated from samples taken at Mission.

TABLE 27—Currently available population statistics for Fraser River pink salmon in the brood years 1957, 1959, 1961 and 1963.

ABUNDANCE (millions)	BROOD YEAR			
	1957	1959	1961	1963
A. Total spawners	2.425	1.078	1.094	1.953
B. Female spawners	1.423	0.596	0.654	1.217
C. Eggs deposited[a]	2,874.5	1,084.7	1,569.2	2,434.8
D. Total fry	—	—	143.6	284.2
E. Total return[b]	6.459	1.884	5.262	2.217
RATE OF PRODUCTION				
Eggs per spawner (C/A)	1,185	1,006	1,434	1,247
Freshwater survival (D/C)	—	—	9.2%	11.7%
Marine survival (E/D)	—	—	3.7%	0.8%
Overall survival (E/C)	0.22%	0.17%	0.34%	0.09%
Return per spawner (E/A)	2.66	1.75	4.81	1.14

[a] Potential egg deposition (estimated total fecundity).

[b] Catch plus spawning escapement in the subsequent brood year (from Hourston, Vernon and Holland, 1965).

estimates in the light of other numerical data currently available for the biennial runs since 1957 (TABLE 27). It can be seen that, for the 1961 brood year, the fry abundance estimate (in 1962) provides considerable additional information over that available for previous brood years. The separation of overall survival into freshwater and marine components will allow more effective investigation of the environmental influences during these two principal phases of the life history. It can be noted that although the 1963 brood produced a much larger number of fry than the 1961 brood, the total return (in 1965) was much less, due to a very low marine survival.

Freshwater survival estimates (TABLE 27) for the 1961 brood (9.2%) and the 1963 brood (11.7%) fall within the range which might be expected on the basis of investigations elsewhere. Estimates based on extensive trapping programs on Fraser River tributary populations since 1957 have indicated egg-to-fry survivals ranging from 3.7% (in the Vedder River) to 30.0% (in Seton Creek). In other areas of the Pacific coast, several investigators have reported on egg-to-fry survival for much smaller pink salmon populations which could be enumerated by means of weirs (TABLE 28).

Marine survival (percentage of fry returning as adults to coastal waters) of Fraser River pinks was estimated to be 3.7% for the 1961 brood year and 0.8% for the 1963 brood year (TABLE 27). Because of the difficulty of distinguishing the catches contributed by particular spawning populations, marine survival of pink salmon has seldom been estimated in other areas. However, Parker (1964), by marking a known proportion of the seaward migrant fry and sampling extensively the commercial catches of the following year, estimated a marine survival

TABLE 28—Some published records of freshwater survival (percentage, egg to fry) of pink salmon in small streams.

STREAM	AREA	FRESHWATER SURVIVAL			YEARS OF DATA	AUTHORITY
		Max.	Min.	Mean		
Hook Nose Creek	Central B. C.	16.5	0.88	5.6	10	Hunter, 1959
Sashin Creek	S. E. Alaska	22.8	0.1	4.2	19	Merrell, 1962
Nile Creek	Vancouver Island	32.3	0.35	—	3	Wickett, 1962

of 22% for the 1960 brood year at Hook Nose Creek in central British Columbia. Thus it is probable that marine survival of Fraser River pinks could reach considerably higher levels than that attained by the 1961 and 1963 broods.

Total marine survival (percentage of fry returning as adults to the spawning grounds) for Fraser pinks of the 1961 brood (1.36%) and for the 1963 brood (0.4%) were also within the range observed for populations elsewhere. At Hook Nose Creek, during the 14 years between 1947 and 1960, total marine survival ranged from 0.2% to 5.2% (Parker, 1964), with a mean of 1.77%.

Potential egg deposition per spawner has varied considerably from year to year (Table 27), in part due to the variable proportion of females in the spawning population (55% — 62%) but chiefly as a result of variations in fecundity (1,820 — 2,400). While this source of variability is undoubtedly low in relation to the effects of fluctuations in survival, nevertheless, within the four broods for which information is currently available, the greatest number of eggs per spawner (1,434) was 43% higher than the smallest number (1,006) and thus this factor could affect significantly the return per spawner.

In 1964, the long initial period of relatively clear water conditions in the lower Fraser River provided an unusually good opportunity to obtain information on the effects of changes in turbidity and of light on the vertical distribution of pink fry. These observations (Figure 17) led to the conclusion that, in this usually very turbid section of stream, pink fry were generally distributed more or less at random with respect to depth. However, during periods of relatively clear water, the fry tended to be concentrated near the surface in daylight.

Some observations on vertical distribution of pink fry have also been made at trapping sites on some of the larger tributary spawning streams of the Fraser system. In these streams the water is usually very clear in comparison to that in the lower Fraser. In each of these streams at least part of the cross section at the trapping site extends to depths of 10 ft or more and, at intervals throughout the migration, samples are taken at a series of depths to obtain information on the vertical distribution of fry. In all these streams, fry migration is restricted almost entirely to the hours of darkness. In the Harrison River, where the gradient is relatively gentle and the trapping site is located below a section of smooth flow, pink fry are invariably concentrated near the surface. However, in the Vedder River, where the gradient is relatively steep and the trapping site is located below a section of turbulent flow, pink fry are invariably distributed to much greater depths than in the Harrison River. Observations at a temporary trapping site on the Thompson River indicate that, while pink fry in this stream usually tend to be concentrated near the surface, they are distributed to greater depths during periods of turbid water. In a relatively shallow (5 ft) and somewhat turbid tributary of the Skeena River, McDonald (1960) found that migrant pink fry tended to be nearer the surface during the day than at night. In the sea, newly arrived pink fry have also been observed to be concentrated near the surface.

On the basis of these observations it is hypothesized that seaward migrant pink fry prefer to remain in the upper layers of water and that they maintain this preferred position by visual contact with the water surface. In the usually very clear water of the tributary spawning streams the fry are able to maintain this contact even in darkness except where vertical turbulence results in velocities which exceed their swimming capacity. In the lower Fraser River where, even during periods of relatively clear water, turbidities are much higher than in the spawning tributaries, pink fry lose contact with the surface during darkness and are distributed downwards by the turbulent mixing action of the stream flow. As turbidities increase, later in the season, fry are unable to maintain contact with the surface even in daylight and are distributed throughout all depths by vertical turbulence.

It is of interest that chum salmon fry, which are somewhat larger than pinks, are invariably concentrated near the surface throughout their migration in the lower Fraser River (Todd, 1964).

SUMMARY

Pink salmon fry migrate to sea from the Fraser River in the spring of the even-numbered years as progeny of the large spawning runs which occur only in the autumn of the odd-numbered years. Since most of the fry emanate from tributary and main stem spawning areas immediately above the estuarial portion of the river, estimation of their abundance entailed development of sampling methods which would not be affected by fluctuations in flow due to the tidal swing.

The daily volume of net seaward flow could be estimated from determinations of discharge at gauging stations situated above tidal influence. Thus the object of the sampling program was to determine the mean daily number of fry present per unit volume of water flowing through a cross section of the lower Fraser River. From these parameters, the daily abundance of seaward moving fry could be calculated.

The sampling site at Mission, about 50 miles above the river mouth, is situated downstream from all but negligible numbers of pink salmon spawners. The river at this point is comparatively straight and flows smoothly in a channel approximately 1500 ft wide and 30 ft deep with steep banks and a relatively flat bottom.

The basic sampling gear consisted of a pontoon-mounted, incline-plane trap with a frontal aperture 40 in. deep and 48 in. wide. For each sample, this trap was propelled against the current for 15 min by a power boat so adjusted as to maintain a uniform velocity of 2.6 ft/sec into the trap aperture. Thus each sample consisted of the fry present in 31,300 sq ft of water. A series of about 8 such samples was taken from each of three lateral positions in the stream cross section between the hours of 0500 and 1300 daily.

During two 24 hr periods each week, information on vertical and diurnal distribution of fry was obtained by operating, in addition to the trap, a similarly propelled gear fitted with conical nets, one of which was fished on the surface and the other alternately at 7.5, 10.5 and 13.5 ft below the surface. At greater depths, information was obtained by operating a stationary net at 13.5, 19.5 and 25.5 ft below the surface during the same two periods each week.

On the basis of the data obtained on the lateral, vertical and diurnal distribution of fry, the daily trap samples were weighted so that they would be representative of fry concentration (fry per unit volume) across the entire width and depth of the stream cross section during full 24 hr periods. Adjustments were also made to account for non-uniform stream discharge within the cross section. From the resultant daily estimates of mean fry concentration at Mission and estimates of daily river discharge, the daily abundance of pink fry could be determined.

The total abundance of pink fry migrating to sea from the Fraser River was estimated to be 143.6 million in 1962 and 284.2 million in 1964. On the basis of these estimates, the freshwater (egg to fry) survivals for the 1961 and 1963 brood years were 9.2% and 11.7% respectively. These values are within the range of survival found in investigations of pink salmon stocks elsewhere.

The relationship of water transparency and the degree of variability exhibited by parallel samples indicated that pink fry were grouped in schools early in the season and that schooling decreased during darkness and with increasing turbidity.

On the basis of the relative catches in a series of paired upstream and downstream runs with the mobile trap and of limited observations, it appeared that the directional orientation of pink fry was random during the migration through the lower Fraser River.

Changes in the vertical distribution of pink fry were associated with turbidity of the water and with the incidence of daylight. It was concluded that pink fry in the lower Fraser River prefer to be near the surface but that darkness or high turbidity caused the fry to lose contact with the surface and become distributed throughout all depths by the vertical turbulence of the stream.

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