LIBRARY
U. S. Bureau of Commercial Fisheries
Fish-Passage Research Program
U. S. Naval Air Station, Building 67
Seattle 15, Washington

DOWNSTREAM MOVEMENT OF SALMONIDS AT BONNEVILLE DAM

SPECIAL SCIENTIFIC REPORT–FISHERIES No. 236

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

EXPLANATORY NOTE

The series embodies results of investigations, usually of restricted scope, intended to aid or direct management or utilization practices and as guides for administrative or legislative action. It is issued in limited quantities for official use of Federal, State or cooperating agencies and in processed form for economy and to avoid delay in publication.

United States Department of the Interior, Fred A. Seaton, Secretary
Fish and Wildlife Service, Arnie J. Suomela, Commissioner

DOWNSTREAM MOVEMENT OF SALMONIDS AT BONNEVILLE DAM

by

Joseph E. Gauley, Raymond E. Anas and
Lewis C. Schlotterbeck
Fishery Research Biologists
Bureau of Commercial Fisheries

Special Scientific Report--Fisheries No. 236

Washington, D. C.
January 1958

ABSTRACT

At Bonneville Dam most downstream-migrant salmonids were caught during hours of darkness during the years 1946, 1949, 1950, and 1953. In 1952, however, the majority were day migrants. Hourly fishing in 1952 and 1953 indicated that maximum movement of chinook salmon and steelhead trout tends to occur at dawn and dusk; additional data are needed for blueback and silver salmon. Although the data are far from conclusive, the percentage of chinook salmon that migrate at night appears to be more highly correlated with turbidity than with days elapsed from start of sampling. Other factors, which undoubtedly affect day-night migration, were not tested.

TABLE OF CONTENTS

	Page
Methods	1
Hourly movement	3
Chinook fingerlings	3
Chinook yearlings	5
Bluebacks	5
Silvers	5
Steelheads	6
Discussion of hourly movement	6
Day and night movement	7
Comparison between 1952 and 1953	7
Factors affecting movement at Bonneville	7
Summary and conclusions	10
Literature cited	10

FIGURES

Nos.		
1.	Location of the fingerling bypasses and bypass traps at Bonneville Dam	2
2.	Diagrammatic drawing of an auxiliary-water screen pit showing positions of fingerling bypasses and fingerling traps	2
3.	Hourly catches of chinook fingerlings in 1952 and 1953. Each hour represents the summation of the year's catch for that hour	3
4.	Percent of chinook fingerlings caught each hour during four 72-hour periods in 1953	3
5.	Hourly catches of chinook yearlings in 1952 and 1953. Each hour represents the summation of the year's catch for that hour	5
6.	Percent of chinook yearlings caught each hour during three 72-hour periods in 1953	5

Figures - Cont'd

Nos.		Page
7.	Hourly catches of bluebacks in 1952 and 1953. Each hour represents the summation of the year's catch for that hour	5
8.	Hourly catches of silvers in 1952 and 1953. Each hour represents the summation of the year's catch for that hour	6
9.	Hourly catches of steelheads in 1952 and 1953. Each hour represents the summation of the year's catch for that hour	6
10.	Percent of steelheads caught each hour during two 72-hour periods in 1953	6
11.	Percent of night-migrant chinook fingerlings and yearlings plotted against numbers of fish (1952 and 1953). Lines shown are the least-squares fits	8
12.	Percent of night-migrant chinook fingerlings and yearlings plotted against days from start of sampling (1952 and 1953). Lines shown are the least-squares fits	8
13.	Percent of night-migrant chinook fingerlings and yearlings plotted against Secchi-disk readings (1952 and 1953). Lines shown are the least-squares fits	10

TABLES

1.	Hourly catches of downstream-migrant salmonids in 1952. Each hour represents the summation of the year's catch for that hour	4
2.	Hourly catches of downstream-migrant salmonids in 1953. Each hour represents the summation of the year's catch for that hour	4
3.	Numbers of downstream-migrant salmonids caught within sampling periods at Bonneville Dam from 1946-1953	8

DOWNSTREAM MOVEMENT OF SALMONIDS AT BONNEVILLE DAM

Bonneville Dam is the first structure across the Columbia River that adult salmon and steelhead trout surmount on their spawning migration, and the last one that downstream migrants pass on their way to the ocean. The spillways and turbines of the several dams completed, under construction, or planned for the Columbia and its tributaries present a series of hazards to the young fish. Information on the time of day when seaward migrants move downstream may be useful in the development of methods of guiding them safely past these structures. If dams kill or injure significant numbers of migrants, adjustments might be made at critical hours to allow safe passage. For example, if the turbines are less harmful to downstream migrants than the spillway at Bonneville, closing spillway gates for short periods to coincide with peak downstream movement or when releases from hatcheries are moving past the dam would allow more fish to pass through the turbines and thus minimize losses. This report contains data collected at Bonneville which may be useful as a guide for protecting downstream migrants in this way.

Earlier investigators determined that salmonids migrate seaward in much greater numbers at night than during the day (Barnaby, 1944; Hoar, 1951; Oregon State Game Commission, Fishery Division, 1952). Foerster (1929) noted that downstream-migrant sockeye salmon (Oncorhynchus nerka) migrated only at night at the start of the run, all during the day at the peak of the run, and only at dawn at the end of the season. Data collected at Bonneville in the present study indicated that, at least for some species, maximum movement occurs at dawn and dusk, and although most downstream-migrant salmonids move past the dam at night, some migrate during the daytime.

Members of U. S. Fish and Wildlife Service collected all the data used in this report. H. B. Holmes, K. G. Weber, and C. J. Burner reviewed the manuscript and made extremely helpful suggestions.

METHODS

The fishways at Bonneville Dam have auxiliary-water systems that transport several hundred c.f.s. of forebay water to the fishways and fishway collecting systems through valve-controlled conduits. This water provides additional flow to attract upstream migrants into the fishways. Before the auxiliary water enters the conduits, it is screened to keep out debris and fish.

Bypasses carrying 10 to 15 c.f.s. were designed for each screen pit when the dam was constructed to provide a safe downstream route for fish that entered the auxiliary-water systems. Figure 1 shows the location of the auxiliary-water systems and fingerling bypasses. Inclined-plane fingerling traps, designed by the Service, were placed in all of the bypasses except the one at the head of the Bradford Island fishway. These traps capture all migrants that pass through the fingerling bypasses and counts of each species in the hourly catches of these traps provide the data on day and night movement past the dam of the seaward-migrant fish.

An advantage of the inclined-plane trap is that it does not interfere with the flow through the bypass and no migrants elude the trap when it is raised to collect the live fish. Figure 2 is a diagrammatic drawing of an auxiliary-water screen pit showing the positions of the conduits, screens, bypasses and inclined-plane fingerling traps.

No catch data from Tanner Creek bypass, which has not been sampled since 1948, are included in this report.

The following species were studied: chinook (Oncorhynchus tshawytscha), blueback (O. nerka), and silver (O. kisutch) salmon, and steelhead trout (Salmo gairdnerii). In this report chinook fingerlings are defined as chinook salmon that migrate seaward during their first year of life, whereas chinook yearlings migrate seaward during the spring of their second year. Adult steelhead trout returning to

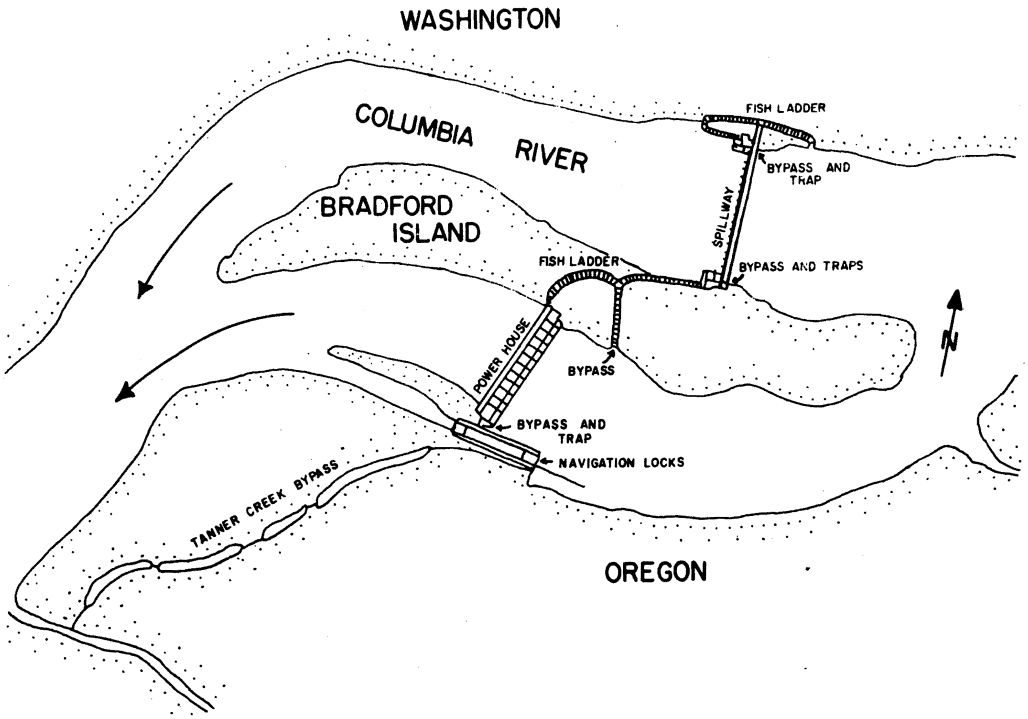

Figure 1.--Location of the fingerling bypasses and bypass traps at Bonneville Dam

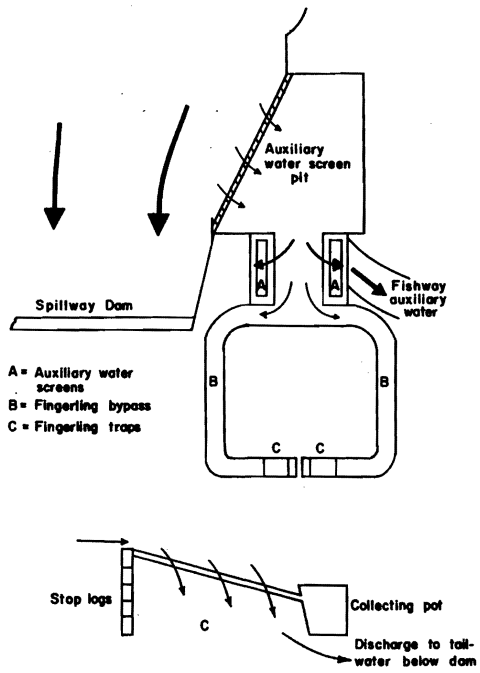

Figure 2.--Diagrammatic drawing of an auxiliary-water screen pit showing positions of fingerling bypasses and fingerling traps.

the ocean are, in a sense, downstream migrants. Only juvenile downstream migrants are considered in this report.

HOURLY MOVEMENT

The hourly catches of all species are listed in table 1 for 1952 and in table 2 for 1953. The catches in table 1 represent four periods (April 9-11, April 22-25, April 28 - May 1, and May 5-7) totalling 240 hours of sampling; the catches in table 2 represent four periods (March 10-13, April 20-23, April 28 - May 1, and May 4-7) totalling 288 hours of sampling. These periods were selected because migrants were most abundant on those dates. Hourly sampling was limited to two traps (one in the powerhouse channel and the other in the spillway channel) because only one observer was available for each 8-hour shift.

Chinook Fingerlings

Chinook fingerlings in both 1952 and 1953 were caught in greatest numbers during early morning and early evening hours (figure 3). In both years the peak morning hour was 6 to 7 a.m. and the peak evening hour, 7 to 8 p.m. The catch drops off rather sharply on both sides of these hours.

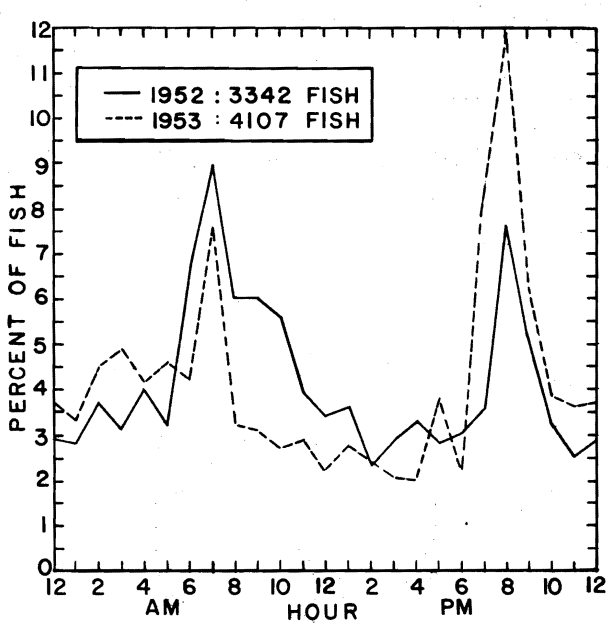

Figure 3.--Hourly catches of chinook fingerlings in 1952 and 1953. Each hour represents the summation of the year's catch for that hour.

Although the percentages of night migrants in 1952 and 1953 differed, the hourly catches reached their maxima at the same hours.

Four 72-hour periods were plotted for 1953 (figure 4). From March 10 to March 13

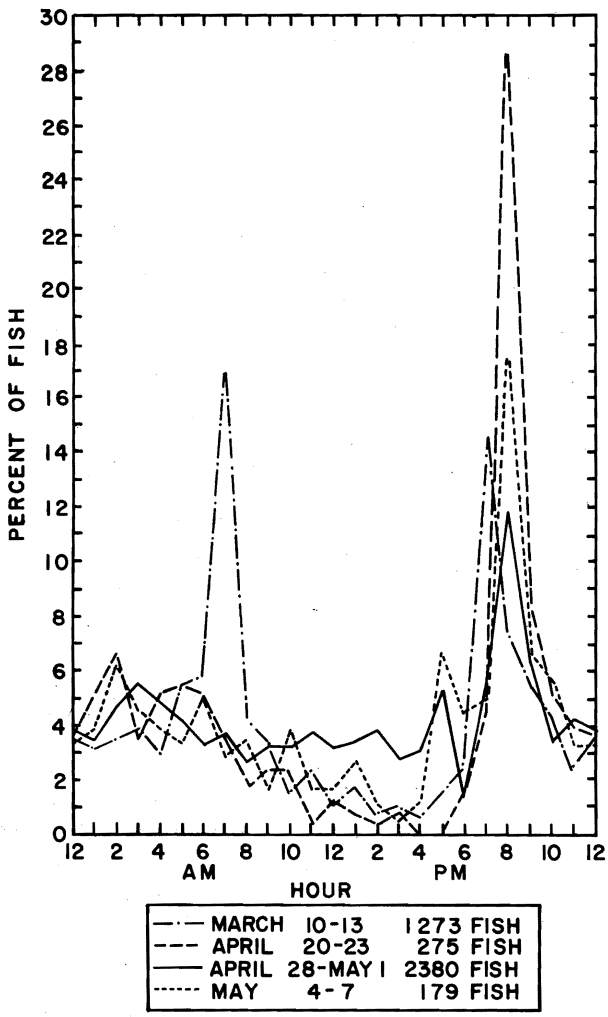

Figure 4.--Percent of chinook fingerlings caught each hour during four 72-hour periods in 1953.

sunrise was about 6:15 a.m. and sunset about 6:15 p.m. The catch peaked at 7 a.m. and 7 p.m., which coincides with the hours of dawn and dusk. The three periods from April 20 to May 7 had small morning peaks, all earlier than 7 a.m. A well-marked peak occurred in all three periods at 8 p.m. Sunrise during these periods was between 4:30 and 5 a.m., and sunset between 7 and 8 p.m. There were too few fish in some of

Table 1.--Hourly catches of downstream-migrant salmonids in 1952. Each hour represents the summation of the year's catch for that hour.

Hour ending at	Chinook fingerlings	Chinook yearlings	Bluebacks	Silvers	Steelheads	Total
12	96	25	14	6	25	166
AM 1	93	31	11	6	27	168
2	123	36	9	11	18	197
3	102	29	11	3	27	172
4	135	40	11	12	23	221
5	106	38	13	10	34	201
6	221	65	9	5	92	392
7	300	56	19	7	46	428
8	201	42	8	7	46	304
9	200	35	5	8	49	297
10	188	39	13	8	54	302
11	130	35	8	5	33	211
12	115	29	11	2	39	196
PM 1	119	36	9	7	54	225
2	76	36	10	8	45	175
3	96	33	14	4	38	185
4	109	41	8	3	49	210
5	94	38	8	5	26	171
6	100	33	11	2	30	176
7	121	29	9	2	19	180
8	256	49	8	9	34	356
9	171	56	12	2	31	272
10	107	32	13	7	21	180
11	83	35	7	5	32	162
Total	3,342	918	251	144	892	5,547

Table 2.--Hourly catches of downstream-migrant salmonids in 1953. Each hour represents the summation of the year's catch for that hour.

Hour ending at	Chinook fingerlings	Chinook yearlings	Bluebacks	Silvers	Steelheads	Total
12	151	26	4	5	37	223
AM 1	136	30	5	1	20	192
2	183	27	6	5	35	256
3	200	29	3	2	32	266
4	170	38	4	10	30	252
5	190	50	2	6	28	276
6	173	51	1	3	39	267
7	317	18	-	6	13	354
8	131	18	1	-	15	165
9	127	19	2	3	26	177
10	109	21	6	7	13	156
11	121	22	3	3	22	171
12	92	28	2	-	14	136
PM 1	113	33	3	1	20	170
2	99	29	6	1	16	151
3	85	19	1	3	20	128
4	82	19	2	1	13	117
5	154	12	3	2	10	181
6	91	13	1	3	19	127
7	334	10	-	4	19	367
8	489	49	9	6	52	605
9	257	31	6	6	37	337
10	157	33	10	4	29	233
11	146	21	8	7	35	217
Total	4,107	646	88	89	594	5,524

the periods to plot 1952.

Chinook Yearlings

The catch of chinook yearlings peaked in the morning and evening in both years (fig. 5). The morning peak was at 6 a.m. in both years, which is 1 hour earlier than that for fingerlings. The evening peak in 1952 was at 9 p.m., and in 1953 at 8 p.m.

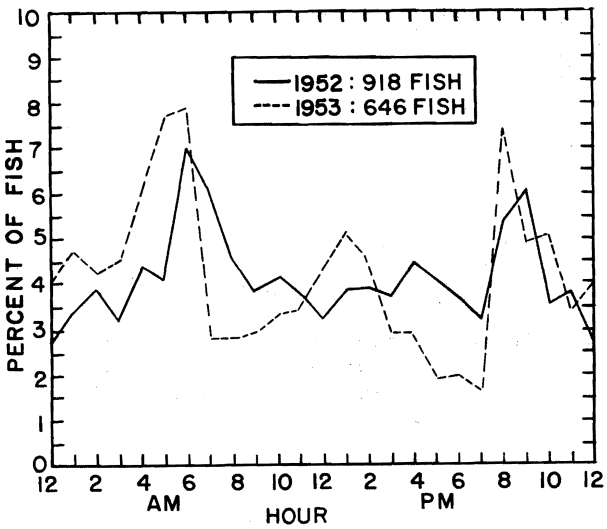

Figure 5.--Hourly catches of chinook yearlings in 1952 and 1953. Each hour represents the summation of the year's catch for that hour.

Three 72-hour periods in 1953 were plotted, and morning and evening peaks are evident. The morning peaks did not coincide, but occurred at 4, 5, and 6 a.m. The evening peaks coincided at 8 p.m. The period from May 4 to May 7 had a slightly higher 2 p.m. peak than the one at 8 p.m. (fig. 6).

Bluebacks

A morning peak of bluebacks at 7 a.m. occurred in 1952, with the catch gradually diminishing during the succeeding hours. The 1953 data were opposite with noticeable evening and night peaks (fig. 7). Additional data are needed to determine if this graph accurately defines hours of downstream movement.

Silvers

In 1952, silvers peaked at 2 and 4 a.m.; the third highest mode occured at 8 p.m. (fig. 8). After the 4 a.m. peak the catch fluctuated widely with morning

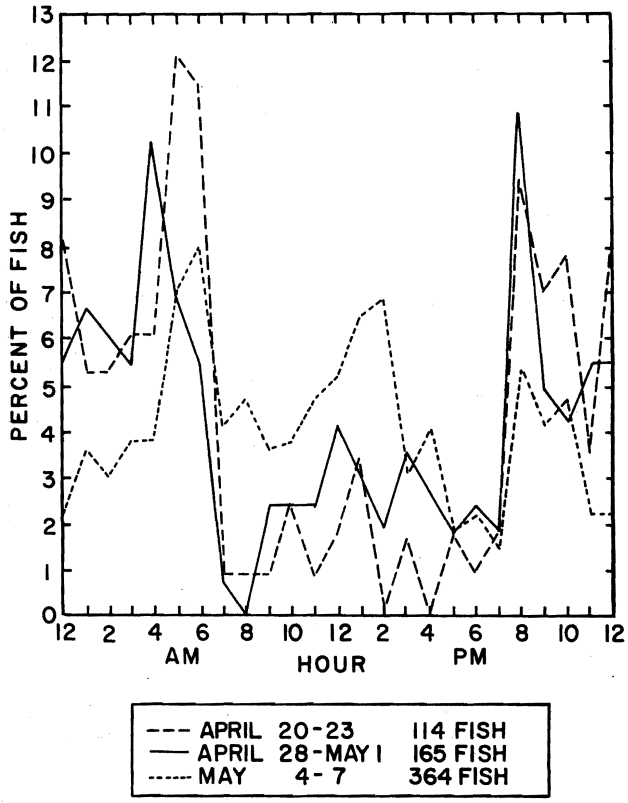

Figure 6.--Percent of chinook yearlings caught each hour during three 72-hour periods in 1953.

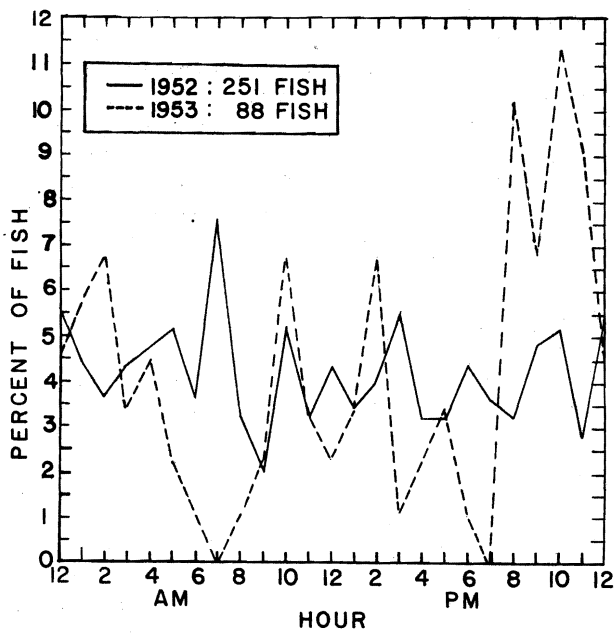

Figure 7.--Hourly catches of bluebacks in 1952 and 1953. Each hour represents the summation of the year's catch for that hour.

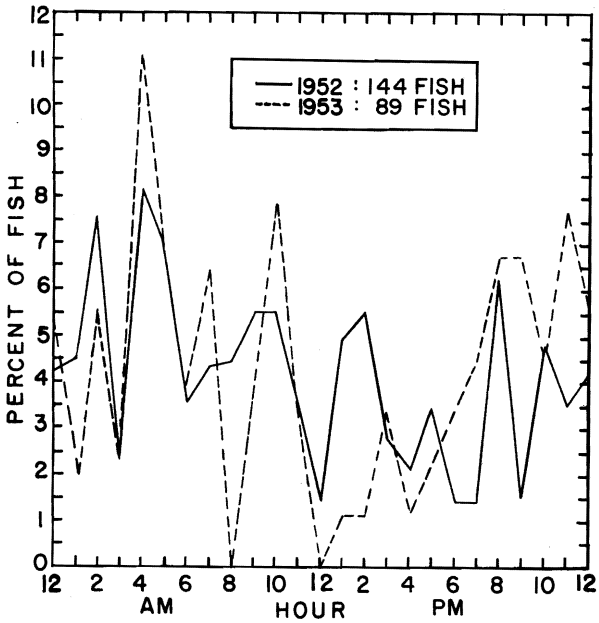

Figure 8.--Hourly catches of silvers in 1952 and 1953. Each hour represents the summation of the year's catch for that hour.

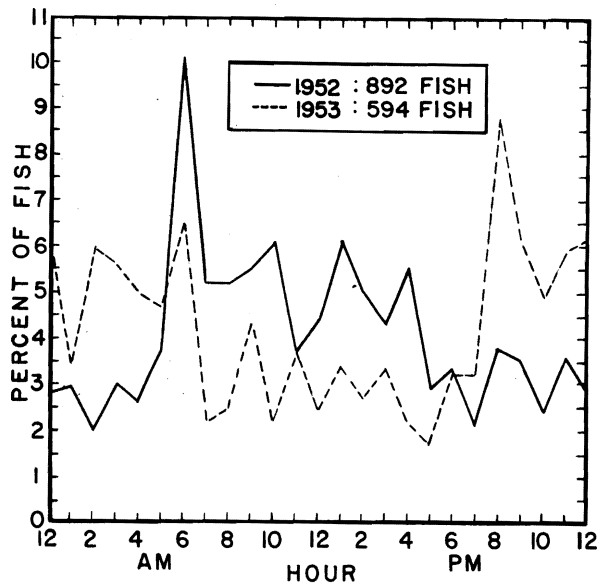

Figure 9.--Hourly catches of steelheads in 1952 and 1953. Each hour represents the summation of the year's catch for that hour.

peaks at 7, 9, and 10 a.m. Because comparatively few fish were taken, these hours may be of no significance.

Steelheads

Well-marked peaks of steelheads occurred at 6 a.m. in 1952 and 1953, but only 1953 had a noticeable evening peak (fig. 9). Two 72-hour fishing periods in 1953 having similar hours of sunrise and sunset were plotted. Both periods have peaks at 8 p.m., but the morning periods lack any discernible modes (fig. 10).

Discussion of Hourly Movement

Hourly fishing of the fingerling traps in 1952 and 1953 indicates that at dawn and dusk there is an increase in the migration rate of most downstream-migrant salmonids at Bonneville Dam. Chinook fingerlings and yearlings showed dawn and dusk peaks in both years. Steelheads had a morning peak in both years, but an evening peak only in 1953. Silvers and bluebacks exhibited a tendency to migrate at all hours. The data on hourly migration are not conclusive because too few years have been sampled; they are nevertheless indicative of migration behavior.

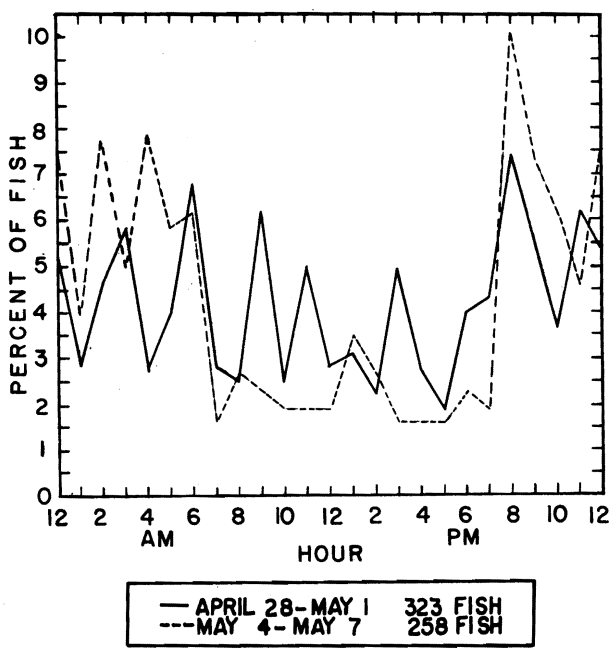

Figure 10.--Percent of steelheads caught each hour during two 72-hour periods in 1953.

DAY AND NIGHT MOVEMENT

Comparison between 1952 and 1953

Sampling from 1946 to 1950 indicated that although most downstream-migrant salmonids passed Bonneville Dam during hours of darkness, some move seaward during daylight hours. The hourly data collected in 1952 and 1953 were separated into day (5:01 a.m. to 7 p.m.) and night (7:01 p.m. to 5 a.m.) periods. These hours were chosen because they coincided best with the hours preceding daybreak and following nightfall; in this way no daylight was included in the night period.

The trap catches in 1952 had more daytime than night migrants even though the hourly data showed modes at dawn and dusk in both 1952 and 1953. The numbers of chinook yearlings, bluebacks, and silvers were not significantly different ($P > .05$) between the day and night periods in 1952; more chinook fingerlings and steelheads were caught during the daylight than the night period ($P < .01$). Although the time of year and duration of fishing periods in 1953 were similar to those of 1952, all species were caught in significantly greater numbers ($P < .01$ for all species) during the night periods in 1953. The chi-square test was used to determine the significance of the differences between day and night periods.

Table 3 summarizes the data for each year. Sampling in 1947, 1948, and 1951 was not possible because other experiments were being conducted during those years. The daily sampling periods were changed because of the exploratory nature of the sampling program.

Factors Affecting Movement at Bonneville

Several factors influence movement of each species at Bonneville, resulting not only in variations in the proportions migrating within periods of time, but also variations in the catches of each trap. This variability in trap catches, although expected, makes interpretation of the data difficult. It is assumed here that the combined catches of the traps gives the best estimate of the relative numbers of migrants passing the dam. Some of the factors that might affect movement are (1) operation of the dam, (2) races of fish, (3) size of migrants, (4) number of migrants, (5) weather conditions, and (6) physical variables of the river (flow, temperature, and turbidity).

Operation of the dam introduces variables which are very difficult to evaluate. Some of these, such as changes in the spillway gate settings and powerhouse operations, are changed over short intervals of time and might affect catches. At night the demand for power drops and the flow of water decreases as one or more generators are closed down. At such times, spillway gates may be opened to keep the water level below the top of the spillway gates. Thus, flow conditions in both channels are altered and migration patterns may be affected. Variations between traps and also any daily differences in catches of the same trap may be caused by operational changes of the dam, but the volume of auxiliary-water, which draws the fish into the bypass areas, is seldom changed over short periods of time, and hence should not affect movement of the fish within daily periods.

Another possible variable is the different behavior of races. Rich (1920) states there is evidence that juvenile Columbia River chinooks from particular tributaries tend to migrate at the same time and school together during the seaward migration. At present there is no practical way to distinguish races at Bonneville; hence, this variable was not tested. Salmon are released by several hatcheries above Bonneville. The distribution of hatchery fish in the river may be different from that of the wild migrants at the time they pass the dam. Many releases migrate past Bonneville within a short period of time; thus, the proportion of migrants caught by each trap would be affected by such schools of fish.

The size of migrants may be closely associated with races and time of year; insufficient data are available for a study of this variable.

The effect of weather conditions on migration at Bonneville would be difficult to separate and analyze, because the weather is so closely associated with other variables such as condition of the river and corresponding operation of the dam.

Table 3.--Number of downstream-migrant salmonids caught within sampling periods at Bonneville Dam from 1946 - 1953.

Period sampled	Daily periods	Total hours sampled	Chinook Fingerlings	Chinook Yearlings	Bluebacks	Silvers	Steelheads
Mar. 27-Sept. 5, 1946	6:01 a.m.-6 p.m.	4,760	1,317	439	157	146	863
	6:01 p.m.-6 a.m.	4,966	4,854**	846**	412**	154	1,452**
Mar. 29-Apr. 20, 1949	6:01 a.m.-6 p.m.	644	1,237	422	15	2	80
	6:01 p.m.-6 a.m.	674	2,948**	1,363**	28	23**	173**
Mar. 21-May 27, 1950	Sunrise-Sunset	1,493	681	928	141	26	445
	Sunset-Sunrise	1,123	819**	1,443**	294**	21	597**
Apr. 10-May 7, 1952	5:01 a.m.-7 p.m.	140	2,070**	548	142	73	620**
	7:01 p.m.-5 a.m.	100	1,272	370	109	71	272
Mar. 10-May 7, 1953	5:01 a.m.-7 p.m.	168	2,028	312	31	37	259
	7:01 p.m.-5 a.m.	120	2,079**	334**	57**	52**	335**

** Number of migrants in designated period different from number in period paired with it at the 1-percent significance level ($P < 0.01$).

The number of fish migrating might affect the proportion moving at night, but no correlation coefficient was computed for this variable because the components are interrelated (Snedecor, p. 162). The fingerling trap catches may not depict the exact number of migrants that pass Bonneville Dam, but it is assumed here that the data approximate the abundance of migrants during the periods studied. In all years except 1946 the periods were of relatively short duration. Figure 11 shows the least-squares regression lines for chinook fingerlings and yearlings comparing number of fish and proportion of night migrants in 1952 and 1953.

On the hypothesis that day-night movement may be associated with time of year, dates were selected when samples of chinook salmon were sufficiently large to test in 1952 and 1953 (March 1 for fingerlings and April 1 for yearlings). Sampling extended about 95 days for fingerlings and about 35 days for yearlings. Least-squares regression lines were plotted (fig. 12) and correlation coefficients were computed. The correlation coefficients for fingerlings (0.104; $P > 0.50$) and yearlings (0.352; $P > 0.40$) were not significant. This variable might be correlated with size of fish because the size of the migrants changes as the season progresses but seems not to be true.

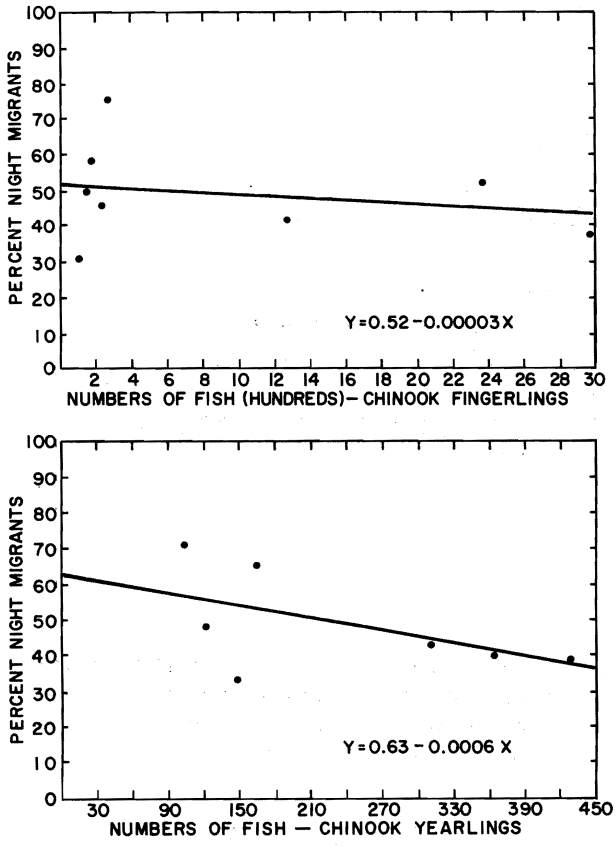

Figure 11.--Percent of night-migrant chinook fingerlings and yearlings plotted against numbers of fish (1952 and 1953). Lines shown are the least-square fits.

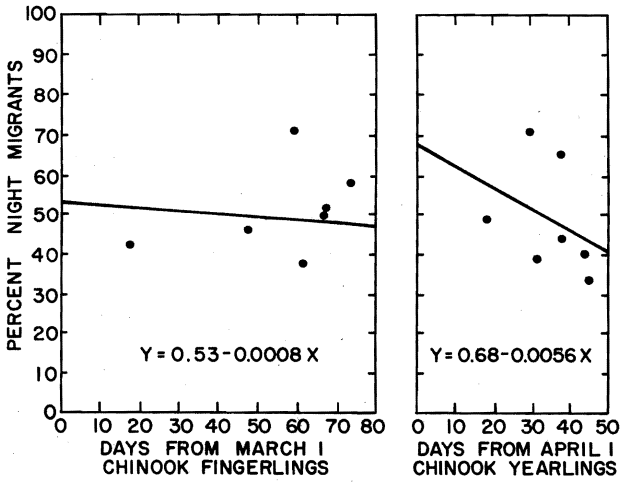

Figure. 12--Percent of night-migrant chinook fingerlings and yearlings plotted against days from start of sampling (1952 and 1953). Lines shown are the least-square fits.

River flow and water temperature, which may influence the total number of fish migrating over long periods of time, probably do not change the pattern within 24-hour periods. River flow does alter conditions at the dam to the extent that it governs operation of the spillway gates and, to a lesser degree, operation of the powerhouse; in this way it might be a secondary cause of variations in movement of seaward migrants.

The river condition most apt to influence day-night movement of salmonids is turbidity, because light penetration of the water is affected. The chinook fingerlings in 1952 and 1953 were abundant enought to form eight groups for statistical analysis, and the yearlings seven groups, thus permitting the fitting of regression lines by the method of least squares and computing coefficients of correlation between several factors, as shown in figure 13. The other species were not tested because some of the periods had few fish. Secchi-disk readings and percent night migrants were lowest in 1952. The correlation coefficients for fingerlings (0.651; $P > 0.20$) and yearlings (0.663; $P > 0.30$) were not significant at the five percent level.

It is realized that the lack of data precludes the acceptance of any of these values as facts, but comparison of the P-values suggests that within the limits encountered in this report the percentage of night-migrant chinook salmon is more highly correlated with turbidity than with days elapsed from start of sampling.

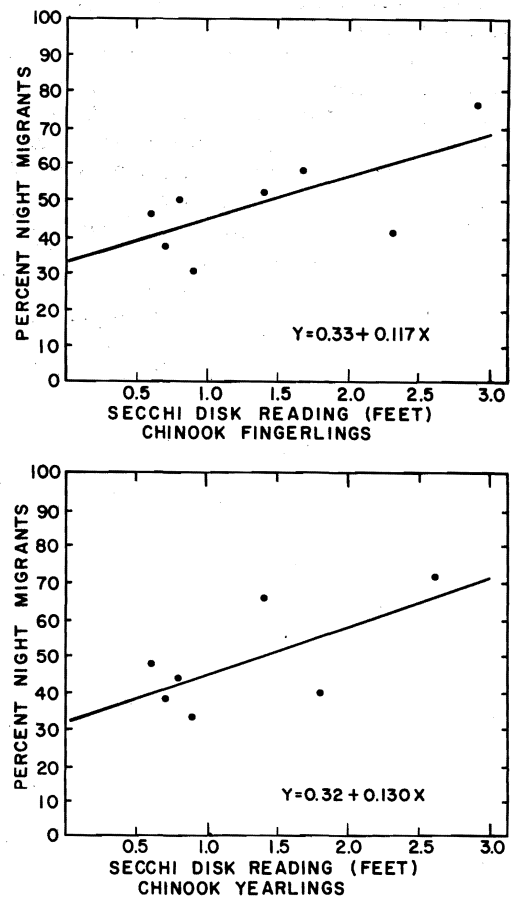

Figure 13.--Percent of night-migrant chinook fingerlings and yearlings plotted against Secchi-disk readings (1952 and 1953). Lines shown are the least-square fits.

SUMMARY AND CONCLUSIONS

1. Inclined-plane fingerling traps, located in the fingerling bypasses of Bonneville Dam, were used to collect all of the data in this report.

2. Hourly sampling in 1952 and 1953 indicates that chinook salmon and steelhead trout increase their rate of downstream migration during the hours at dawn and dusk. Additional data are needed for blueback and silver salmon.

3. Although the correlation coefficients were not significant, the data suggest that the relative numbers of chinook salmon which migrate at night are more closely associated with varying turbidity of the river than with time of year (or advance of the migration period).

4. Data collected at Bonneville Dam indicate that, although in most years downstream-migrant salmonids tend to migrate predominantly at night, some years may have more day migrants.

5. A knowledge of the proportion of downstream migrants sampled by the fingerlings bypasses would increase the value of the data in this report.

LITERATURE CITED

Barnaby, J. T.
1950. Fluctuations in abundance of red salmon, Oncorhynchus nerka (Walbaum), of the Karluk River, Alaska. U. S. Dept. Interior, Fish. Bull. Fish and Wildlife Service., vol. 50, pp. 237-295.

Literature Cited - Cont'd

Foerster, R. E.
1929. An investigation of the life history and propagation of the sockeye salmon (Oncorhynchus nerka) at Cultus Lake, British Columbia. No. 3 - The downstream migration of the young in 1926 and 1927. Biol. Bd. of Canada, Contr. to Canadian Biol. and Fish., New Series, vol. 5, no. 3, pp. 57-82.

Hoar, W. S.
1951. The behavior of chum, pink and coho salmon in relation to their seaward migration. Jour. Fish. Res. Bd. Canada, vol. 8, no. 4, pp. 241-263.

Oregon State Game Commission, Fishery Division
1952. Annual Report. 308 pp.

Rich, W. H.
1922. Early history and seaward migration of chinook salmon in the Columbia and Sacramento Rivers. Bull. U. S. Bur. Fish., vol. 37, 1919-1920, pp. 1-74.

Snedecor, G. M.
1946. Statistical methods applied to experiments in agriculture and biology. The Iowa State College Press, Ames, Iowa, 4th ed., 485 pp.

INT.-DUP. SEC., WASH., D.C. 30819