EVALUATION OF THE 1-ON-10-SLOPE FISH LADDER AT ICE HARBOR DAM

by

Charles R. Weaver

and

Clark S. Thompson

December 1964

FISH-PASSAGE RESEARCH PROGRAM
U.S. Bureau of Commercial Fisheries
Seattle, Washington

EVALUATION OF THE 1-ON-10-SLOPE FISH LADDER AT ICE HARBOR DAM[1]

INTRODUCTION

Fish Passage facilities at Ice Harbor Dam on the Snake River consist of two pool-and-overfall fish ladders: (1) a 1-on-16-slope fishway 24 feet wide of conventional design and (2) a 1-on-10-slope fishway 16 feet wide usually referred to as the Ice Harbor design (fig. 1). Both fishways rise 1 foot between pools attaining a total ascent of about 100 feet. The Ice Harbor design fishway is steeper, shorter, and more economical to build but, as a result of previous laboratory tests, is expected to pass fish as efficiently as other fishways now operating on the Columbia River system.

The Ice Harbor fishway, designed by the Corps of Engineers, employs the results of recent fish passage research conducted by the Bureau of Commercial Fisheries. The prototype fishway has undergone careful scrutiny during each phase of development. After suitable hydraulic conditions were established by model studies, the full size fishway was tested with fish; first in the laboratory and then in the field. During laboratory tests migrant salmonids ascended a six-pool ladder under various flow conditions and weir crest designs. Certain conditions were found to be best and some slight modifications were made. The final results of performance tests showed that the test fishway should pass salmonids as well as a conventional 1-on-16-slope design (Thompson and Gauley[2]). Finally, the full length of the prototype fishway was evaluated in the field under normal operating conditions.

The following is a report of the field evaluation conducted at Ice Harbor Dam from May 10 through October 5, 1962. The primary objective of the study was to determine if the 1-on-10-slope ladder would satisfactorily pass the numbers and species

---

1/ Conducted by the Bureau of Commercial Fisheries under contract (number DA-45-164-CIVENG-62-175) with the U.S. Army Corps of Engineers. Preliminary report submitted November 26, 1962.

2/ Thompson, Clark S. and Joseph R. Gauley. Laboratory Evaluation of the 1-on-10-Slope Ice Harbor Fishway Design. Manuscript.

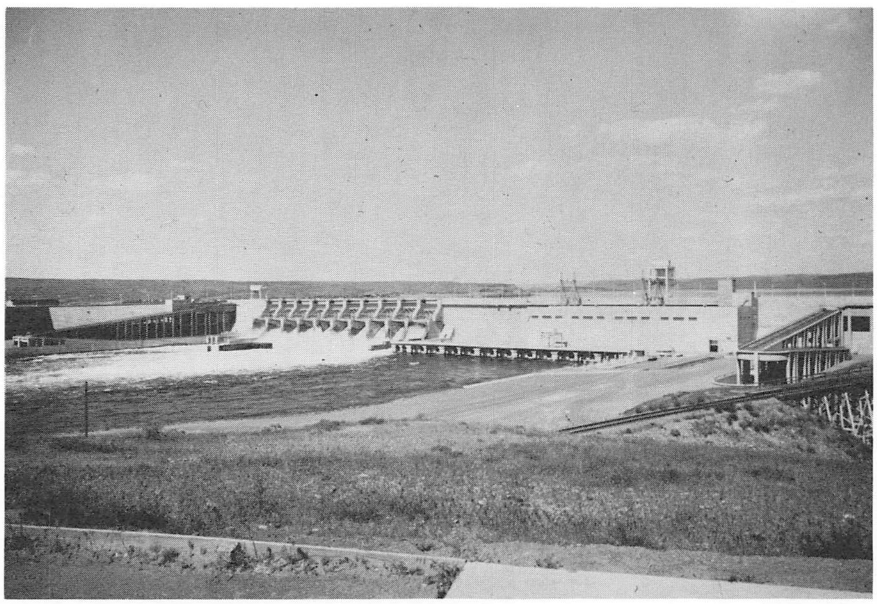


Figure 1.--A view of Ice Harbor Dam showing the 1-on-16 slope fishway on the south shore (right) and the 1-on-16 slope fishway on the north shore (left). The cofferdam cell below the spillway was present during all fishway tests but has since been removed.

of fish it may normally be expected to accommodate at Ice Harbor Dam. Passage in the 1-on-10-slope ladder was evaluated by comparing the performance of fish ascending it with the performance of fish ascending the conventional 1-on-16-slope ladder.

METHODS AND MATERIALS

Criteria employed in comparing the performance of fish in the two ladders included: (1) proportions of fish successfully negotiating comparable sections of the two ladders during a given period, (2) rates and patterns of movement through comparable test sections (same or similar number of pools), and (3) fallback activity (downstream passage) within the test area.

Observations were made within a 74-pool test area of each ladder. Temporary partitions were installed longitudinally throughout the test area dividing each ladder into a test and bypass side. Only the test side was employed in the study. Count stations installed at several different elevations within the test area provided means of comparing the performance of fish as they ascended various segments of the test areas in each ladder.

Test Area

The test area in both fishways extended from weir elevations[3/] 359 to 433 and occupied just half of the divided fishway (fig. 2). The fishways were divided by a temporary partition installed longitudinally down the center line throughout each test area--a 2-inch timber partition in the 1-on-10-slope fishway (fig. 3) and a 1- by 2-inch welded fabric partition in the 1-on-16-slope fishway (fig. 4).

Screened barrier gates were hinged on the end of the divider partitions just downstream from each test area (fig. 2). Gates were approximately the length of a fishway pool and equipped with control cables operated from small hand winches mounted on top of the fishway. By swinging a diversion gate, it was possible to divert all of the fish ascending the ladder into the test side only, the bypass side only, or both sides simultaneously.

3/ Weir elevations designated as elevation in feet above mean sea level.

ICE HARBOR FISH LADDERS

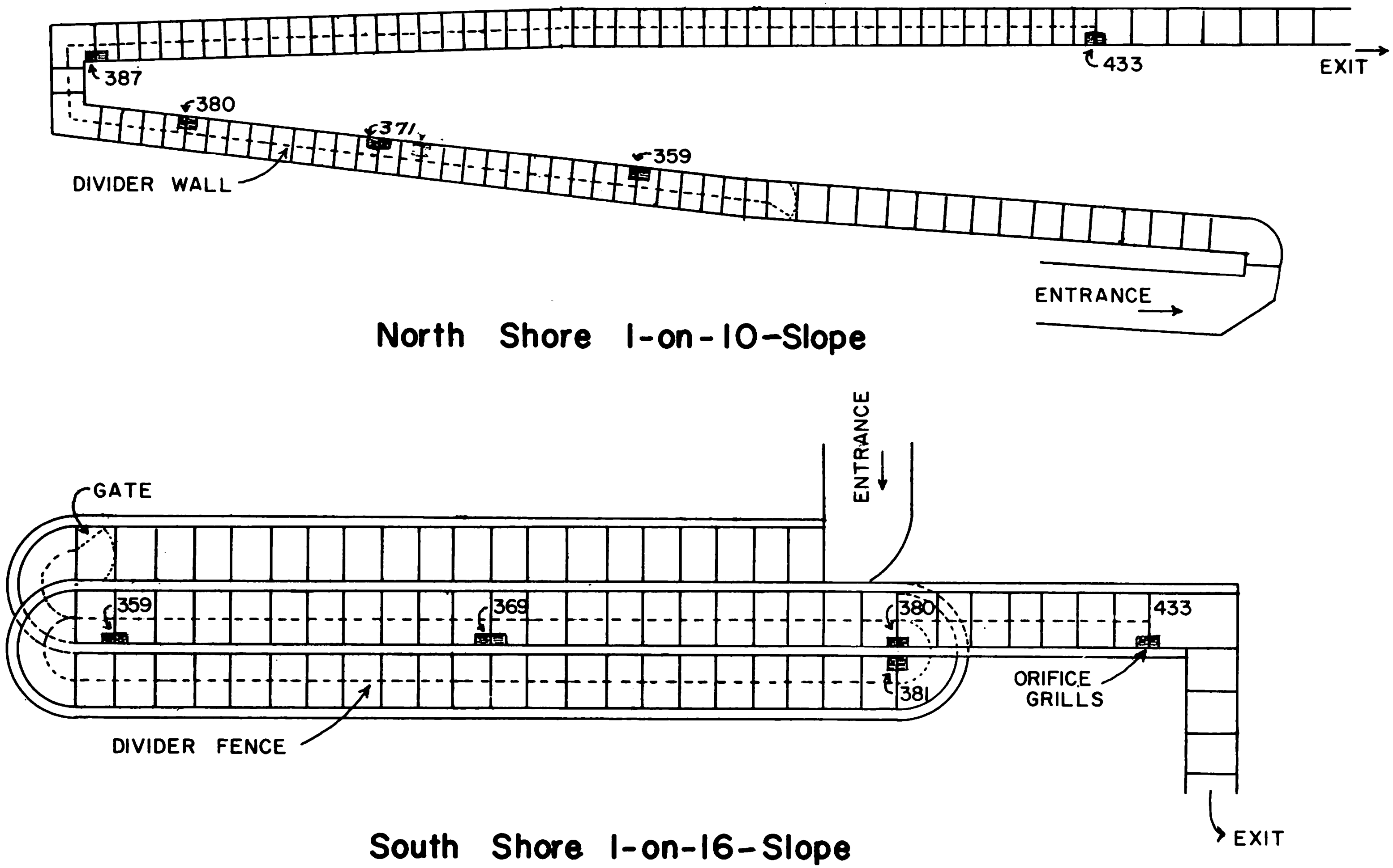


Figure 2.- -Sketch of Ice Harbor fish ladders showing locations of count stations.

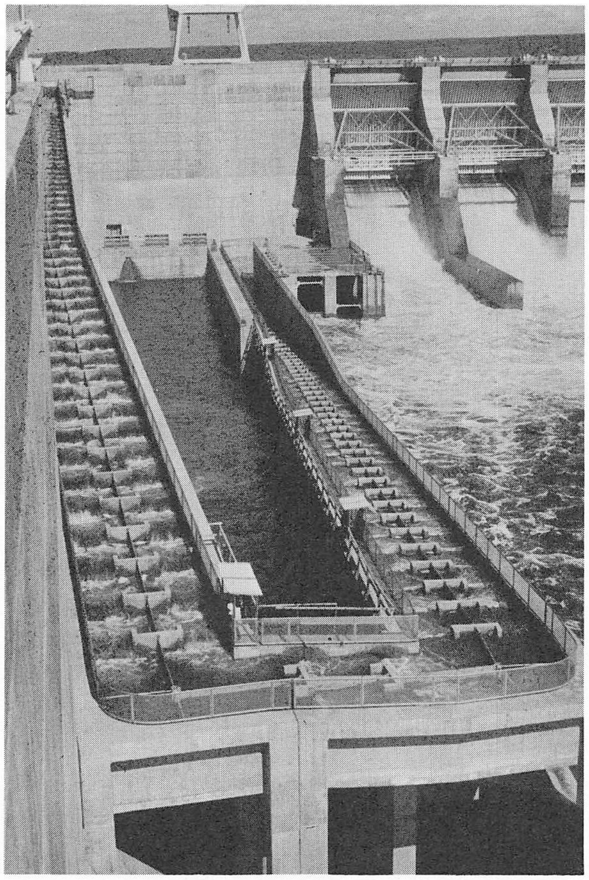


Figure 3.--View of the north shore 1-on-10 slope fish ladder showing the timber divider wall and location of the five count stations. The uppermost count station (elevation 433) is barely visible at the upper left corner of the photograph.

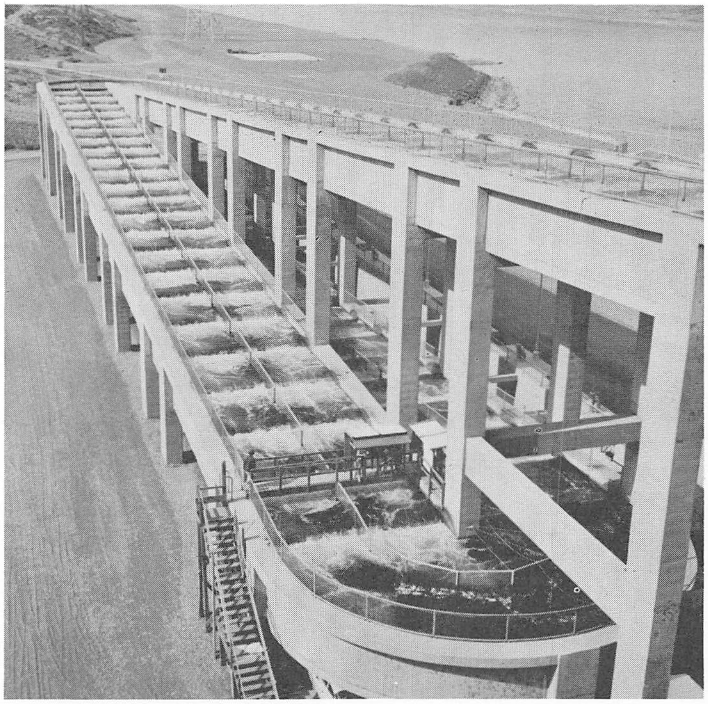


Figure 4.--View of the south shore 1-on-16 slope fish ladder showing the divider screen and count stations for weir elevations 380 (to right of bridge) and 381 (on the bridge).

Counting stations located at weir elevations 359, 371, 380, 387, and 433 in the 1-on-10-slope fishway and at elevations 359, 369, 380, 381, and 433 in the 1-on-16-slope fishway provided fish counts at comparable locations in the test area. To ensure complete counts at each of these stations, fish were forced to cross the weir crest by grilling the orifices on both sides of the weir. Orifice grills are shown in figure 5. All grills were hinged at the bottom so that orifices could be left open between test periods. At the uppermost counting station (weir 433), finger traps installed on the weir crests deterred fish from dropping back into the test area. Water depth over the finger trap was approximately 6 inches.

Timing of Fish

Fish passage through segments of the fishway was timed and recorded for individual weir crossings at each counting station. This was accomplished by installing a system of pushbutton switches from each count station to corresponding pens on an electrically driven time event recorder. Marks on the time-scaled recorder chart provided a permanent record of fish passage at each station.

The method of counting fish and timing was the same in both fishways. Each counter held a small box containing four pushbuttons labeled salmon up, salmon down, others up, and others down. When a fish crossed the counting weir, the counter depressed the appropriate button (fig. 6) which activated the corresponding recorder pen. An observer at the recorder (fig. 7) compiled at 5-minute intervals the number of salmon and other species crossing each counting weir.

A sheltered control center at each fishway housed the recorder while field phones provided direct communication between fish counters and the observer at the recorder.

TEST PROCEDURE

A basic operational procedure was established to standardize tests between the two fishways. The plan was flexible enough, however, to cope with unusual conditions and the availability of personnel. Tests were scheduled to include all parts of the seasonal migration whenever adequate numbers of fish were available.

Operational Sequence

The operational sequence was basically the same for all tests in both fishways. Twelve to 24 hours before each test the

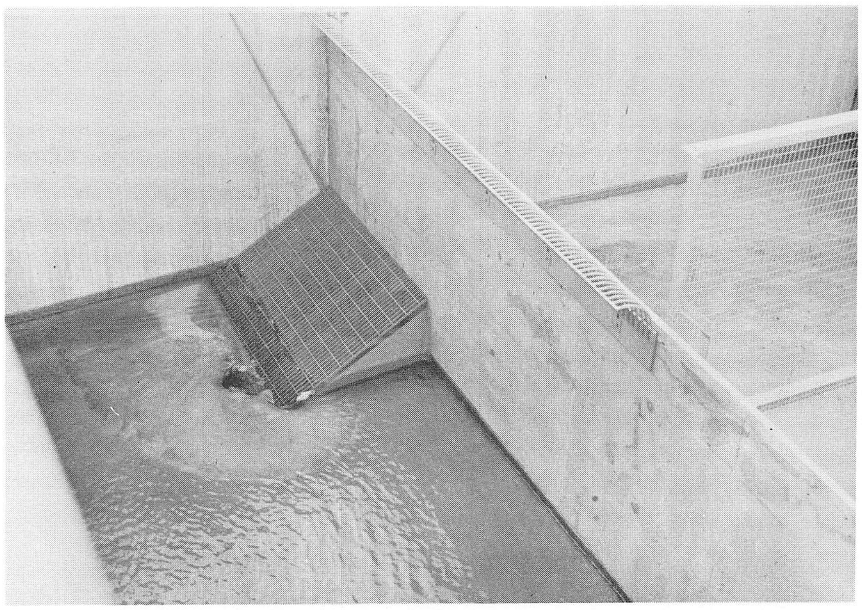


Figure 5.--Orifice grill on the upstream side of weir 433 in the 1-on-16 slope fishway is typical of grills on both sides of each counting weir. The finger trap on the weir crest prevents fish from dropping back into the test area.

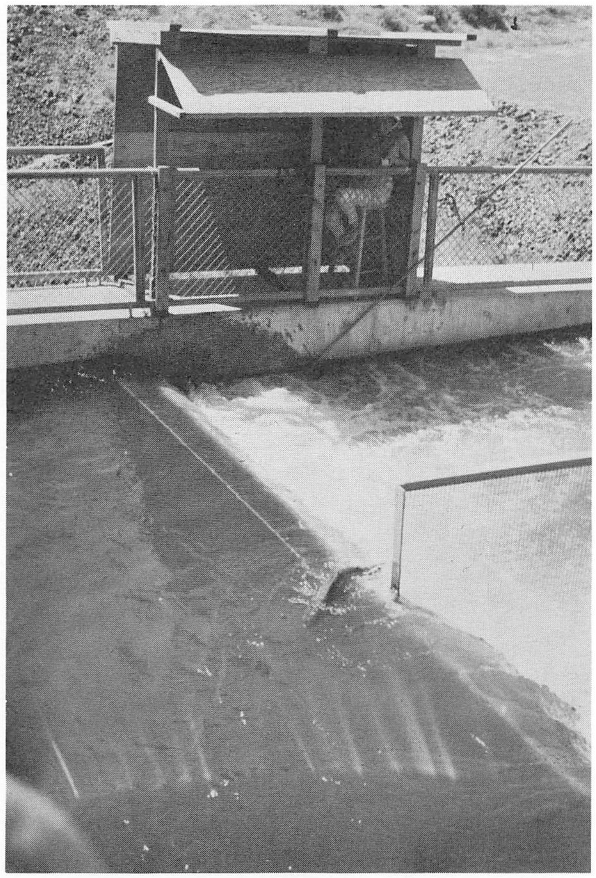


Figure 6.--A salmon being counted over weir 433 in the 1-on-16-slope fishway. Passage of the fish is recorded by pressing a button on the small box held by the counter. This action marks a tape on the recorder located at the control center.

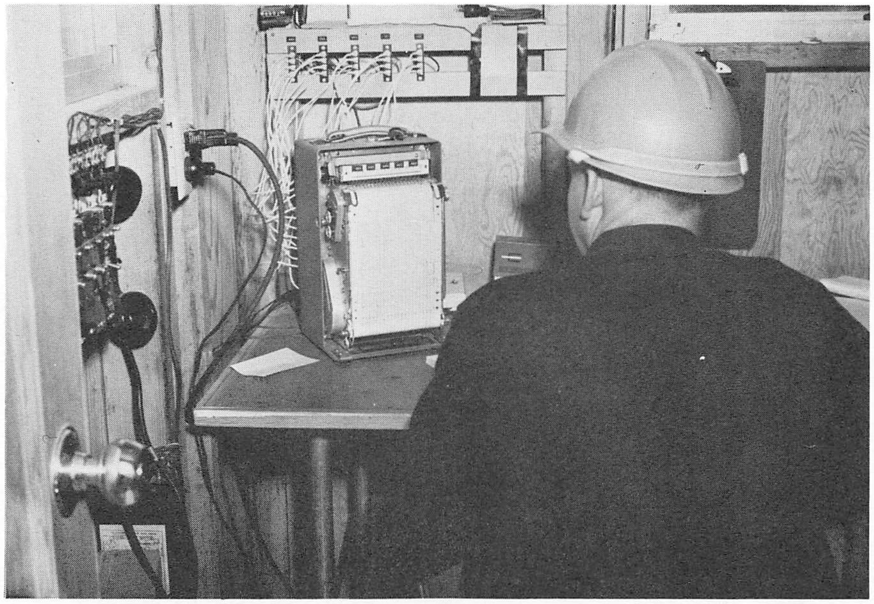


Figure 7.--A time event recorder located at one of the two control centers. Fish counts from all counting weirs are transmitted to the recorder and appear as marks on the moving tape. Recorder tape runs at the rate of 1½" per minute.

barrier gate was positioned to block the lower end of the test area and divert all fish through the bypass side of the fishway. This usually cleared the test area of all but nonsalmonids. Each test was started at 8:00 a.m.; that is, the recorder was started at this time and counters started counting as soon as they arrived at their stations; five to 10 minutes later. Approximately 30 minutes of counting at each station revealed the movement (or lack of movement) of any fish remaining in the test side of the fishway. The barrier gate was then positioned to open the test side and block the bypass side thus diverting the entire fishway migration through the test area.

A 2- to 3-hour entry period usually provided an adequate sample and still left enough time for all fish to complete the fishway ascent during the test period. A scarcity of fish during some tests (especially in the 1-on-10-slope ladder) caused low entry rates, so entry periods were extended to increase the sample size. The entry periods and numbers of fish entered during tests used for the analysis are given in tables 1 and 2.

Counting continued at all stations throughout the duration of the test which was usually terminated around 4:30 p.m. During the 8-hour test, counters generally worked a 50-minute shift at one station after which they had a short rest period and time to get to their next station. The sequence of stations and count schedules were assigned at random to prevent individuals from being regularly assigned to particular stations.

<u>Scheduling of Tests</u>

Tests were scheduled to coincide with the arrival of the various species and races of salmonids entering the Snake River; hence, the number of tests conducted depended upon the number of fish available during each portion of the run. When we were unable to obtain adequate numbers of fish during the 2- to 3-hour entry period, testing was discontinued until the run increased. Daily fishway counts of salmon and steelhead graphed in figure 8 show the seasonal distribution of salmonids. Test days are also indicated.

Whenever possible the north and south ladders were tested simultaneously or on alternate days. In a few instances, tests were conducted in the same ladder for more than one successive day.

The number of count stations employed in each ladder varied throughout the test series. Counts were always maintained at the three comparable weir elevations 359, 380, and 433 in both

Table 1.--Net upstream counts of salmonids and nonsalmonids at each counting station 1/ in the 1-on-10 slope fish ladder during fishway evaluation tests at Ice Harbor Dam May 12 to October 4, 1962.

Date		Entry period (hours)	Station 359 S	Station 359 NS	Station 359 Total	Station 371 S	Station 371 NS	Station 371 Total	Station 380 S	Station 380 NS	Station 380 Total	Station 387 S	Station 387 NS	Station 387 Total	Station 433 S	Station 433 NS	Station 433 Total
May	12	2.50	37	2	39	35	4	39	36	0	36	30	3	33	35	1	36
	13	2.50	60	0	60	59	0	59	57	1	58	57	2	59	55	1	56
	16	5.25	280	1188	1468	243	720	963	228	468	696	248	315	563	232	34	266
June	21	2.70	26	288	314	22	350	372	25	317	342	21	375	396	21	138	159
	22	2.00	14	94	108	14	297	311	14	249	263	13	246	259	15	131	146
	23	2.00	19	64	83	21	116	137	26	101	127	25	131	156	18	95	113
	26	2.08	7	15	22	8	9	17	6	5	11	3	0	3	7	8	15
3/	27	3.00	137	11	148	139	17	156	141	16	157	89	1	90	139	7	146
3/	28	4.75	244	165	409	227	222	449	221	164	385	2	2	4	224	56	280
3/	29	3.00	262	645	907	271	395	666	257	646	903	65	5	70	260	163	423
	30	2.25	93	722	815	88	869	957	90	641	731	80	728	808	92	512	604
July	2	2.50	90	79	169	---	2/---	---	89	75	164	---	---	---	79	151	230
	3	2.75	19	39	58	---	---	---	23	25	48	---	---	---	18	37	55
	8	2.00	5	8	13	---	---	---	6	6	12	---	---	---	6	26	32
Aug.	8	2.08	3	2	5	3	1	4	3	3	6	3	8	11	3	6	9
	9	7.92	3	20	23	2	9	11	2	11	13	3	9	12	3	13	16
	15	3.00	11	3	14	11	6	17	9	5	14	---	---	---	12	2	14
	17	3.00	64	37	101	65	22	87	70	17	87	---	---	---	67	9	76
Sept.	8	2.30	26	32	58	---	---	---	24	27	51	---	---	---	24	9	33
	9	2.50	37	25	62	36	25	61	36	27	63	---	---	---	48	12	60
	10	3.00	34	33	67	20	46	66	22	34	56	---	---	---	25	36	61
	11	2.70	69	92	161	---	---	---	73	74	147	---	---	---	84	37	121
4/	12	2.50	---	---	---	52	122	174	50	116	166	---	---	---	68	39	107
	13	3.00	168	108	276	144	109	253	145	137	282	---	---	---	154	70	224
	14	2.70	71	34	105	---	---	---	62	31	93	---	---	---	60	12	72
	17	3.00	21	5	26	---	---	---	20	6	26	---	---	---	22	6	28
	18	2.00	172	18	190	---	---	---	183	19	202	---	---	---	185	7	192
	19	2.50	319	112	431	---	---	---	318	70	388	---	---	---	298	29	327
	20	3.10	227	29	256	---	---	---	221	42	263	---	---	---	234	29	263
	21	2.60	108	9	117	101	10	111	111	2	113	70	23	93	100	16	116
	25	2.00	243	43	286	---	---	---	226	38	264	---	---	---	227	10	237
	26	2.00	70	20	90	---	---	---	69	12	81	---	---	---	67	6	73

Table 1--Net upstream counts of salmonids and nonsalmonids at each counting station 1/ in the 1-on-10 slope fish ladder during fishway evaluation tests at Ice Harbor Dam May 12, to October 4, 1962 (continued)

Date		Entry period (hours)	Number of salmonids (S) and nonsalmonids (NS) counted at each station														
			Station 359			Station 371			Station 380			Station 387			Station 433		
			S	NS	Total	S	NS	Total	S	NS	Total	S	NS	Total	S	NS	Total
Sept	27	2.00	184	31	215	___	___	___	183	23	206	---	---	---	181	17	198
	28	2.00	207	2	209	---	---	---	202	9	211	---	---	---	199	13	212
	29	3.25	147	34	181	141	26	167	130	31	161	126	26	152	161	9	170
Oct	1	2.00	45	8	53	---	---	---	45	8	53	---	---	---	48	3	51
	3	2.50	18	3	21	16	6	22	16	7	23	15	6	21	16	4	20

1/ Counting stations are identified as elevation in feet above mean sea level.

2/ Denotes no count.

3/ Terminated count at elevation 387 before test was completed.

4/ Count at 359 not obtained due to mechanical difficulties.

Table 2.--Net upstream counts of salmonids and nonsalmonids at each counting station 1/ in the 1-on-16 slope fish ladder during fishway evaluation tests at Ice Harbor Dam May 12 to October 4, 1962.

Date		Entry period (hours)	Number of salmonids (S) and nonsalmonids (NS) counted at each station															
			Station 359			Station 369			Station 380			Station 381			Station 433			
			S	NS	Total	S	NS	Total	S	NS	Total	S	NS	Total	S	NS	Total	
May	17	2.30	562	217	779	553	208	761	563	112	675	474	121	595	545	18	563	
	18	2.50	7	28	35	3	19	22	4	28	32	3	35	38	4	167	171	
	21	2.75	9	171	180	13	75	88	11	54	65	4	870	874	14	690	704	
	22	2.83	14	33	47	13	2	15	15	-61 2/		7	405	412	18	97	115	
June	19	2.00	66	193	259	68	250	318	85	83	168	39	192	231	82	109	191	
	20	2.00	108	1035	1143	132	888	1020	117	495	612	88	575	663	157	354	511	
	24	2.00	193	227	420	205	215	420	219	83	302	3/---	---	---	216	174	390	
	25	2.00	134	239	373	131	200	331	131	132	263	116	225	341	145	201	346	
	26	2.00	371	114	485	374	79	453	375	44	419	286	92	378	---	---	---	4/
	27	2.80	320	336	656	318	286	604	318	103	421	203	78	281	321	171	492	5/
	28	3.00	284	990	1274	289	1001	1290	284	436	720	222	68	290	303	444	747	5/
	29	3.00	63	686	749	72	750	822	72	307	379	---	---	---	76	497	573	
July	1	2.70	58	99	157	53	94	147	43	70	113	39	168	207	56	109	165	
	2	2.50	16	66	82	---	---	---	16	24	40	---	---	---	16	106	122	
	3	3.00	15	228	243	14	210	224	15	103	118	---	---	---	16	166	182	
	9	2.00	17	15	32	---	---	---	16	18	34	---	---	---	15	110	125	
Aug.	2	2.33	9	78	87	6	66	72	7	51	58	3	54	57	8	58	66	5/
	14	2.00	282	9	291	321	31	352	154	39	193	---	---	---	183	70	253	
	16	3.00	59	62	121	57	104	161	20	35	55	---	---	---	38	61	99	
	18	3.00	126	107	233	171	75	246	85	53	138	---	---	---	120	108	228	
	20	2.80	31	499	530	36	619	655	44	297	342	---	---	---	43	289	332	
Sept	8	2.00	206	534	740	262	437	699	225	547	772	---	---	---	309	493	802	
	9	2.20	323	496	819	243	502	745	351	471	822	---	---	---	399	592	991	
	10	1.70	132	273	405	56	281	337	58	265	323	---	---	---	89	544	633	
	11	2.00	626	422	1048	583	498	1081	465	596	1061	---	---	---	653	529	1182	
	12	2.00	336	241	577	327	168	495	251	217	468	---	---	---	343	456	799	
	13	1.80	620	314	934	691	219	910	596	216	812	---	---	---	719	334	1053	
	14	2.00	335	408	743	352	325	677	319	356	675	---	---	---	410	429	839	
	17	2.00	796	222	1018	---	---	---	872	186	1058	---	---	---	636	203	839	6/
	18	2.00	979	578	1557	---	---	---	965	412	1377	---	---	---	588	475	1063	6/
	19	2.00	1274	982	2256	---	---	---	1261	982	2243	---	---	---	853	666	1519	6/
	20	1.90	943	444	1387	---	---	---	988	425	1413	---	---	---	693	345	1038	6/

Table 2.--Net upstream counts of salmonids and nonsalmonids at each counting station 1/ in the 1-on-16-slope fish ladder during fishway evaluation tests at Ice Harbor Dam May 12 to October 4, 1962 (continued).

Date	Entry period (hours)	Number of salmonids (S) and nonsalmonids (NS) counted at each station														
		Station 359			Station 369			Station 380			Station 381			Station 433		
		S	NS	Total	S	NS	Total	S	NS	Total	S	NS	Total	S	NS	Total
Sept 25	2.00	491	73	564	---	---	---	501	97	598	---	---	---	521	178	699
26	1.70	203	350	553	---	---	---	160	434	594	---	---	---	227	408	635
27	2.00	181	294	475	---	---	---	171	317	488	---	---	---	184	269	453
28	2.00	588	332	920	---	---	---	472	422	894	---	---	---	611	194	805
Oct. 1	2.00	190	189	379	---	---	---	203	207	410	---	---	---	239	158	397
2	2.00	229	186	415	272	171	443	225	231	456	189	217	406	250	178	428
4	5.00	252	321	573	---	---	---	265	199	464	---	---	---	299	114	413

1/ Counting stations are identified as elevation in feet above mean sea level.

2/ More nonsalmonids dropped back downstream than were counted upstream.

3/ Denotes no count.

4/ Count at elevation 433 not obtained due to mechanical difficulties.

5/ Terminated count at elevation 381 before test was completed.

6/ Hole in divider screen in pool elevation 433, allowing fish to escape into bypass side.

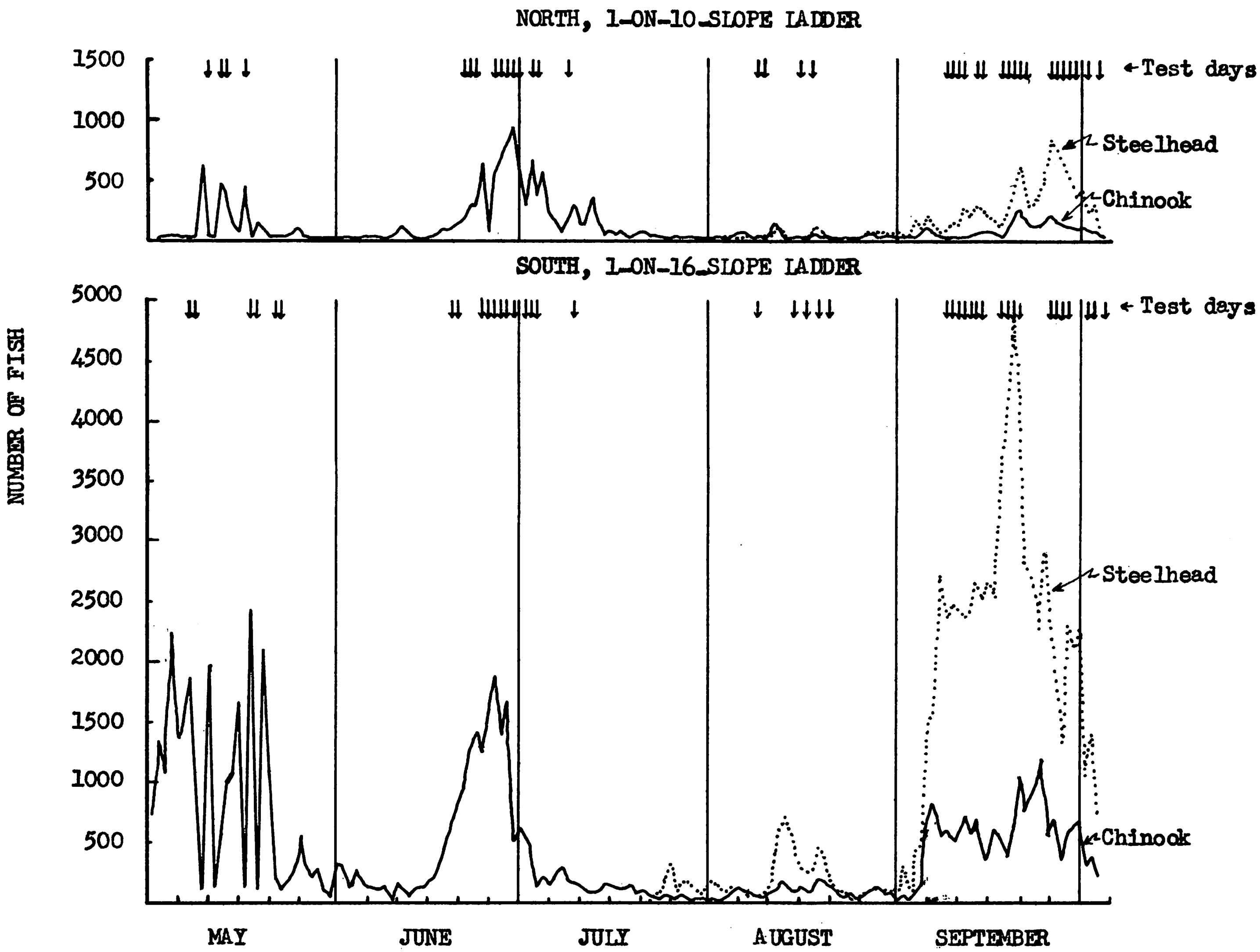


Figure 8.- -Daily counts of chinook salmon and steelhead trout ascending the Ice Harbor fish ladders (Corps of Engineers count stations). Arrows at the top of each graph indicate days tests were conducted.

ladders. Counts at the other two stations were used intermittently, depending on the type of test being conducted and the number of personnel available.

OPERATIONAL CRITIQUE

Before presenting the results of the tests, certain factors which somewhat limited the scope of the study and influenced comparisons of the performance of fish in the 1-on-10- and 1-on-16-slope ladders should be discussed. These are associated primarily with the numbers of fish involved in the tests and accuracy of counts in the 1-on-10- and 1-on-16-slope ladders.

Factors Influencing Numbers of Fish in Tests

Ideally, comparisons of the efficiencies of the 1-on-10- and 1-on-16-slope ladders could best be made if the numbers of fish, species composition and entry rates were similar in the two ladders. Unfortunately these conditions were rarely experienced throughout the course of the study, and there was generally considerable variation between ladders (tables 1 and 2).

Variations in the numbers of fish within ladders during the experimental period (tables 1 and 2) were generally associated with the seasonal pattern of the runs. The consistently larger sample sizes in the 1-on-16-slope ladder, however, were due to the fact that generally more fish used this ladder. Although unequal utilization of the two ladders had been anticipated when formulating the design for the 1-on-10-slope ladder (a factor contributing to its narrower width), it is possible that the proportion of fish using this ladder during certain phases of the study may have been even less than could be normally expected.

During the spring chinook run (May), a section of cofferdam remaining from the construction phase of the dam was instrumental in creating a large eddy downstream from the entrance to the 1-on-10-slope ladder. This condition is believed to have prevented many fish from locating the entrance. During the month of May, 90 percent of the total chinook passage over the dam was counted through the 1-on-16-slope ladder. The test on May 16 in the 1-on-10-slope ladder involving 280 salmonids was made possible by special arrangement with the Corps of Engineers whereby the spillway gates were closed for a 2-hour period during the test.

Beginning about mid-June, spillway discharges began decreasing, and it was possible to adjust the various spillway gates to provide a more desirable entrance condition to the north shore ladder. A larger percentage of salmonids entered the 1-on-10-slope ladder during this test period, and during the peak passage days of the summer chinook run, up to 260 fish entered the ladder during the 2- to 3-hour entry period.

There was virtually no spill during the fall chinook and steelhead runs as the entire river flow was being passed through the turbines. Fish following the main flow of the river were thus attracted to the powerhouse collection system and entrance to the 1-on-16-slope ladder. During this period, Corps of Engineers personnel were quite cooperative in opening spillway gates on the north shore prior to and during tests in an attempt to attract more fish into the 1-on-10-slope ladder. Although sample sizes were still smaller than those in the 1-on-16-slope ladder, the numbers of fish utilizing the ladder were probably of the magnitude which may be expected under normal operating conditions in ensuing years.

Accuracy of Counts

Comparisons of the net upstream counts between stations within each ladder for various tests (tables 1 and 2) reveal obvious discrepancies. In many instances, counts at a given station were greater than counts at stations below (lower elevation) this point. In the case of salmonids, counts at the uppermost station (elevation 433) were generally greater than counts at the lower station (elevation 359) in the 1-on-16-slope ladder, indicating more fish exited than had entered. Although similar instances occurred in the 1-on-10-slope ladder, salmonid counts at station 433 were generally lower if not equal to counts at 359. These discrepancies in counts may be attributed to such factors as: (1) observers failing to see all fish passing upstream or downstream (fallbacks) at count stations, (2) differences in ability of observers to discern between species, (3) recruitment or loss of fish in the test side resulting from fish jumping over or passing through holes in the divider barrier separating the test and bypass sides, and (4) mistaking fish surfacing immediately above the counting weir as an upstream passage. All of these occurrences were noted to some degree during the tests.

Visibility and distance from observer to the weir crest varied between count stations and chances for error were greater at some stations than at others. The upper stations (elevation 433) in both ladders were located at the downstream end of the nonoverflow section and the flow over the weir was smooth providing good visibility. It is believed, therefore, that counts at these stations were more accurate than at any other station. Although a similar smooth flow occurred at weir elevation 380 just below the turn pool in the 1-on-16-slope ladder, light conditions and position of the observer in relation to the weir crest were not as desirable as at the upper station. The remaining stations in each ladder were typically rough due to turbulence, entrained air, and the upwelling from the orifice in the pool above.

The station, having the most difficult counting conditions and probably susceptible to the greatest degree of error, was just above the turn (elevation 381) in the 1-on-16-slope ladder (fig. 4). In addition to the undesirable flow characteristics previously mentioned, visibility was further impaired due to the position of the count station in relation to the weir crest. Observers, being positioned upstream from the counting weir, were afforded only a head-on view of the fish as they crossed the weir crest which made identification difficult. Differences in behavior of fish crossing this weir created further difficulties. Salmonids frequently crossed the weir nearer the wall (above the orifice) while nonsalmonids (suckers, squawfish, etc.) crossed upstream nearer the divider screen at the opposite end of the weir and fell back downstream nearer the wall. The effect being that when large numbers of nonsalmonids were passing upstream, the observers may have been distracted by the concentrated activity at one end of the weir and did not observe all upstream passage of salmonids and downstream passage of nonsalmonids which may have occurred at the opposite end of the weir.

Counts in the 1-on-16-slope ladder were probably more susceptible to error than those in the 1-on-10-slope ladder. One reason for this was that observers were required to maintain surveillance over a greater weir span (12 feet in the 1-on-16-slope ladder compared to 5 feet in the 1-on-10-slope ladder). Another reason for this was the generally higher percentage of nonsalmonids in the tests conducted in the 1-on-16-slope ladder, affording a greater chance of making errors in identification of species. Finally, there were several gaps in the divider screen in this ladder where it joined the weir crests large enough to pass nonsalmonids if these fish ascended diagonally across the weir. Several such instances were noted at station 380 before it and all others below this point were repaired just prior to the tests in September. It is likely that passage through these gaps may have occurred more frequently at the counting stations where all fish were required to swim over the weir crest due to the blocked orifice. No salmonids were ever noted passing through these gaps, and it is doubtful that many did due to their larger size and swimming attitude (directly over and at nearly right angles to the crest) as they crossed the weir.

Finally, differences in the accuracy of the observers must be considered. None of the ladies employed for the study had any prior experience counting fish and had to be trained during the course of the study. All of the observers were quite conscientious in their efforts to achieve accurate counts; however, some were undoubtedly more adept than others. It is likely that some errors arose from the differences in their ability to account for and properly identify every fish that crossed the weir at the counting station. In view of the brief time required for the fish to cross the weirs, even the best observers could understandably make errors in discerning between salmonids and nonsalmonids of nearly equal size.

RESULTS

In conducting this study, it was assumed that any undesirable design features of the 1-on-10-slope ladder serious enough to pose a question as to its acceptability as a suitable passage facility might be manifested by: (1) a smaller proportion of salmonids completing the ladder, (2) unusual passage patterns within the ladder, (3) significantly slower rates of passage, or (4) greater fallback activity during the tests. Tests in the conventional 1-on-16-slope ladder provided the standard for comparison.

The study was concerned primarily with the performance of salmonids in the two ladders. Observations of the performance and behavior of nonsalmonids were considered as an incidental phase of the experiments.

Proportion of Salmonids Completing the Ladders

The discrepancies in counts between stations and differences noted between ladders preclude straightforward comparisons of the proportions of salmonids completing the two ladders during the test periods. It is believed that with few exceptions only a small proportion of salmonids may have failed to complete either ladder during the test period. It has been noted that generally more salmonids were counted out of the test section than had entered in the 1-on-16-slope ladder, and although this frequently occurred in the 1-on-10-slope ladder, generally fewer numbers were counted out than had entered. Proportions completing the test sections of the two ladders for paired tests based upon the counts at stations 359 and 433 ranged from 81 tc 129 percent in the 1-on-10-slope ladder and from 60 to 150 percent in the 1-on-16-slope ladder.

Passage Patterns

If the performance of salmonids in the 1-on-10-slope and 1-on-16-slope ladders were comparable, we would expect the fish to demonstrate similar patterns of movement in ascending the test sections of the two ladders, and these would be reflected in the passage patterns at the count stations. Passage patterns at the various count stations within the test sections of the two ladders are presented graphically in Appendix figures 1 to 21. Only paired tests (conducted on the same or alternate days) involving larger sample sizes have been considered. Some tests in which operational difficulties prevented obtaining comparable data in the two ladders were omitted.

In preparing the graphs, counts at each station were grouped by 15-minute intervals beginning with the time of passage of the first fish over the first station (elevation 359). The 15-minute counts (expressed as percentages of the total number counted) for each station were then plotted separately on the same time scale. Since entry periods and the rate at which fish entered were frequently different in the two ladders, each ladder was first graphed separately on the same scale, then the 1-on-16-slope graphs were superimposed upon the 1-on-10-slope graph so that the entry curves (passage at elevation 359) coincided. This was accomplished in each instance by matching the two entry curves at the point at which 50 percent of the fish had entered. The relationship between other stations was not changed by this manipulation. It was done merely to facilitate the comparison of passage patterns at the various count stations in the two ladders.

Comparisons of the passage patterns at the various count stations for these paired tests indicate the behavior and rate of passage of salmonids in the two ladders were quite similar. There was no evidence that salmonids were being delayed or exhibiting unusual behavior patterns in either the 1-on-10-slope or 1-on-16-slope ladders.

Occasionally differences in the conformation of the passage curves between stations may be noted which indicate salmonids were being delayed. Two such instances could be associated with abnormal conditions which occurred during the test. The first is illustrated in Appendix figure 15. Note that passage of salmonids over the upper station (elevation 433) in the 1-on-10-slope ladder dropped more abruptly between hours 3 and 4 than would be expected on the basis of the passage at either station 359 or 380. This was noted while the test was in progress as passage at the upper station actually stopped for a 5-minute interval just before hour 4. Upon checking the ladder, it was found that Corps of Engineers personnel had been removing trash from the forebay immediately in front of the fish ladder exit. A skip had been lowered into the water, and a worker had been raking the debris into it. They had been working for about 20 minutes and were just completing the job when noted. It is quite likely that this disturbance was responsible for the temporary cessation of passage noted.

Passage at the upper station (elevation 433) in the 1-on-16-slope ladder was also abnormal on this day as salmonids were being counted here before any had entered the test side of the ladder. This was due to a hole in the divider screen between the test and bypass sides of the ladder in pool elevation 433 which allowed fish to enter and escape from the test side.

The second unusual occurrence which seemed to have influenced passage in the 1-on-16-slope ladder took place on September 25. About 1½ hours after the test began, observers reported the water at the upper end of the 1-on-16-slope ladder was turning green. A check of the forebay in the vicinity of the fish ladder exit revealed an algae bloom was apparently occurring. Visibility in the ladder became progressively worse during the next two hours, then began improving, and two hours later conditions were back to normal. Secchi disc readings dropped from approximately 6 feet to 1.5 feet then back to 6 feet during the 4-hour period. It is believed that this dense concentration of algae, occurring during the test period, was responsible for the differences between the general conformation of the passage curves at elevations 380 and 433 in the 1-on-16-slope ladder (Appendix fig. 16). Apparently most of the salmonids had crossed the count station at elevation 380 before becoming influenced by the algae condition.

It may also be noted that passage through this section (elevation 380 to 433) was considerably slower in the 1-on-16-slope ladder than in the 1-on-10-slope ladder. Strangely enough, the algae bloom was localized to the south shore and was only barely perceptible in the 1-on-10-slope ladder. This phenomenon provides a good example of the differences which might have consistently prevailed had salmonids been significantly slower in one ladder than in the other.

Rate of Passage

The preceding graphic illustrations of passage patterns in the two ladders indicated that salmonids were ascending the two ladders at approximately the same rate. This relationship was further inspected by comparing passage times through comparable sections of the ladders.

Since it was impossible to time individual salmonids as they ascended the test sections in the two ladders, passage times must be based upon the group performance of the fish in each test. A measure based upon the time at which 50 percent of the fish had passed each station has been employed. The elapsed time between any two stations was computed by subtracting the time at which the median fish had crossed the lower station from the time at which the median fish had crossed the upper station. The median fish was based upon the total number of fish counted at each station.

To facilitate the comparison between sections involving unequal numbers of pools the above elapsed times were converted to average pool times by dividing the values by the number of pools between the stations.

Comparable sections.--Rates of passage through comparable sections (elevation 359 to 380 and 380 to 433) for paired tests in the two ladders are given in table 3. In pairing tests, only those which were conducted on the same day or alternate days in the two ladders were considered. Paired tests involving less than 10 salmonids in either ladder were omitted as were those in which operational difficulties or unusual occurrences prevented obtaining comparable data in the two ladders. Salmonids in tests conducted from May 16 to July 3 were predominantly chinook salmon while those in tests from August 14 to October 3 were predominantly steelhead trout (based upon counts made by Corps of Engineers, table 4).

There was considerable variation in pool times between and within ladders. Differences between ladders for individual paired tests ranged from 0.11 to 2.45 minutes per pool in the first 21-pool section (elevation 359 to 380) and from 0.08 to 0.62 minutes per pool in the next 53-pool section (elevation 380 to 433). The above values expressed in elapsed times are from 2.3 to 51.4 minutes and from 0.8 to 33.0 minutes respectively.

Although the nature of the differences between ladders varied between tests, average pool times in the 1-on-10-slope ladder generally were less than in the 1-on-16-slope ladder in the first 21 pools and greater than in the 1-on-16-slope ladder in the next 53 pools. Average pool times within the first 21-pool section were consistently greater than those within the next 53-pool section in both ladders. Analysis of variance tests on

Table 3.--Rates of passage of salmonids through comparable sections in the 1-on-10-slope and 1-on-16-slope ladders for paired tests conducted during the period May 16 to October 3.

Date		Rate of passage through--						No. of fish entering ladder	
		First 21 pools		Next 53 pools		Total 74 pools			
1-on-10	1-on-16	1-on-10	1-on-16	1-on-10	1-on-16	1-on-10	1-on-16	1-on-10	1-on-16
		Minutes per pool		Minutes per pool		Minutes per pool			
May 16	May 17	1.41	1.88	1.60	1.61	1.54	1.69	280	562
June 21	June 20	.98	1.33	1.30	1.54	1.21	1.48	26	108
23	24	1.26	.91	.67	1.29	.84	1.18	19	193
27	27	1.74	1.58	1.38	1.42	1.49	1.46	137	320
28	28	1.84	1.65	1.47	1.30	1.57	1.40	244	284
29	29	1.86	1.65	1.60	1.27	1.68	1.38	262	63
30	July 1	1.81	2.16	1.28	1.12	1.43	1.41	93	58
July 3	3	1.87	2.25	1.31	.95	1.47	1.32	19	15
Aug. 15	Aug 14	.81	3.26	1.04	1.58	.98	2.06	11	282
17	16	1.55	1.90	1.31	.98	1.38	1.24	64	59
Sept 8	Sept 8	1.24	1.40	1.17	1.26	1.19	1.30	26	206
10	10	1.54	1.78	1.16	1.13	1.27	1.31	34	132
11	11	.54	1.72	1.32	1.08	1.10	1.26	69	626
13	13	1.73	1.51	1.57	1.26	1.62	1.33	168	620
14	14	3.12	1.63	.91	1.32	1.54	1.41	71	335
26	26	2.69	2.58	1.20	1.06	1.62	1.49	70	203
27	27	1.42	2.00	1.44	1.18	1.43	1.41	184	181
28	28	1.69	2.32	1.32	.99	1.42	1.36	207	588
Oct 1	Oct 1	1.38	1.50	1.19	1.44	1.24	1.46	45	190
3	2	.92	2.12	1.19	.96	1.12	1.29	18	229
Mean		1.57	1.86	1.27	1.24	1.36	1.41		

Table 4.--Species composition of salmonids ascending the 1-on-10-slope and 1-on-16-slope ladders during tests conducted on the same or alternate days from May 16 to October 3. Percentages are based on counts made by the Corps of Engineers.

Date		Chinook salmon		Steelhead trout		Blueback salmon		Silver salmon	
1-on-10	1-on-16	1-on-10	1-on-16	1-on-10	1-on-16	1-on-10	1-on-16	1-on-10	1-on-16
		Percent		Percent		Percent		Percent	
May 16	17	90.5	99.6	9.5	.4	0	0	0	0
June 21	June 20	99.4	98.6	.6	1.4	0	0	0	0
23	24	97.7	98.1	2.3	1.9	0	0	0	0
27	27	99.1	99.1	.9	.6	0	.3	0	0
28	28	99.4	98.7	.6	1.2	0	.1	0	0
29	29	99.5	97.8	.5	2.2	0	0	0	0
30	July 1	100.0	99.6	0	.2	0	.2	0	0
July 3	3	98.0	87.9	1.7	11.4	.3	.7	0	0
Aug. 15	Aug. 14	18.7	24.8	81.3	75.2	0	0	0	0
17	16	30.4	18.1	69.6	81.9	0	0	0	0
Sept 8	8	25.0	19.8	75.0	77.0	0	0	0	3.2
10	10	21.0	22.5	75.5	72.4	0	0	3.5	5.1
11	11	20.8	21.7	77.7	72.7	0	0	1.5	5.6
13	13	22.3	19.7	74.9	75.3	0	0	2.8	5.0
14	14	22.1	15.0	75.9	78.9	0	0	2.0	6.1
26	26	20.0	28.0	78.9	70.9	0	0	1.1	1.1
27	27	19.8	19.4	78.9	79.6	0	0	1.3	1.0
28	28	24.4	19.9	74.2	78.1	0	0	1.4	2.0
Oct 1	1	28.9	24.7	69.5	74.8	0	0	1.6	.5
3	2	21.6	22.7	78.4	76.2	0	0	0	1.1

the data in table 5 indicated the differences between ladders was not great enough to indicate that passage in the 1-on-10-slope ladder was significantly slower or faster than in the 1-on-16-slope ladder within either of the two test sections. The tests did indicate, however, that salmonids ascended the upper 53-pool test section in each ladder significantly faster than they did the lower 21-pool test section.

Similar sections.--In addition to the three comparable stations (elevations 359, 380, and 433), counts were frequently made at two other stations in each ladder which, although located at different elevations, encompassed similar sections of the ladders. The stations were located at elevations 371 and 387 in the 1-on-10-slope ladder and at elevations 369 and 380 in the 1-on-16-slope ladder. These stations permit further comparisons of the rates of passage of salmonids within the first 21-pool section previously discussed and sections involving turn pools in each ladder.

A comparison of the rates of passage of salmonids through two similar sections within the first 21 pools of the test section in each ladder is given in table 5. Comparisons are made (1) between the first 12 pools (elevations 359 to 371) in the 1-on-10-slope and the first 10 pools (elevations 359 to 369) in the 1-on-16-slope ladder and (2) between the remaining 9 pools (elevations 371 to 380) in the 1-on-16 slope ladder and the remaining 11 pools (elevations 369 to 380) in the 1-on-16-slope ladder. The original intent was to locate the second count station in each ladder at elevation 369 providing two comparable sections of 10 and 11 pools respectively between elevation 359 and 380. Unfortunately, the orifice grills were installed at elevation 371 in the 1-on-10-slope ladder by mistake and the error was not discovered until after the fishway was watered.

The mean values for the 11 tests in table 5 indicate there was little difference in the rate at which salmonids ascended the two sections in either ladder. Rates of passage for individual tests varied; they were sometimes faster in the first than in the second section and vice versa. With two exceptions, the same relationship was noted between ladders: when salmonids in the 1-on-10-slope ladder were faster in the first section, those in the 1-on-16-slope ladder were also faster.

Passage in the 1-on-10-slope ladder was generally faster than in the 1-on-16-slope ladder in both sections. An analysis of variance indicated these differences between ladders were significant. Although a similar relationship was noted in

Table 5.--Rate of passage of salmonids through similar sections in the 1-on-10-slope and 1-on-16-slope ladders for paired tests.

Date		Rate of passage through--			
		First section[1]		Second section[2]	
1-on-10	1-on-16	1-on-10 (12 pools)	1-on-16 (10 pools)	1-on-10 (9 pools)	1-on-16 (11 pools)
		Minutes per pool		Minutes per pool	
May 16	May 17	.92	1.73	2.06	2.01
June 21	June 20	1.02	2.31	.92	.45
June 27	June 27	1.85	1.82	1.61	1.36
28	28	1.80	1.33	1.90	1.94
29	29	2.22	1.67	1.39	1.63
30	July 1	2.03	2.27	1.52	2.05
Aug. 15	Aug. 14	.47	1.80	1.27	4.58
17	16	1.44	1.92	1.69	1.87
Sept 10	Sept 10	1.90	2.61	1.07	1.03
13	13	1.88	1.60	1.52	1.44
Oct. 3	Oct. 2	.65	1.80	1.29	2.41
Mean		1.47	1.90	1.48	1.89

1/ From elevations: 359 to 371 in 1-on-10-slope ladder
359 to 369 in 1-on-16-slope ladder

2/ From elevations: 371 to 380 in 1-on-10-slope ladder
369 to 380 in 1-on-16-slope ladder

the comparison between ladders for the entire (21 pools) lower section (table 3), the differences were not significant in this instance.

Counts at weir elevations 387 (1-on-10-slope ladder) and 381 (1-on-16-slope ladder) were occasionally made throughout the test to provide an estimate of the times spent in the turn pools of the two ladders. The results of five paired tests are presented in table 6. Since counts at the above stations were generally made during tests in which counts were made at all stations, pool times for the other three sections in each ladder have been included.

It may be noted that average pool times were greatest for the sections including turns in both ladders; elevations 380 to 387 in the 1-on-10-slope and 380 to 381 in the 1-on-16-slope ladder. Direct comparisons of the times spent in the turn pools of the two ladders are not possible. The turn is accomplished by two 90° turn pools within a 7-pool section in the 1-on-10-slope ladder and in a single 180° turn pool in the 1-on-16-slope ladder (fig. 2). Comparisons of the two count sections indicate, however, that considerably more time was spent in the 1-on-16-slope turn than in the 1-on-10-slope turns. Since there is some question as to the reliability of the counts (elevation 381) from which the 1-on-16-slope estimates were derived, the values given may not provide an entirely accurate measure of the turn-pool time.

In two of the tests (July 1 and October 2), two observers were stationed at the upstream weir (elevation 381) of this turn in an effort to achieve as accurate counts as possible. The average pool time in the July 1 test was 14.8 minutes. In the October 2 test, there was no indication of delay, in fact 50 percent of the fish had crossed the upstream weir (elevation 381) before they had crossed the downstream weir (elevation 380) of the turn. Although the latter is an impossibility, it illustrates that there may have been considerable variation in the times spent in this turn. Due to count difficulties experienced at elevation 381, we may only conclude that there is evidence of delay in the turns of both ladders, and it appears to be greater in the 1-on-16-slope than in the 1-on-10-slope ladder.

The differences indicated in turn-pool times does bring up one question concerning passage times through the remaining upper test sections in each ladder; from elevation 387 to 433 in the 1-on-10-slope ladder and from elevation 381 to 433 in the 1-on-16-slope ladder. The two sections differ in that the 1-on-16-slope section contains a turn pool and the 1-on-10-slope section does not. Estimates of pool times for these sections were

Table 6.--Rate of passage of salmonids through four sections of the test area in each ladder. Data are for paired tests in which counts were made at all stations.

Date	1-on-10-slope ladder 359 to 371 12 pools	371 to 380 9 pools	380 to 387 7 pools	387 to 433 46 pools	1-on-16-slope ladder 359 to 369 10 pools	369 to 380 11 pools	380 to 381 1 pool	381 to 433 52 pools
	Minutes per pool				Minutes per pool			
May 16	.92	2.06	2.71	1.43	----	----	----	----
17	----	----	----	----	1.73	2.01	3.0	1.58
June 20	----	----	----	----	2.31	.45	15.7	1.27
21	1.02	.92	2.87	1.06	----	----	----	----
27	1.83	1.61	2.00	1.29 2/	1.82	1.36	23.2 1/	1.00
30	2.03	1.52	1.79	1.20	----	----	----	----
July 1	----	----	----	----	2.27	2.05	14.8	.86
Oct. 2	----	----	----	----	1.30	2.41	---- 2/	.98
3	.65	1.29	1.14	1.20	----	----	----	----
Mean	1.29	1.48	2.10	1.24	1.[illegible]9	1.66	14.2	1.14

1/ Terminated count early. Passage time based upon the number of fish counted at elevation 380.

2/ Fifty percent of fish were counted at 381 before 50 percent had been counted at 380.

about the same (table 6) indicating that either passage through the upper turn pool in the 1-on-16-slope ladder was faster than was indicated in the lower turn or that salmonids were averaging less time in the other pools than in the 1-on-10-slope ladder. Since the orifices in the lower turn were always blocked to passage during tests, it is quite possible that the fish may have spent more time in this pool than in the upper one where the orifices were open, and passage patterns throughout the upper sections of the two ladders may have been quite similar as indicated.

Fallback Activity

Fallbacks (downstream passage) were recorded at each station on the assumption that, if salmonids were experiencing difficulty ascending the 1-on-10-slope ladder, it might be indicated by abnormal fallback activity. The results of these observations for paired tests in the two ladders are given in table 7. Only the lower four stations are given as the finger trap on top of the weir at elevation 433 deterred fish drifting back toward the crest at this point.

Generally very little fallback activity among salmonids was noted in either ladder. Comparisons between ladders illustrate it occurred more frequently in the 1-on-16-slope ladder.

Observations on Nonsalmonids

Although large numbers of suckers, carp, squawfish, catfish, and other nonsalmonids utilized both fishways throughout the season, it was somewhat difficult to compare the performance of these fish in the two ladders. The nature of their passage was generally prolonged entry and slower rate of movement than salmonids with considerable fallback activity.

Although comparisons of the counts between stations (tables 1 and 2) indicate large percentages of these fish may have completed the 74-pool test section in each ladder, this was believed to be not generally the case. There were nearly always nonsalmonids in the ladders, especially in the 1-on-16-slope ladder, when tests began. Both upstream and downstream passage at all stations were frequently observed before the entry gates were opened. In many instances large numbers of nonsalmonids had been counted at the upper station (elevation 433) in the 1-on-16-slope ladder even before the first salmonid had appeared. These fish were either in the test side of the ladder when the test began or were entering the test side through holes in the divider screen previously mentioned.

Table 7.--Percent of fallbacks (downstream passage) of salmonids in the 1-on-10-slope and 1-on-16-slope ladders at count stations during tests conducted on the same or on alternate days.

	Percent fallbacks[1]								
	1-on-10-slope ladder					1-on-16-slope ladder			
Date	Count stations				Date	Count stations			
	359	371	380	387		359	369	380	381
May 16	.4	.8	.4	.4	May 17	.2	.2	0.0	0.0
June 21	0.0	0.0	3.8	0.0	June 20	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	24	.5	0.0	0.0	---
26	0.0	0.0	0.0	0.0	25	0.0	1.5	0.0	.8
27	0.0	0.0	0.0	0.0*	27	.3	0.0	.3	.5*
28	0.0	0.0	0.0	0.0*	28	1.0	.3	0.0	0.0*
29	0.0	.4	0.0	0.0*	29	1.6	1.4	0.0	0.0*
30	0.0	0.0	0.0	1.2	July 1	1.7	0.0	0.0	0.0
July 2	0.0	---	1.1	---	2	0.0	---	0.0	---
3	0.0	---	0.0	---	3	0.0	6.7	0.0	---
Aug. 15	0.0	0.0	0.0	---	Aug. 14	5.4	11.8	0.0	---
17	1.5	1.5	1.4	---	16	3.3	5.0	0.0	---
Sept. 8	0.0	---	0.0	---	Sept. 8	2.4	0.0	.4	---
9	0.0	0.0	0.0	---	9	.9	0.0	0.0	---
10	0.0	0.0	0.0	---	10	1.5	0.0	0.0	---
11	1.4	---	0.0	---	11	.3	.2	0.0	---
12	---	0.0	0.0	---	12	0.0	0.0	0.0	---
13	.6	0.0	.7	---	13	0.0	0.0	0.0	---
14	2.7	---	0.0	---	14	.3	0.0	0.0	---
17	0.0	---	0.0	---	17	1.1	---	.2	---
18	1.7	---	0.0	---	18	1.4	---	.2	---
19	.3	---	0.0	---	19	.7	---	0.0	---
20	.9	---	.4	---	20	.7	---	0.0	---
25	0.0	---	0.0	---	25	.2	---	0.0	---
26	0.0	---	0.0	---	26	.5	---	0.0	---
27	0.0	---	0.0	---	27	.5	---	0.0	---
28	.5	---	0.0	---	28	0.0	---	0.0	---
Oct. 1	0.0	---	0.0	---	Oct. 1	1.0	---	.5	---
3	0.0	0.0	0.0	0.0	2	1.7	0.0	0.0	1.0

1/ Downstream count ÷ upstream count X 100.

--- Denotes no count.

* Terminated count at station before test was completed.

Probably the best pair of observations relating to performance of nonsalmonids in the two ladders was made on May 16 in the 1-on-10-slope ladder and on May 17 in the 1-on-16-slope ladder (tables 1 and 2). Very few nonsalmonids had entered the 1-on-10-slope ladder during the preceding days, and the 1-on-16-slope ladder had been unwatered on May 16 to repair the divider screen. Both test sections of the ladder were therefore nearly void of nonsalmonids when the tests began. It may be noted that only a small percentage of the nonsalmonids entering the test sections of the two ladders during these tests completed the entire 74-pool test section during the test period.

The percentages of fallbacks occurring at the various stations for paired tests in the two ladders are given in table 8. Based upon fallback activity, there was no indication that nonsalmonids were experiencing difficulty ascending the 1-on-10-slope ladder. Percentages of fallbacks were even lower than those observed in the 1-on-16-slope ladder.

Although nonsalmonids were always observed in the 1-on-16-slope turn pool between weir elevations 380 and 381, there was no evidence of abnormal accumulations in this pool during the tests. These fish were observed even when no tests were in progress and entry to the test side was blocked. They were also noted in the turn pool immediately upstream from the barrier gate between weir elevations 357 and 358. They may have been present in other pools as well but could not be readily observed due to poor visibility.

All indications are that nonsalmonids, although much slower than salmonids, successfully ascended both ladders.

SUMMARY AND CONCLUSIONS

The 1-on-10-slope fish ladder at Ice Harbor Dam was evaluated in its first year of operation to ensure that it provided safe and efficient passage for adult migrating salmonids. The evaluation was accomplished by comparing the performance of salmonids ascending the 1-on-10-slope ladder with the performance of salmonids ascending the conventional south shore 1-on-16-slope ladder. Experiments were conducted intermittently throughout the period May 10 to October 5, 1962, and were scheduled to concur with the peak passage periods of the various runs of chinook salmon and steelhead trout at the dam.

Criteria employed in comparing the performance of fish in the two ladders included (1) proportions of fish successfully negotiating the test sections of the two ladders, (2) rates and

Table 8.--Percent of fallbacks (downstream passage) of nonsalmonids in the 1-on-10-slope and 1-on-16-slope ladders at count stations during tests conducted on the same or on alternate days.

Percent fallbacks[1/]										
1-on-10-slope ladder						1-on-16-slope ladder				
Date		Count stations				Date		Count stations		
		359	371	380	387			359	369	380	381
May	16	13.6	1.9	3.3	1.2	May	17	1.4	1.4	.9	0.0
June	21	8.3	5.7	3.4	5.5	June	20	6.9	6.0	5.5	5.9
	23	3.0	14.7	14.4	5.1		24	12.0	6.9	23.8	----
	26	37.5	18.2	28.6	100.0		25	26.0	22.2	21.4	10.0
	27	0.0	15.0	5.9	----		27	14.1	11.7	22.6	----
	28	5.2	5.1	4.1	*		28	7.8	6.8	7.2	*
	29	1.2	4.1	2.0	*		29	11.2	12.2	14.5	*
	30	1.5	2.2	1.8	2.5	July	1	45.0	40.5	32.0	24.7
July	2	31.9	----	29.2	----		2	39.4	----	57.1	----
	3	33.9	----	26.5	----		3	16.2	14.6	12.0	----
Aug.	17	17.8	15.4	34.6	----	Aug.	16	29.5	17.5	42.6	----
Sept.	8	5.9	----	0.0	----	Sept.	8	30.8	20.0	12.8	----
	9	21.9	3.8	3.6	----		9	27.5	14.3	10.3	----
	10	25.0	17.8	27.6	----		10	46.2	31.5	19.0	----
	11	16.4	----	7.5	----		11	47.1	30.7	17.2	----
	12	----	15.3	10.1	----		12	51.8	41.1	28.6	----
	13	36.1	33.5	19.9	----		13	40.5	35.8	25.8	----
	14	50.0	----	32.6	----		14	37.8	28.6	17.6	----
	18	33.3	----	5.0	----		18	42.9	----	45.0	----
	19	29.6	----	30.0	----		19	30.2	----	15.9	----
	20	39.6	----	22.2	----		20	54.4	----	37.4	----
	25	17.3	----	11.6	----		25	74.5	----	42.9	----
	26	16.7	----	25.0	----		26	28.3	----	15.7	----
	27	11.4	----	8.0	----		27	35.9	----	19.5	----
Oct.	1	0.0	----	0.0	----	Oct.	1	32.7	----	21.6	----

1/ Downstream count ÷ upstream count X 100.

---- Denotes no count.

* Terminated count at station before test was completed.

patterns of movement through these sections, and (3) fallback (downstream passage) activity.

Due to discrepancies in counts of salmonids entering and exiting the test sections of each ladder and inconsistency of discrepancies between ladders, it was impossible to make straightforward comparisons of the proportions of salmonids completing the 74-pool test sections. Generally more salmonids were counted out than had entered in the 1-on-16-slope ladder while fewer salmonids were counted out than had entered in the 1-on-10-slope ladder. It is believed that generally relatively few salmonids failed to complete the test section in either ladder during the test period.

Graphic comparisons of the passage patterns at count stations encompassing comparable or similar test sections indicated salmonids demonstrated similar patterns of movement in the 1-on-10-slope and 1-on-16-slope ladders. Comparison of passage times based upon the time at which 50 percent of the salmonids had crossed each counting station indicated that there was little difference in the rates at which salmonids ascended the entire test area of the two ladders. Average passage times for the entire 74-pool test section based upon the results of 20 paired tests were 100.3 minutes in the 1-on-10-slope ladder and 104.5 minutes in the 1-on-16-slope ladder, equivalent to average rates of 1.36 and 1.41 minutes per pool respectively.

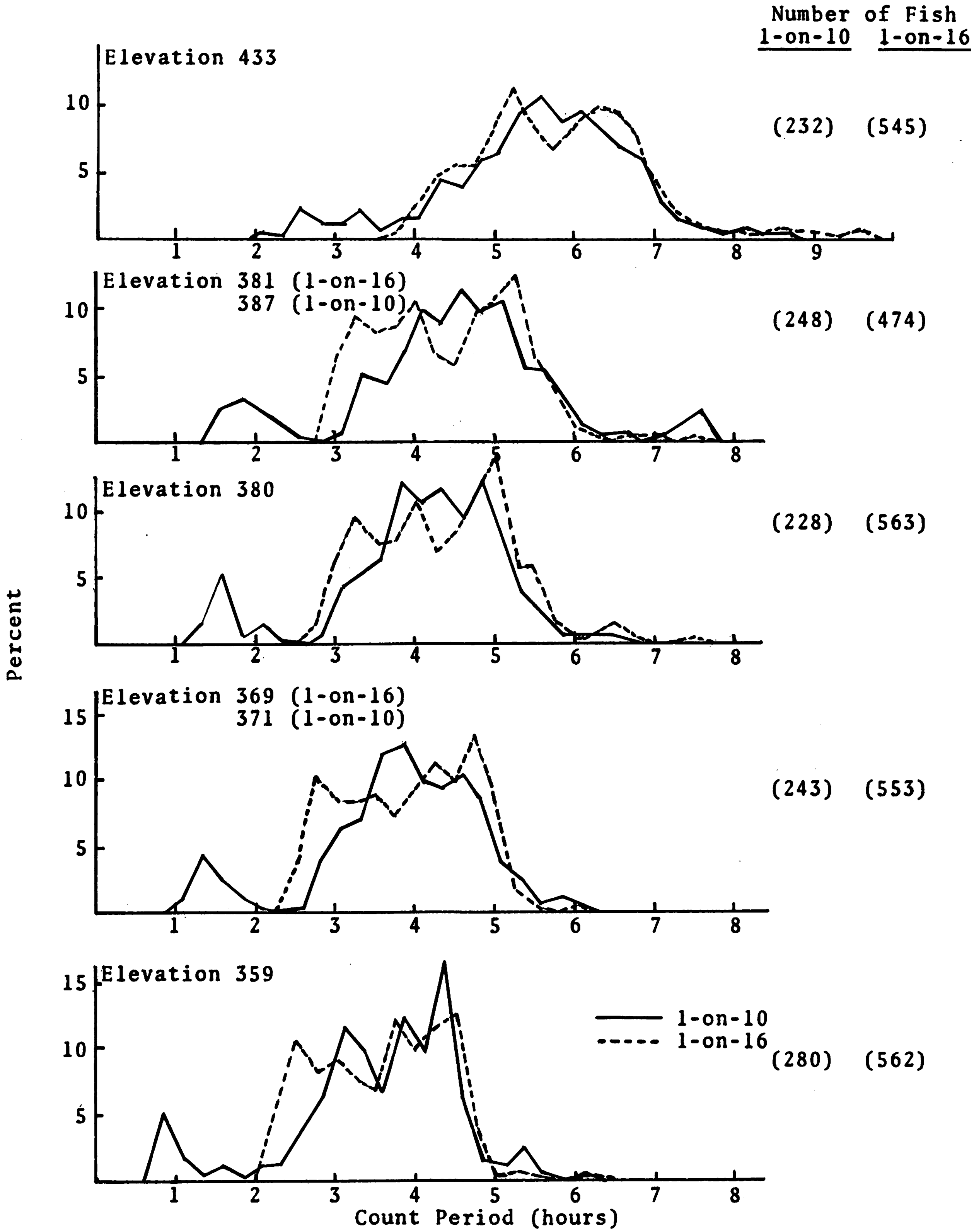
Comparisons between various segments of the test area revealed that rates of passage were significantly faster in the upper 53 pools than in the lower 21 pools in both ladders, and that salmonids in the 1-on-10-slope ladder ascended the first 21 pools faster than those in the 1-on-16-slope ladder. Some delay was noted in the segments involving turn pools in both ladders; and although there was some question as to the reliability of the estimate of turn pool times in the 1-on-16-slope ladder, there was evidence that the delay was longer in the 1-on-16-slope ladder than in the 1-on-10-slope ladder.

Observations of fallback (downstream passage) activity of salmonids during the tests failed to demonstrate any abnormal occurrences in the 1-on-10-slope ladder. In fact, fallbacks occurred more frequently in the 1-on-16-slope ladder.

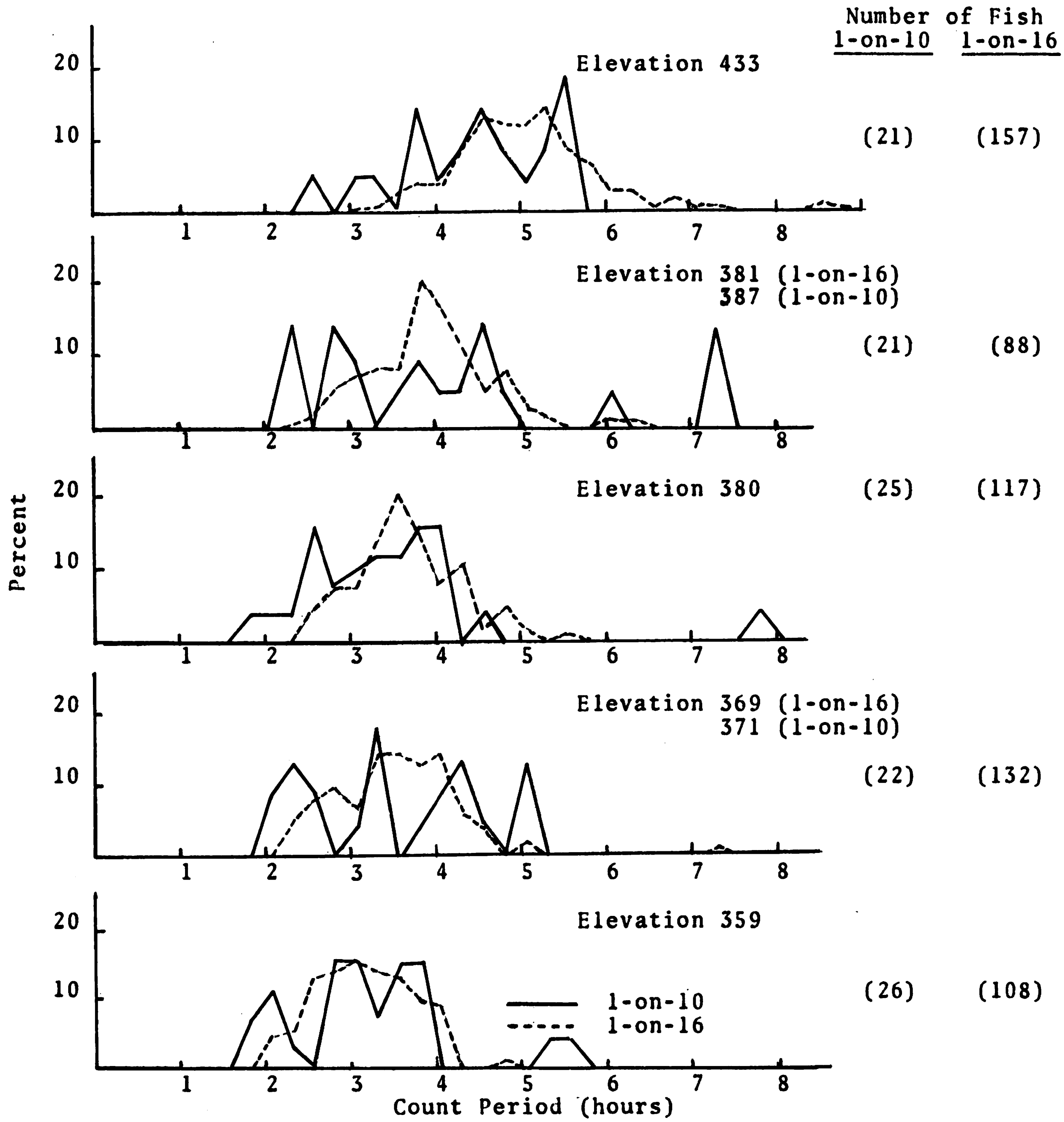
Incidental observations of the behavior of nonsalmonids (suckers, squawfish, carp, etc.) revealed their performance in both ladders was characterized by a much slower rate of passage than salmonids with considerable fallback activity. Although nonsalmonids successfully ascended both ladders, passage patterns at the various count stations indicated relatively small proportions of the fish entering the test sides of the ladders completed the entire 74-pool test area during the count period. Tests conducted on consecutive days indicated that some of these fish may not have completed the test area until the following day.

There was no indication that nonsalmonids were encountering more difficulty in the 1-on-10-slope ladder than in the 1-on-16-slope ladder. Comparisons of fallback activity revealed it occurred more frequently in the 1-on-16-slope ladder.

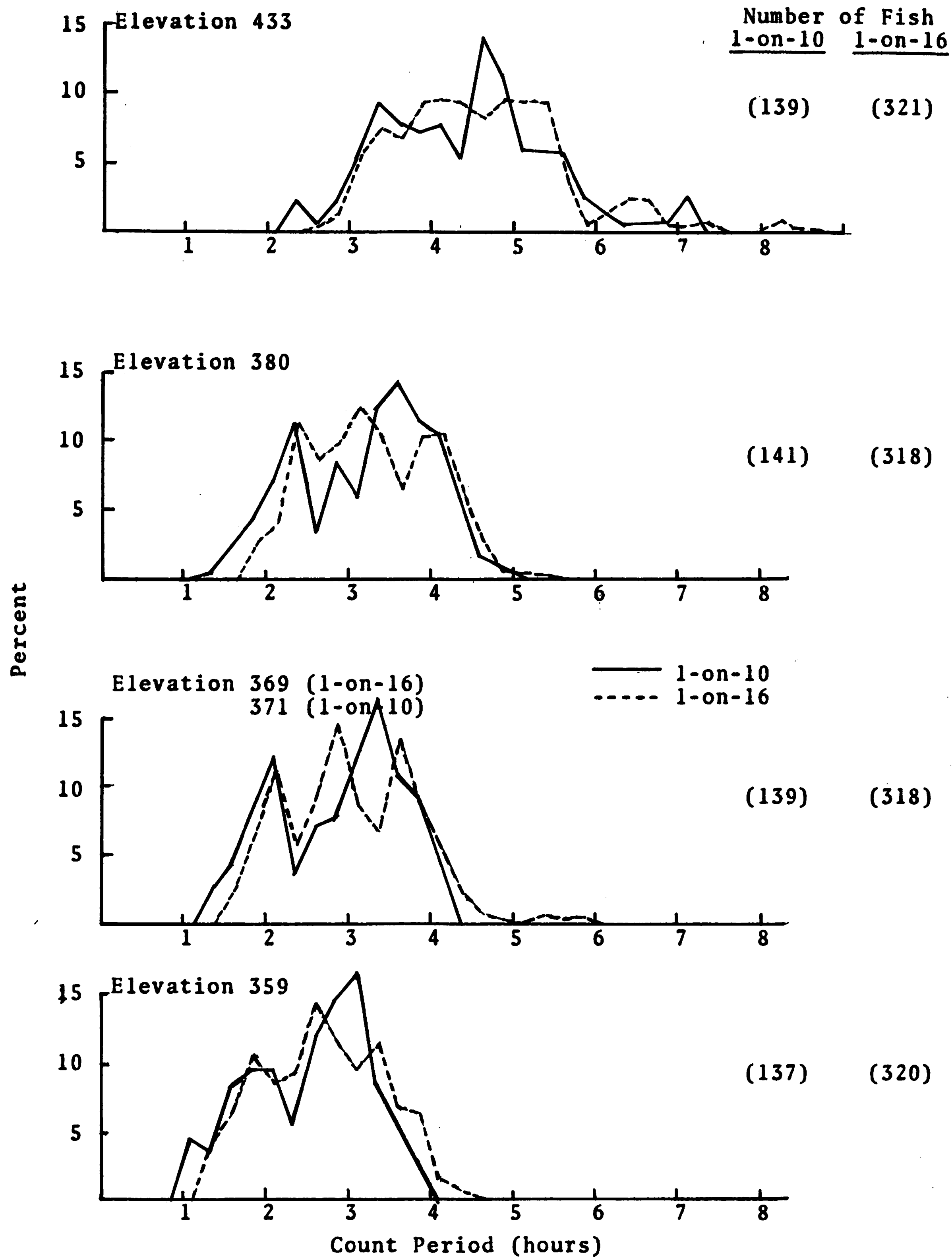
On the basis of the preceding results, it seems safe to conclude that the 1-on-10-slope ladder will provide adequate passage for the number and species of fish it may normally be expected to accommodate at Ice Harbor Dam. Although the numbers of fish utilizing the ladder may at times be somewhat greater than the numbers involved in the test, no problems are foreseen in passage of these fish through the full width ladder. Since little difference could be detected between the performance of salmonids in the two ladders, there is no reason to doubt that a 1-on-10-slope ladder could pass salmonids as efficiently as a conventional 1-on-16-slope ladder designed to accommodate the same number of fish.



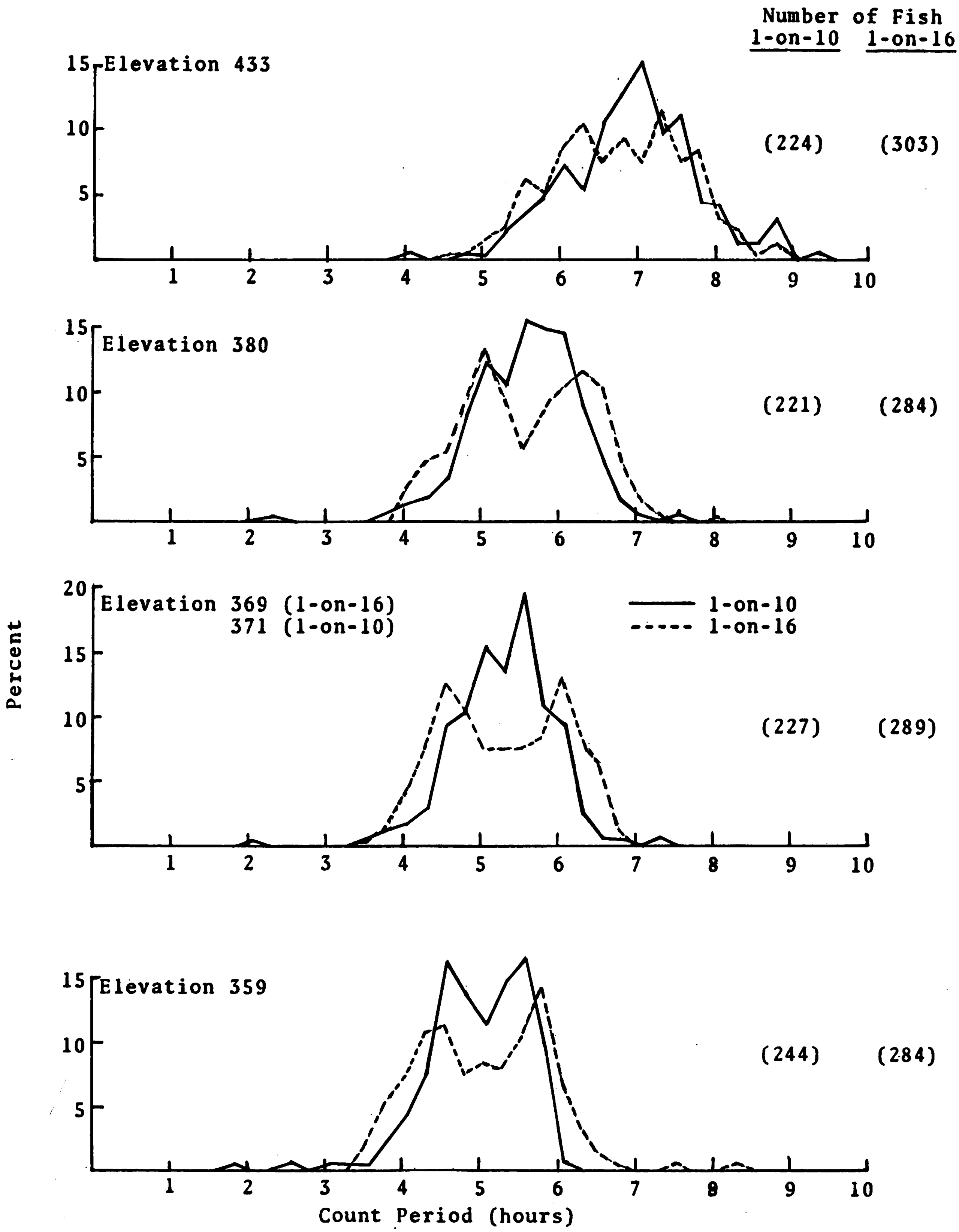
Appendix Figure 1.--Passage of salmonids at each station during tests conducted on May 16 in the 1-on-10-slope ladder and on May 17 in the 1-on-16-slope ladder. Counts are plotted by 15-minute intervals and are expressed as percentages of the total number of fish counted at each station (numbers in parentheses).



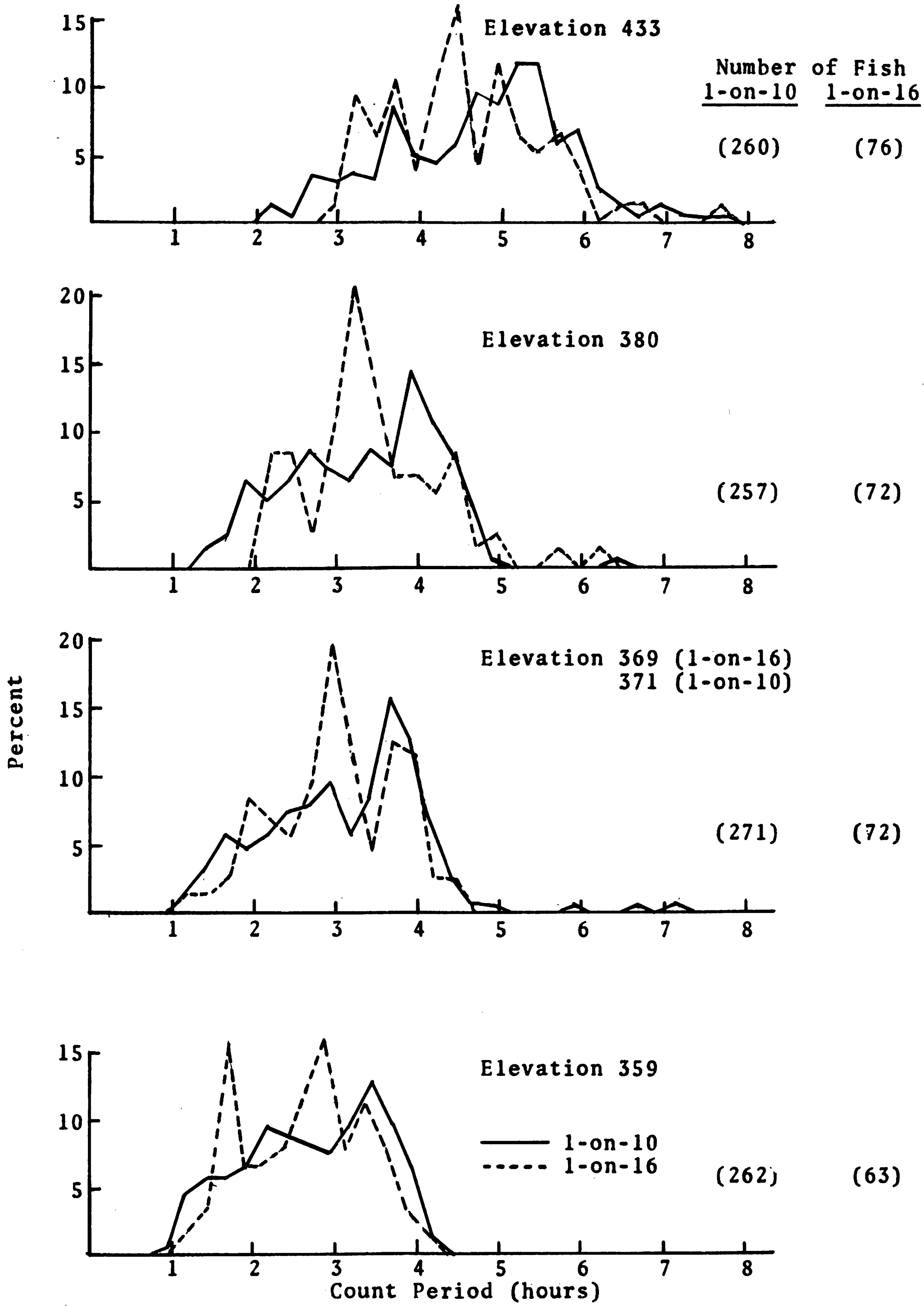
Appendix Figure 2.--Passage of salmonids at each station during tests conducted on June 20 in the 1-on-16-slope ladder and on June 21 in the 1-on-10-slope ladder. Counts are plotted by 15-minute intervals and are expressed as percentages of the total number of fish counted at each station.



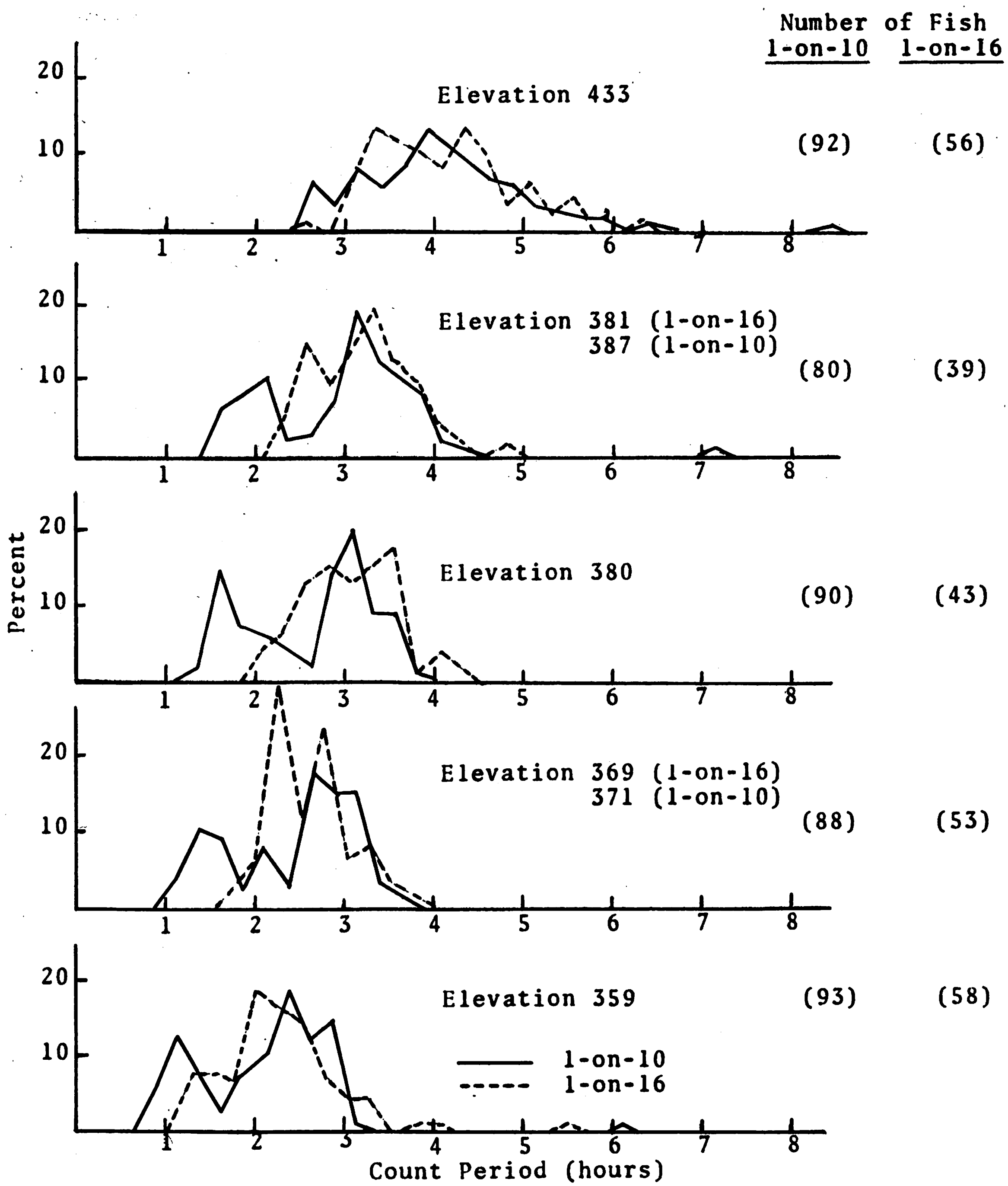
Appendix Figure 3.--Passage of salmonids in the 1-on-10- and 1-on-16-slope ladders June 27, 1962. Counts are plotted by 15-minute intervals and are expressed as percentages of the total number of fish counted at each station (numbers in parentheses).



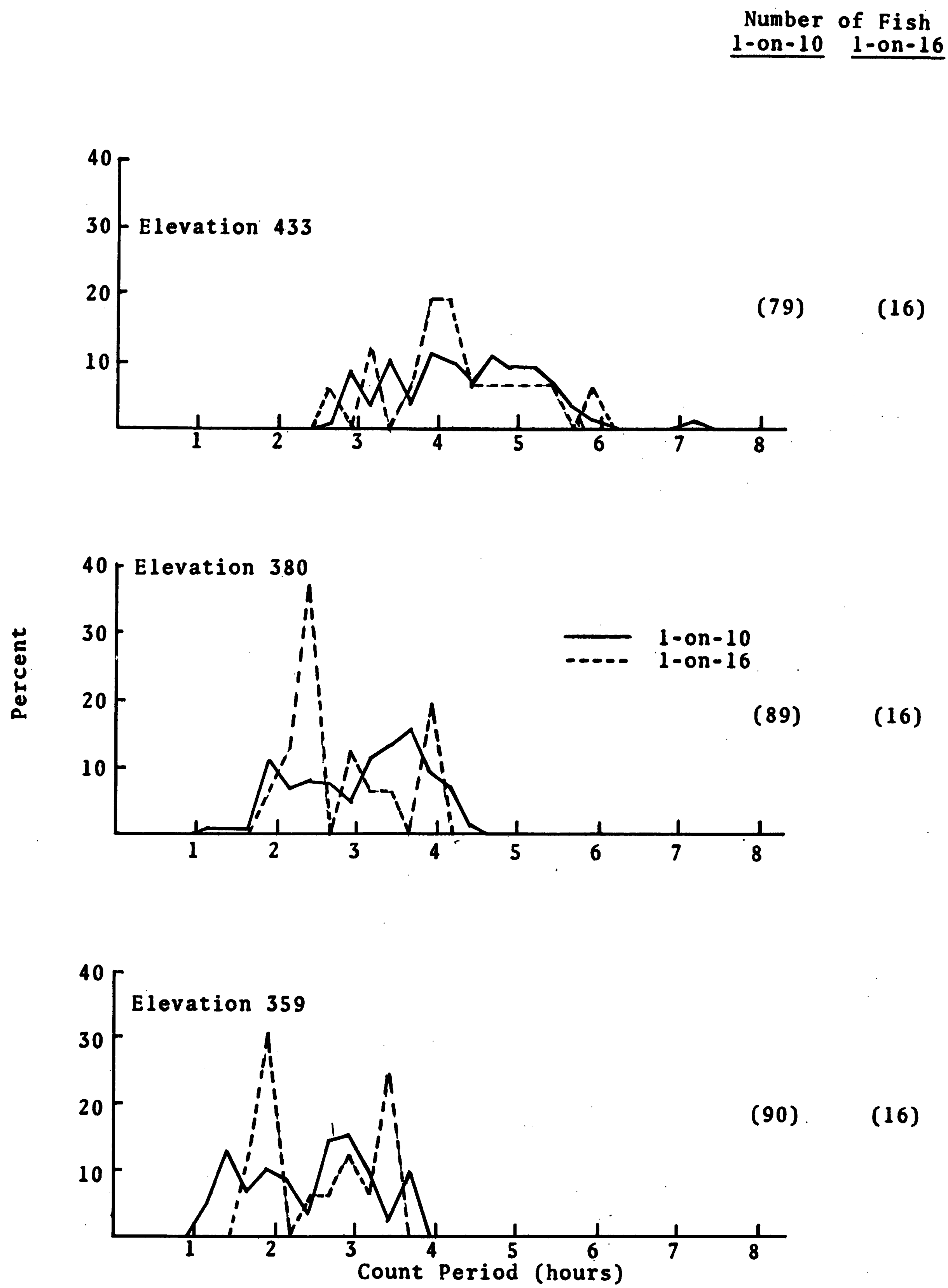
Appendix Figure 4.--Passage of salmonids in the 1-on-10- and 1-on-16-slope ladders June 28, 1962. Counts are plotted by 15-minute intervals and are expressed as percentages of the total number of fish counted at each station (numbers in parentheses).



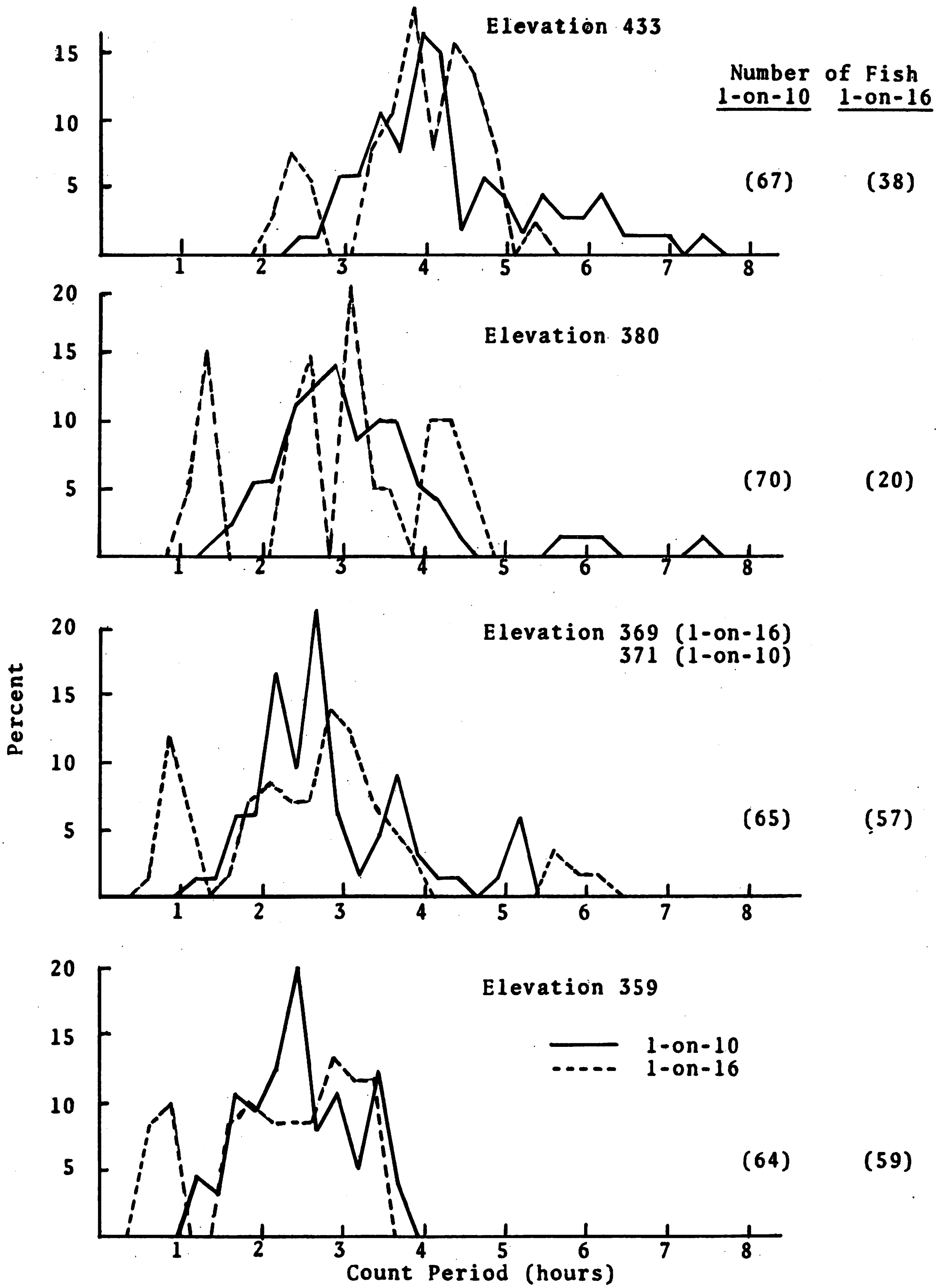
Appendix Figure 5.--Passage of salmonids in the 1-on-10- and 1-on-16-slope ladders June 29, 1962. Counts are plotted by 15-minute intervals and are expressed as percentages of the total number of fish counted at each station (numbers in parentheses).



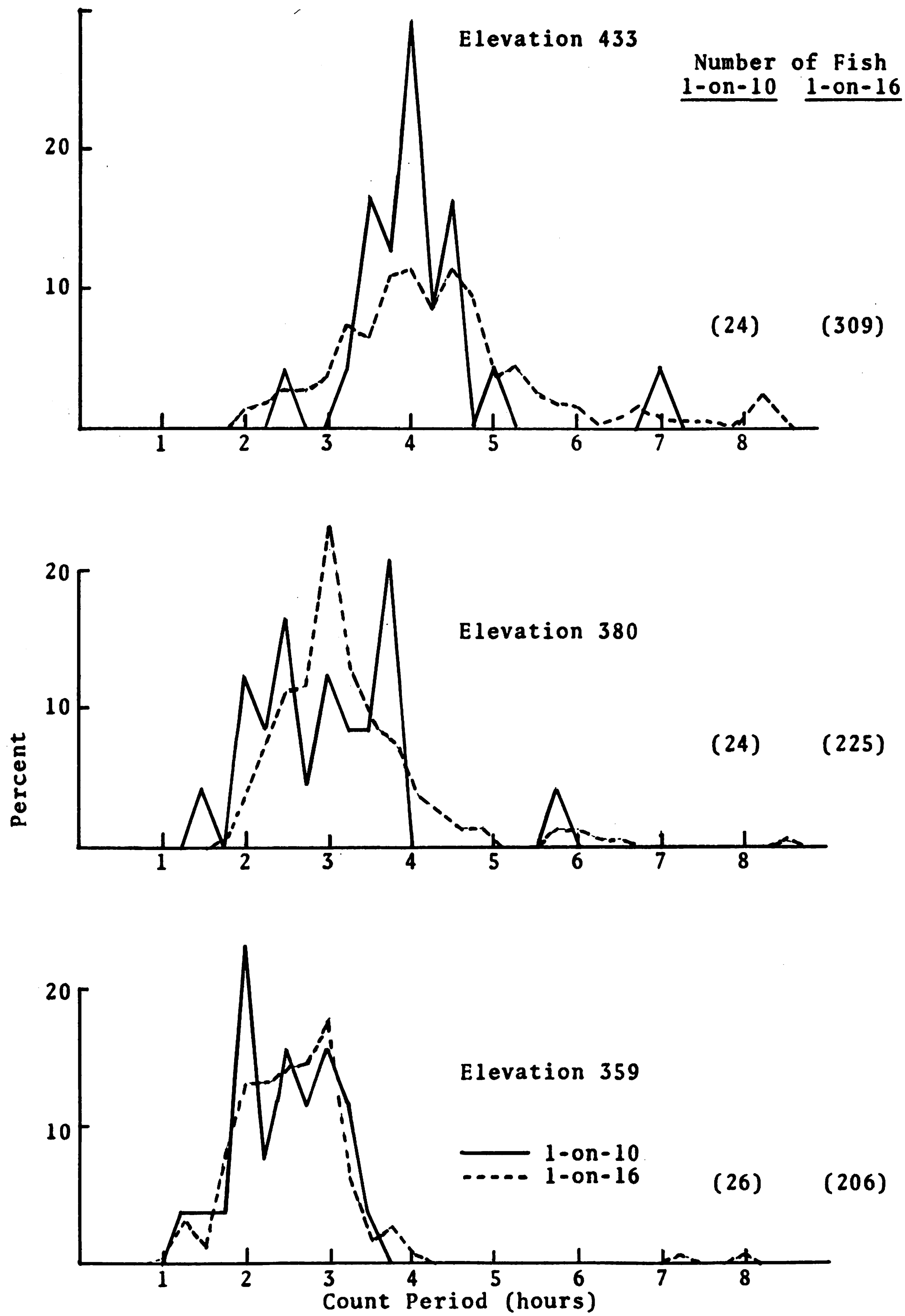
Appendix Figure 6.--Passage of salmonids at each station during tests conducted on June 30 in the 1-on-10-slope ladder and on July 1 in the 1-on-16-slope ladder. Counts are plotted by 15-minute intervals and are expressed as percentages of the total number of fish counted at each station (numbers in parentheses).



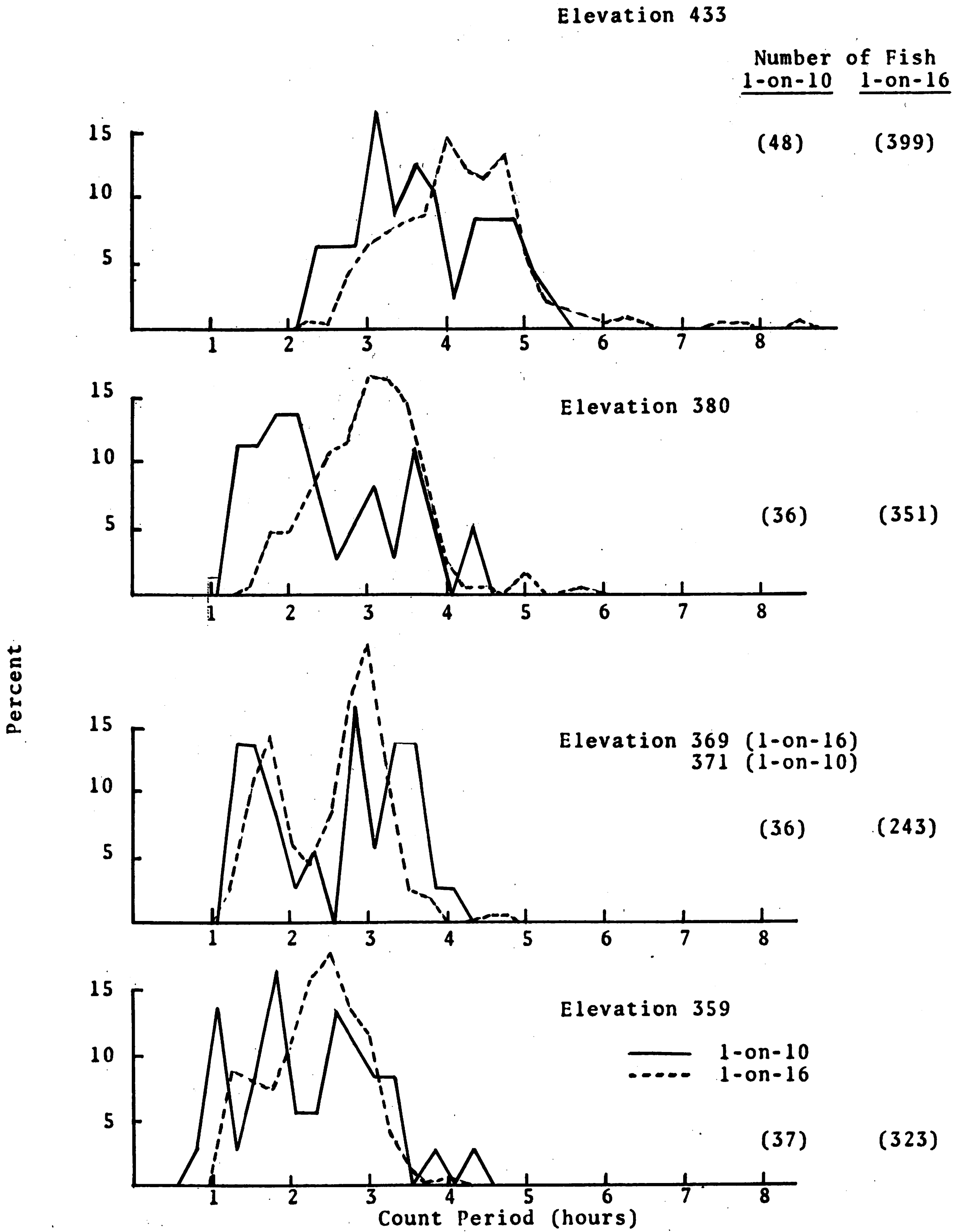
Appendix Figure 7.--Passage of salmonids in the 1-on-10- and 1-on-16-slope ladders July 2, 1962. Counts are plotted by 15-minute intervals and are expressed as percentages of the total number of fish counted at each station (numbers in parentheses).



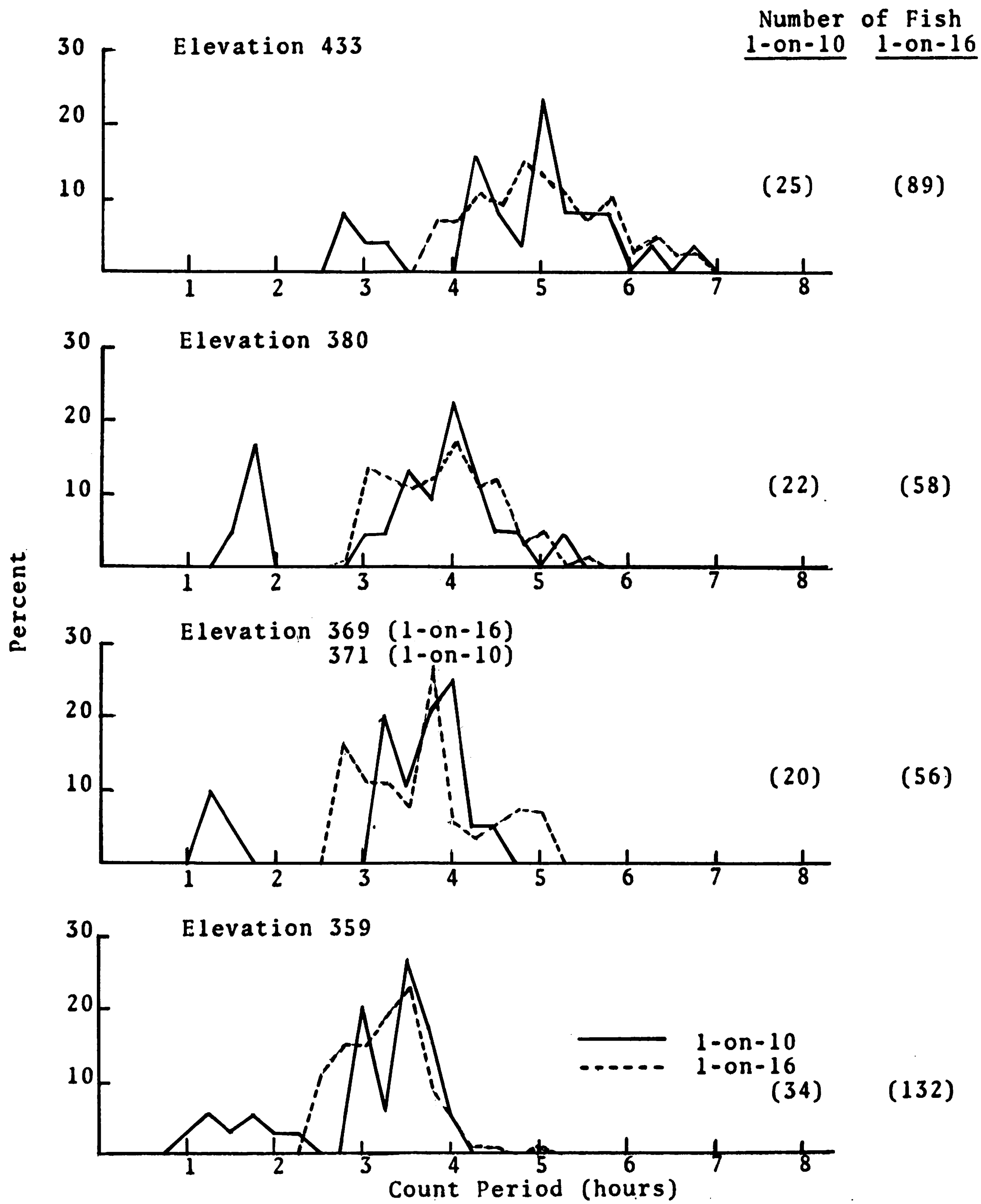
Appendix Figure 8.--Passage of salmonids during tests conducted on August 16 in the 1-on-16-slope ladder and on August 17 in the 1-on-10-slope ladder. Counts are plotted by 15-minute intervals and are expressed as percentages of the total number of fish counted at each station (numbers in parentheses).



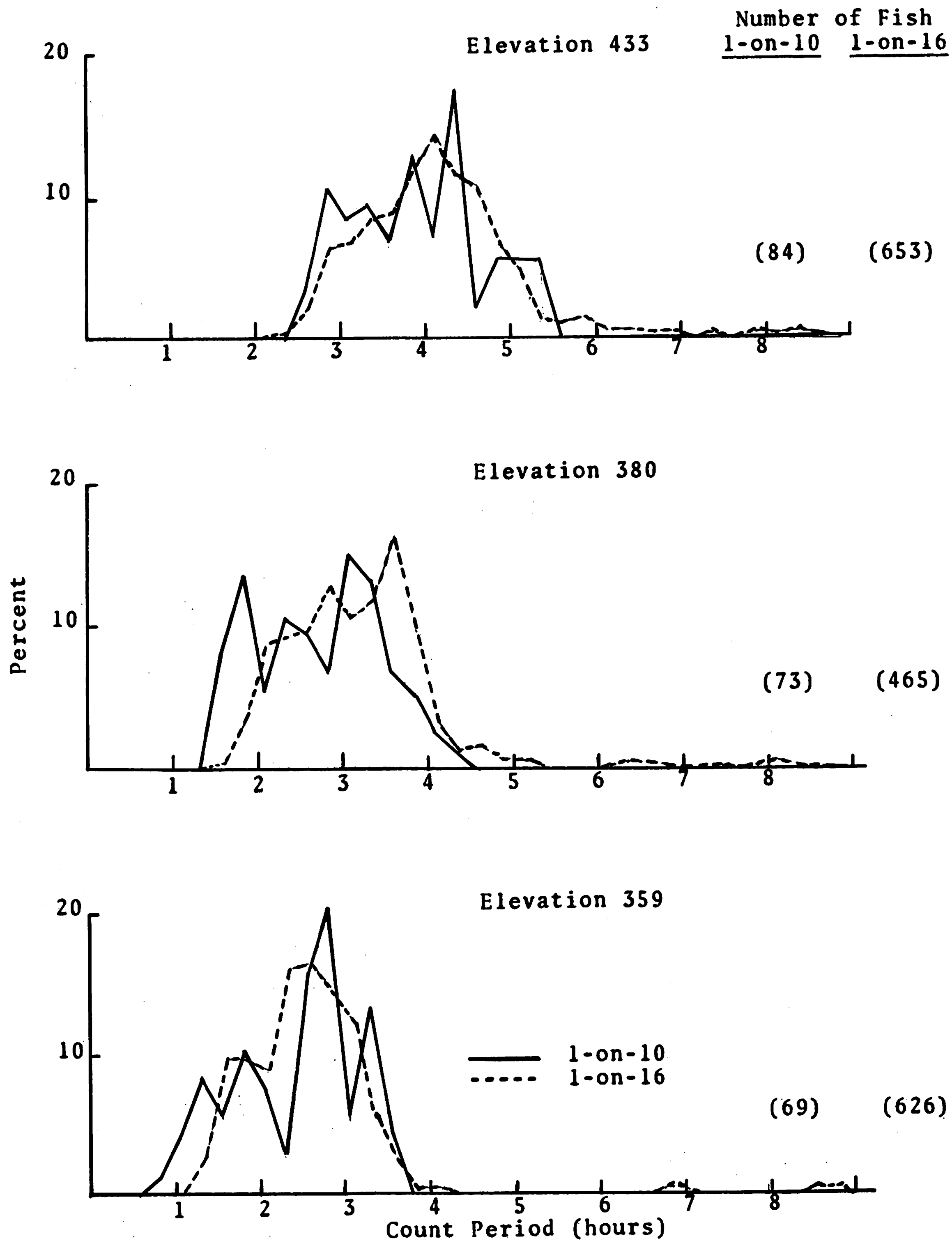
Appendix Figure 9.--Passage of salmonids in the 1-on-10- and 1-on-16-slope ladders September 8, 1962. Counts are plotted by 15-minute intervals and are expressed as percentages of the total number of fish counted at each station (numbers in parentheses).



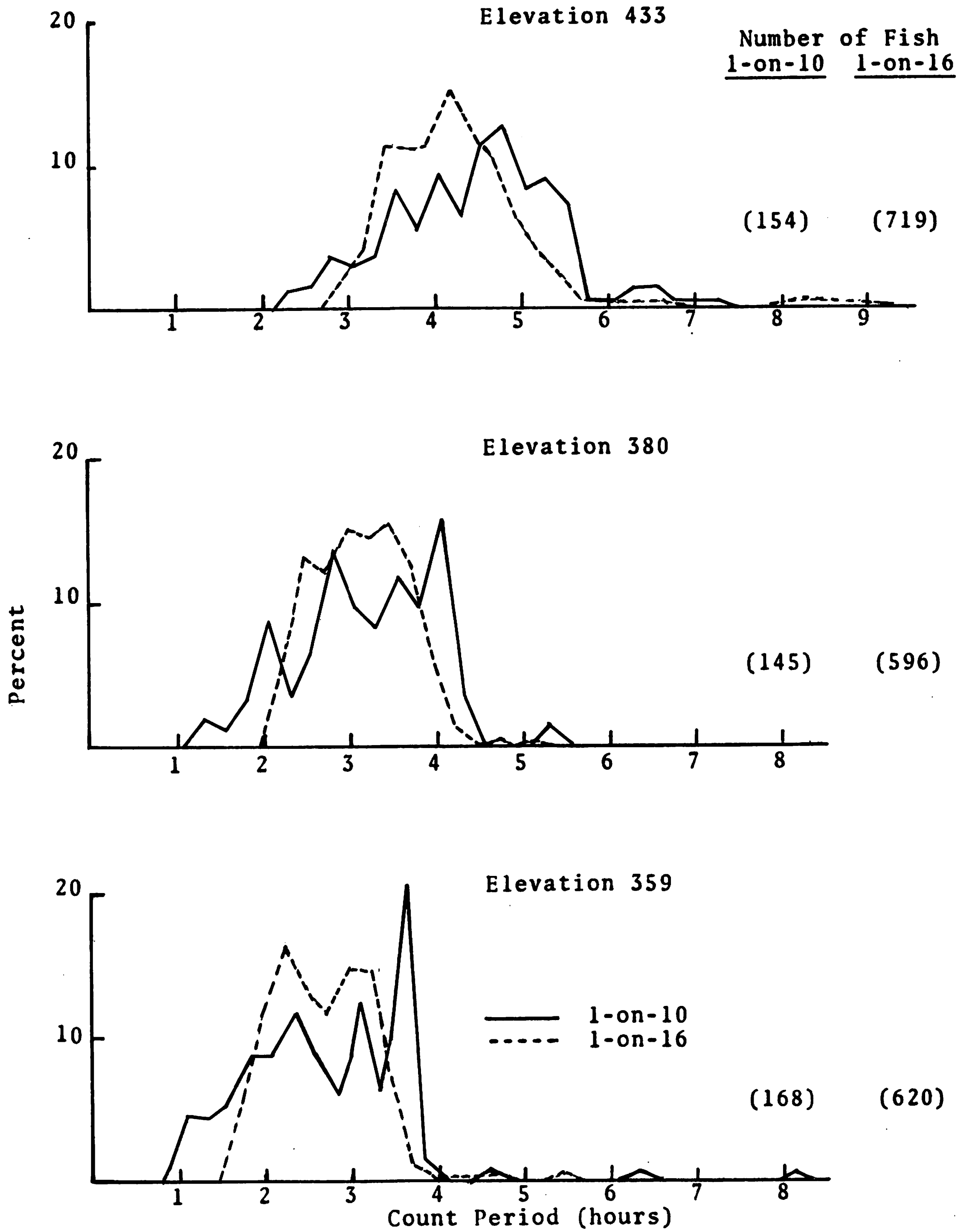
Appendix Figure 10.--Passage of salmonids in the 1-on-10- and 1-on-16-slope ladders September 9, 1962. Counts are plotted by 15-minute intervals and are expressed as percentages of the total number of fish counted at each station (numbers in parentheses).



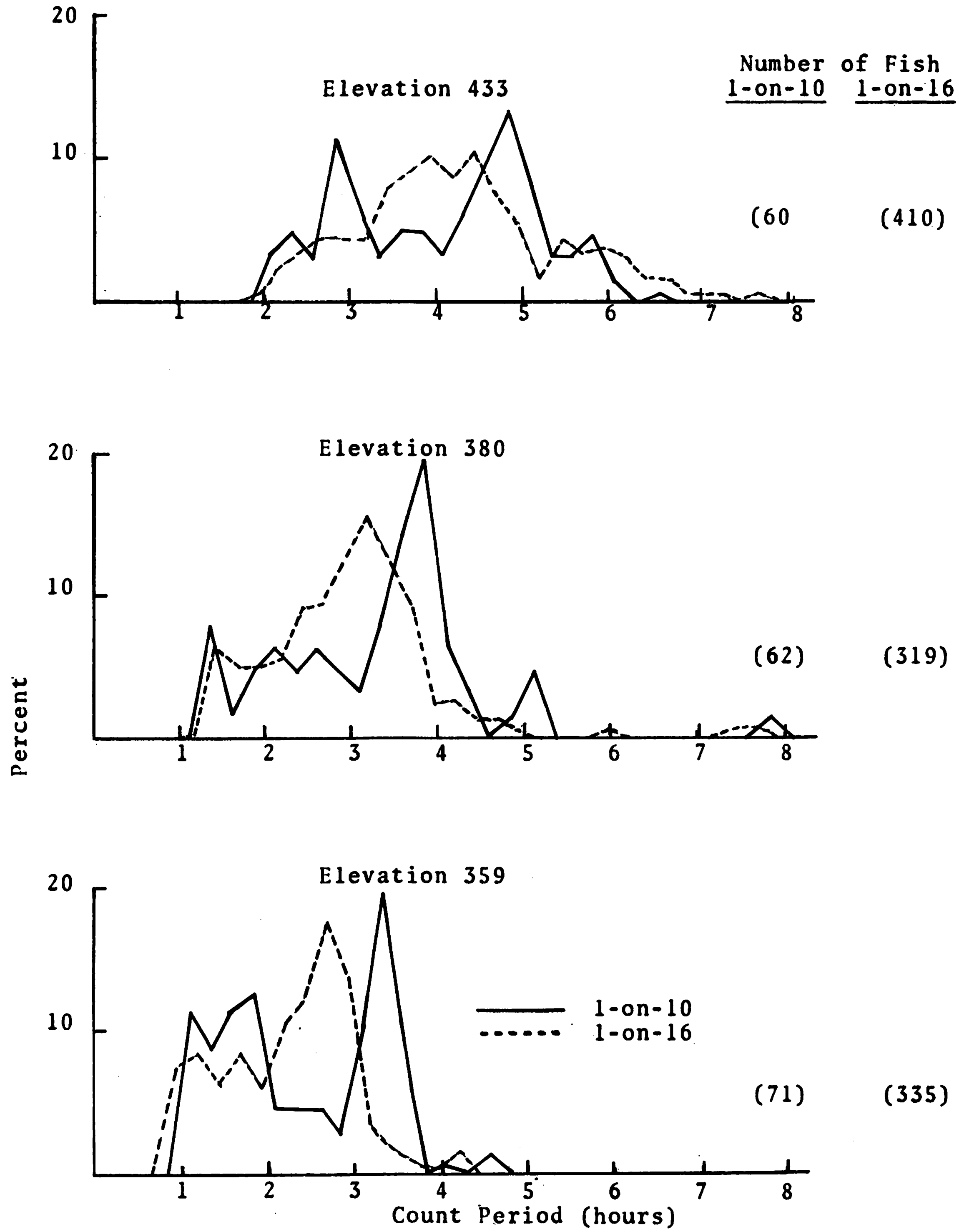
Appendix Figure 11.--Passage of salmonids in the 1-on-10- and 1-on-16-slope ladders September 10, 1962. Counts are plotted by 15-minute intervals and are expressed as percentages of the total number of fish counted at each station (numbers in parentheses).



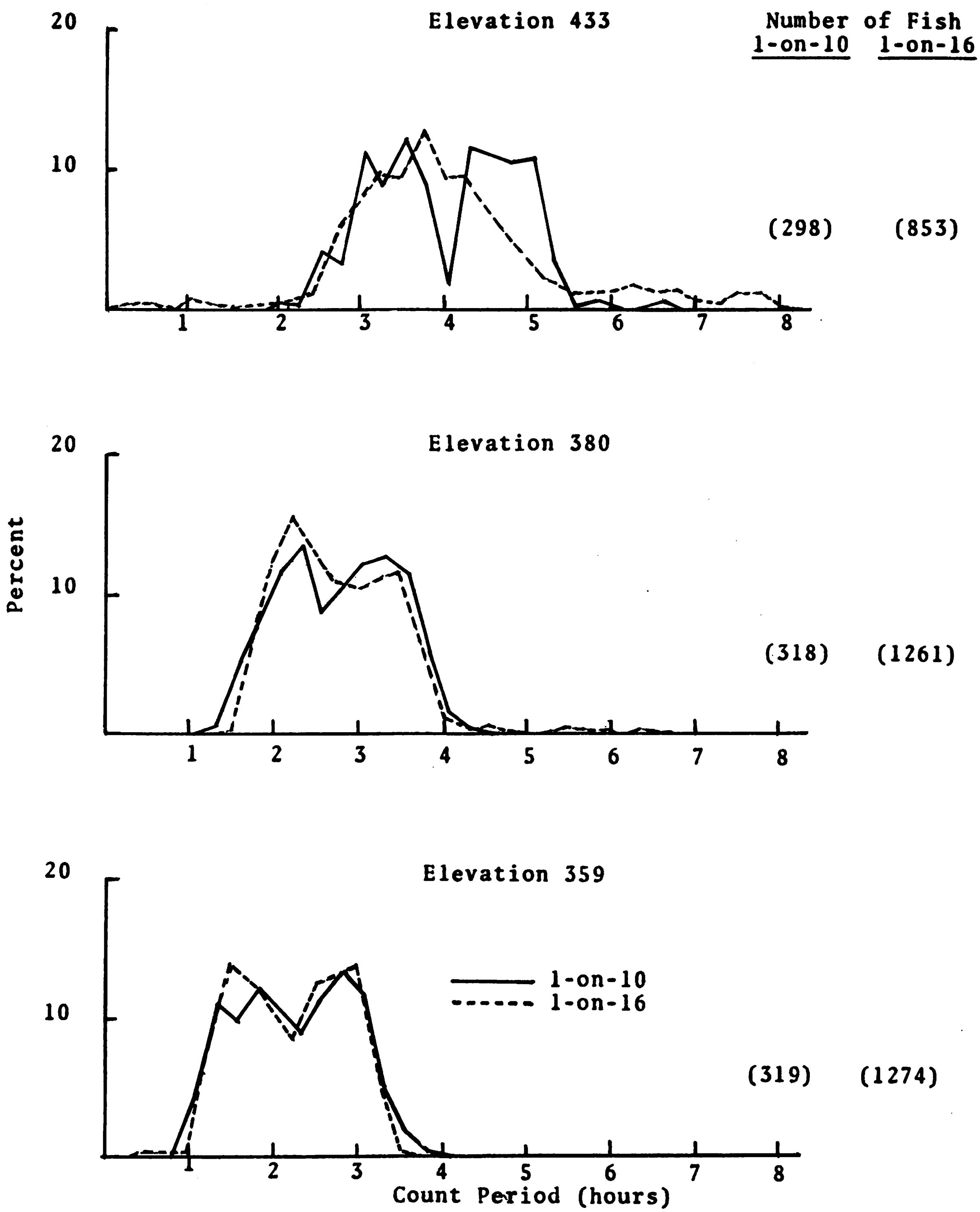
Appendix Figure 12.--Passage of salmonids in the 1-on-10- and 1-on-16-slope ladders September 11, 1962. Counts are plotted by 15-minute intervals and are expressed as percentages of the total number of fish counted at each station (numbers in parentheses).



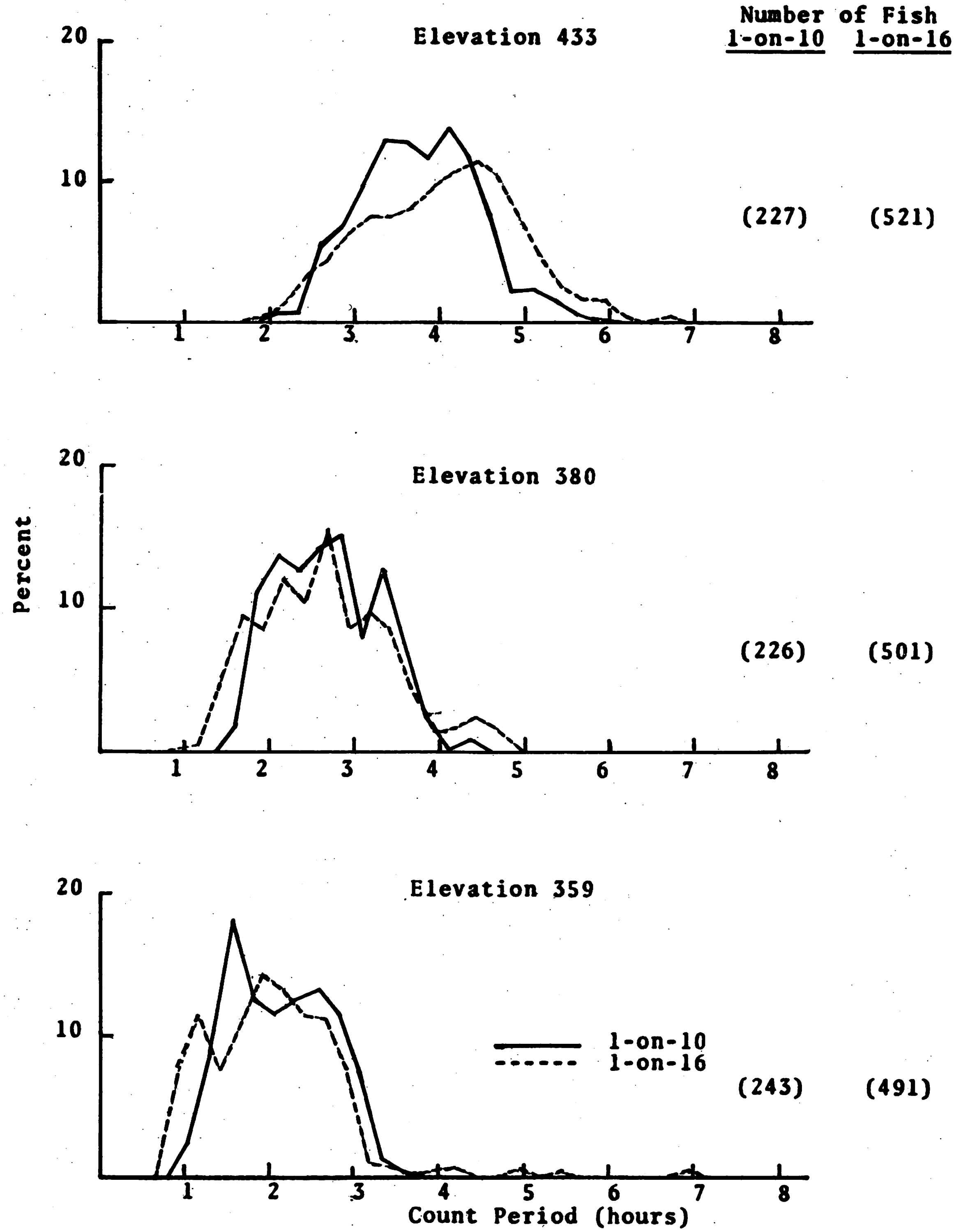
Appendix Figure 13.--Passage of salmonids in the 1-on-10- and 1-on-16-slope ladders September 13, 1962. Counts are plotted by 15-minute intervals and are expressed as percentages of the total number of fish counted at each station (numbers in parentheses).



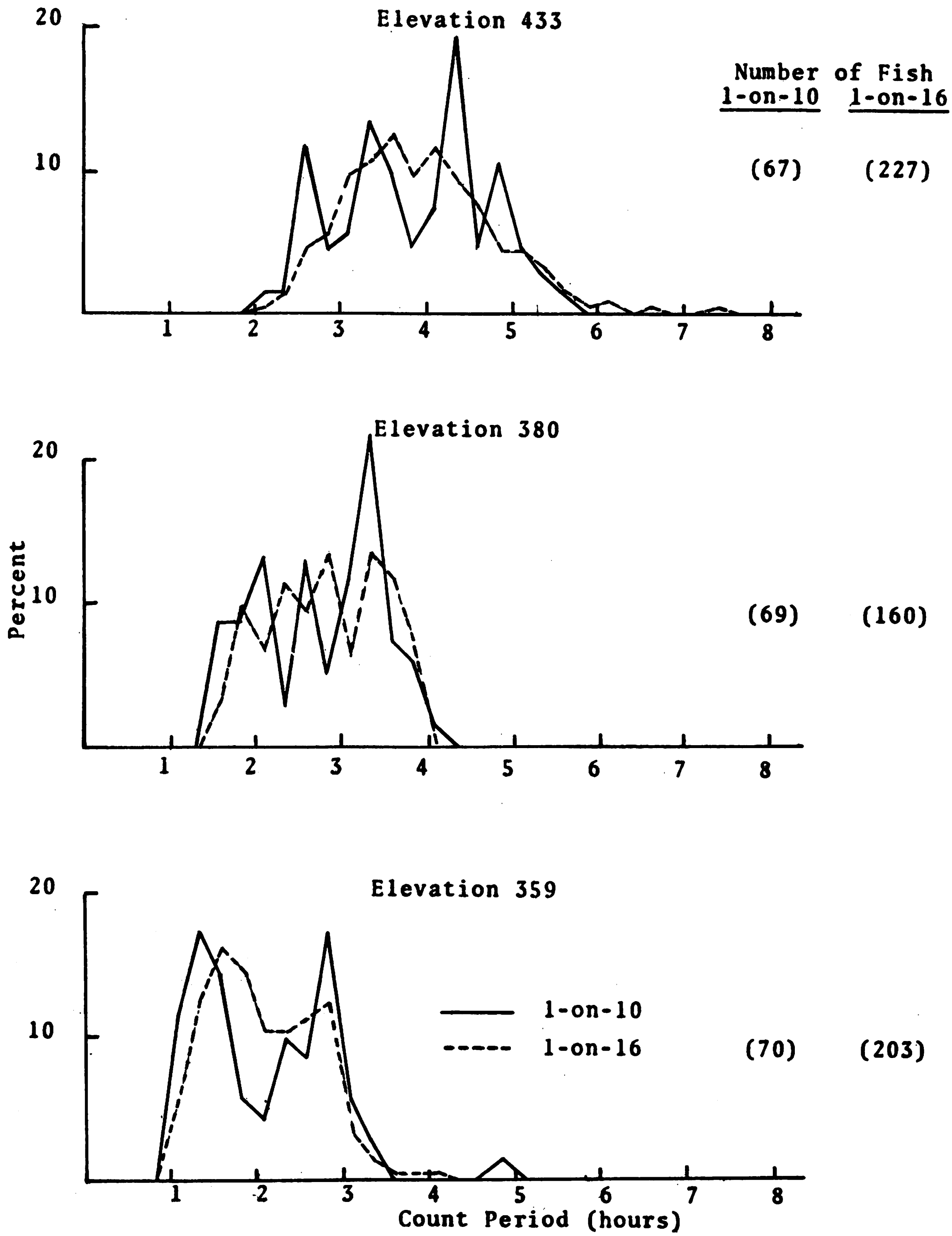
Appendix Figure 14.--Passage of salmonids in the 1-on-10- and 1-on-16-slope ladders September 14, 1962. Counts are plotted by 15-minute intervals and are expressed as percentages of the total number of fish counted at each station (numbers in parentheses).



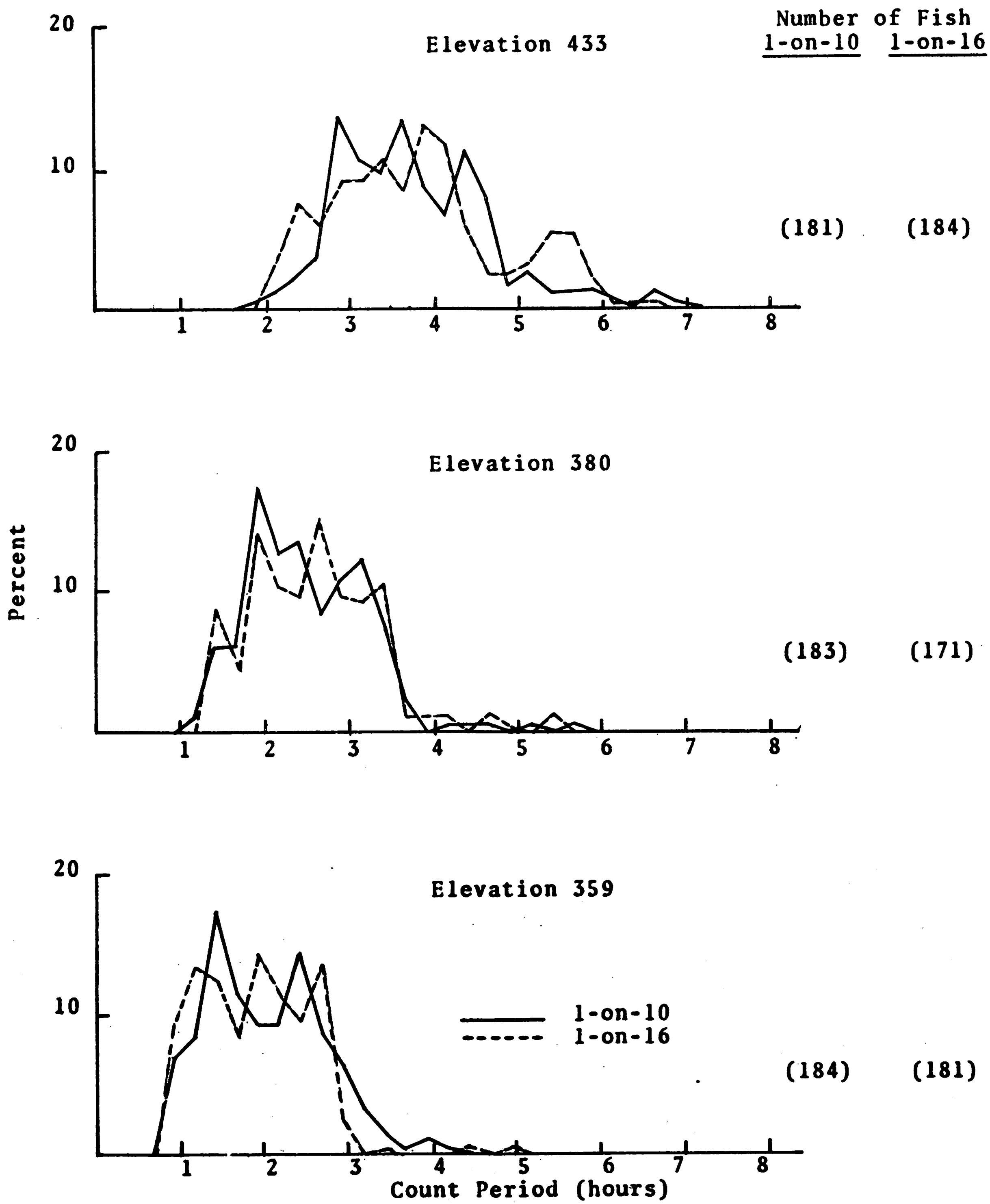
Appendix Figure 15.--Passage of salmonids in the 1-on-10- and 1-on-16-slope ladders September 19, 1962. Counts are plotted by 15-minute intervals and are expressed as percentages of the total numbers of fish counted at each station (numbers in parentheses). Low count at weir elevation 433 in the 1-on-16-slope ladder was due to a hole in the divider screen in pool below.



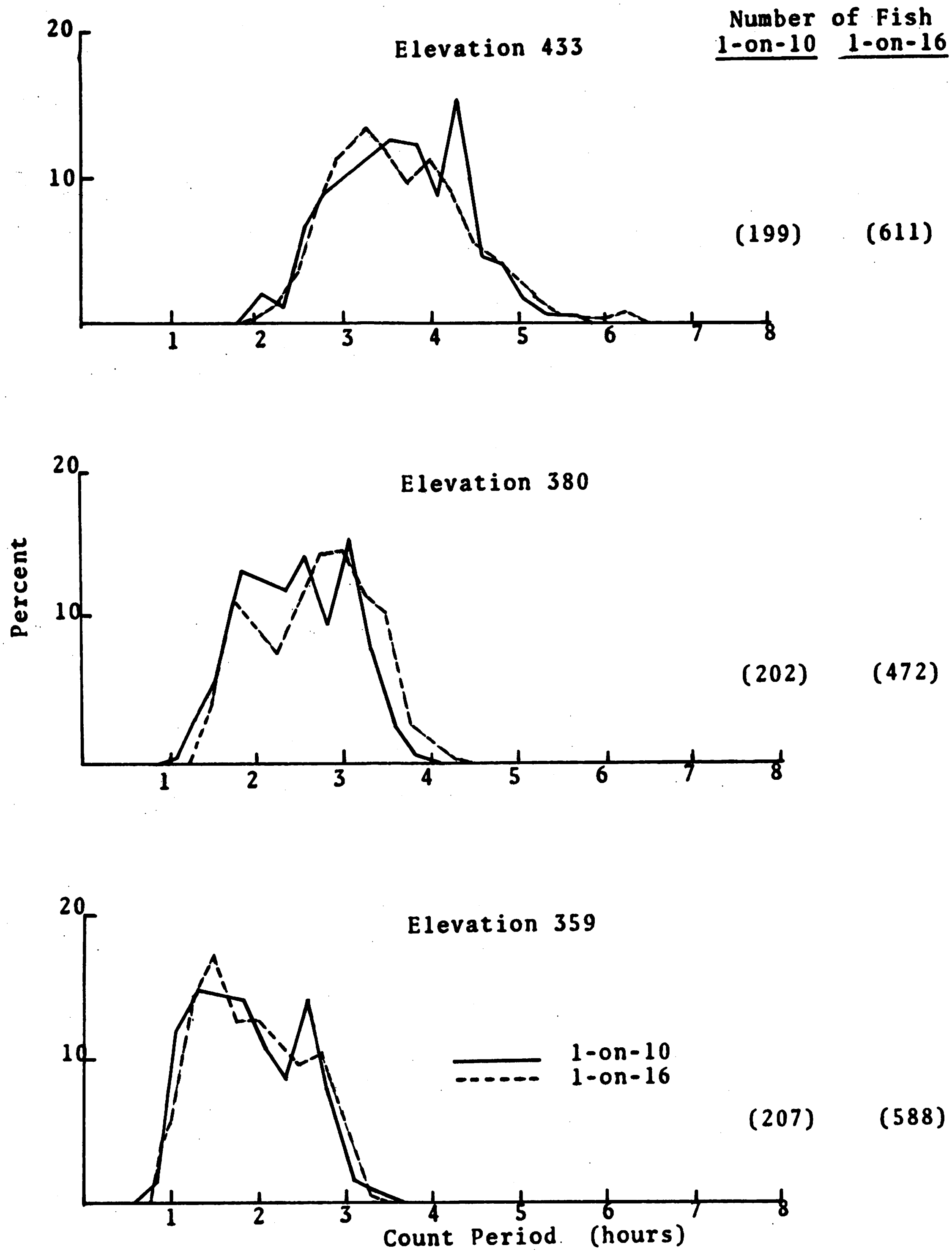
Appendix Figure 16.--Passage of salmonids in the 1-on-10- and 1-on-16-slope ladders September 25, 1962. Counts are plotted by 15-minute intervals and are expressed as percentages of the total number of fish counted at each station (numbers in parentheses).



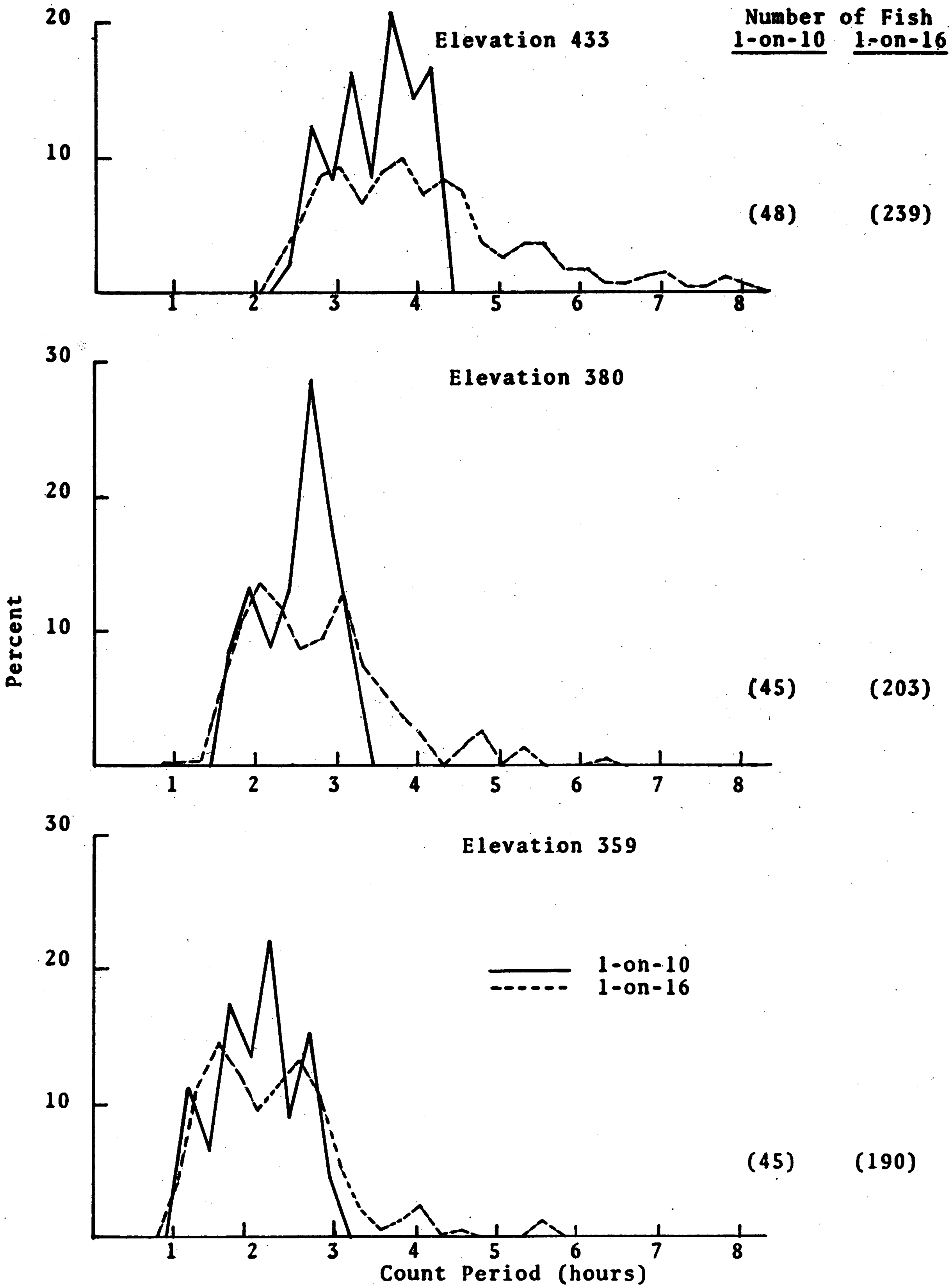
Appendix Figure 17.--Passage of salmonids in the 1-on-10- and 1-on-16-slope ladders September 26, 1962. Counts are plotted by 15-minute intervals and are expressed as percentages of the total number of fish counted at each station (numbers in parentheses).



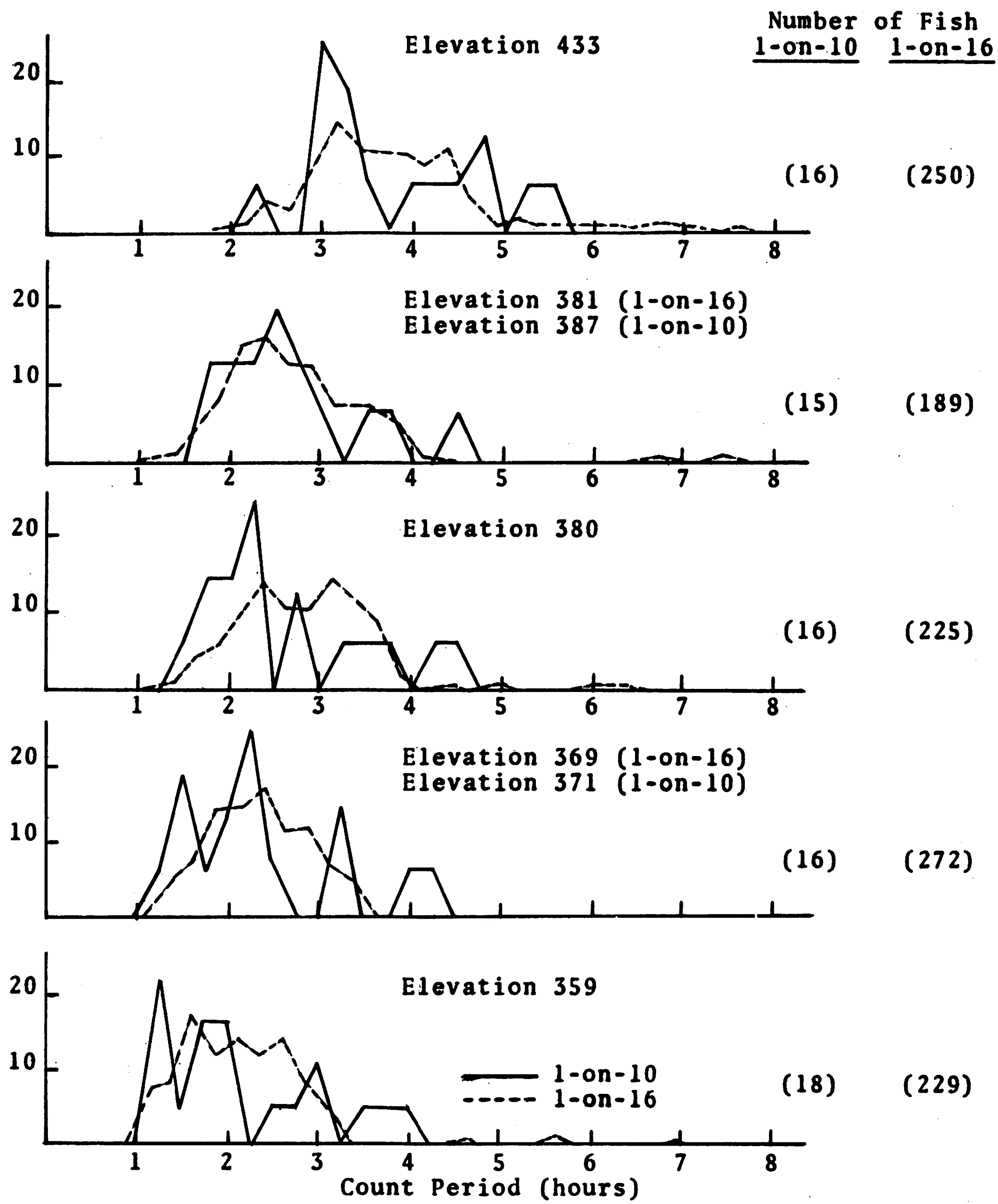
Appendix Figure 18.--Passage of salmonids in the 1-on-10- and 1-on-16-slope ladders September 27, 1962. Counts are plotted by 15-minute intervals and are expressed as percentages of the total number of fish counted at each station (numbers in parentheses).



Appendix Figure 19.--Passage of salmonids in the 1-on-10- and 1-on-16-slope ladders September 28, 1962. Counts are plotted by 15-minute intervals and are expressed as percentages of the total number of fish counted at each station (numbers in parentheses).



Appendix Figure 20.--Passage of salmonids in the 1-on-10- and 1-on-16-slope ladders October 1, 1962. Counts are plotted by 15-minute intervals and are expressed as percentages of the total number of fish counted at each station (numbers in parentheses).



Appendix Figure 21.--Passage of salmonids during tests conducted on October 2 in the 1-on-16-slope ladder and on October 3 in the 1-on-10-slope ladder. Counts are plotted by 15-minute intervals and are expressed as percentages of the total number of fish counted at each station (numbers in parentheses).

FALLBACK OF ADULT CHINOOK SALMON (*Oncorhynchus tshawytscha*) AT ICE HARBOR DAM SPILLWAY--1964

by

James H. Johnson

October 1964

FISH-PASSAGE RESEARCH PROGRAM
U.S. Bureau of Commercial Fisheries
Seattle, Washington