SOME CALCULATIONS REGARDING THE NATURAL SPAWNING OF KING SALMON IN THE SOUTH FORK OF THE EEL RIVER ABOVE BENBOW DAM, SEASON OF 1938-39 [1].

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One basis for calculating the seaward migration of young King Salmon at Benbow Dam during the 1938-39 season (Oct. 1, 1938-Sept. 30, 1939) is the ratio of unmarked to marked fish counted in the downstream trap at that place. On April 21-22, 1939, 41,112 King Salmon fish of the season marked by removal of the adipose and left ventral fins were planted in the South Fork of the Eel River at Richardson Grove and at Piercy (opposite Indian Creek). Later, 1,015 of these were counted through the Benbow Dam fishways (see Table 1). The total migration of unmarked King Salmon (including fish lost in the counting process) consisted of 63,021 fish. On the basis of the ratio 1,015:41,112::63,021:x, we secure the figure of 2,552,630 as the number of downstream migrant naturally-propagated King Salmon passing Benbow Dam during the spring and summer of 1939.

However, there are some fairly obvious corrections to be made in this figure. For one thing, the 63,021 unmarked fish were counted through over a longer period than the 1,015 marked fish. Before the first marked

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TABLE I. - Seaward Migration of Young King Salmon at Benbow Dam (Fish Counted Through South Ladder), Season of 1938-39.

APRIL	Unmarked	Marked	Marked as per cent of Unmarked	MAY	Unmarked	Marked	Marked as per cent of Unmarked	JUNE	Unmarked	Marked	Marked as per cent of Unmarked	JULY	Unmarked	Marked	Marked as per cent of Unmarked	AUGUST	Unmarked	Marked	Marked as per cent of Unmarked
1	19			1	16	0	.0	1	633	33	5.2	1	437	1	.2	1	1	0	
2	6			2	4	0	.0	2	1093	68	6.2	2	395	3	.8	2	3	0	
3	4			3	12	0	.0	3	761	29	3.8	3	477	2	.4	3	5	0	
4	3			4	10	0	.0	4	656	33	5.0	4	456	4	.9	4	9	0	
5	3			5	10	0	.0	5	900	44	4.9	5	374	1	.3	5	10	0	
6	2			6	0	0	.0	6	931	43	4.6	6	315	1	.3	6	4	0	
7	20			7	43	0	.0	7	1280	22	1.7	7	472	0	.0	7	0	0	
8	18			8	139	6	4.3	8	1075	19	1.8	8	414	0	.0	8	0	0	
9	6			9	65	1	1.5	9	1342	29	2.2	9	121	0	.0	9			
10	90			10	203	10	4.9	10	2114	39	1.8	10	575	0	.0	10			
11	71			11	207	14	6.8	11	1986	26	1.3	11	281	1	.4	11			
12	0			12	218	7	3.2	12	1334	14	1.0	12	280			12			
13	2			13	101	0	.0	13**	[10597]			13	76			13			
14	20			14	277	4	1.4	14	1074	8	.7	14	132			14			
15	28			15	472	12	2.5	15	1635	27	1.7	15	52			15			
16	20			16	1425	23	1.6	16	3220	76	2.4	16	51			16			
17	29			17	1009	25	2.5	17	2711	44	1.6	17	2			17			
18	44			18				18	1932	37	1.9	18	59			18			
19	39			19				19	2003	33	1.6	19	9			19			
20	55			20				20	1473	35	2.4	20	56			20			
21	84			21				21	912	17	1.9	21	16			21			
22	152			22				22	1511	15	1.0	22	22			22			
23	95			23				23	1567	9	.6	23	2			23			
24	117	2	1.7	24				24	1422	5	.4	24	7			24			
25	117	5	4.3	25				25	1813	9	.5	25	6			25			
26	127	0	.0	26	5	*1	2.0	26	1137	13	1.1	26	6			26			
27	75	3	4.0	27	269	2	.7	27	1905	15	.8	27	8			27			
28	26	0	.0	28	302	5	1.7	28	180	2	1.1	28	4			28			
29	33	0	.0	29	505	11	2.2	29	387	0	.0	29	2			29			
30	30	2	6.7	30	578	12	2.1	30	551	4	.7	30	2			30			
				31	618	29	4.7					31	2			31			
	1335	12			6488-162				39538	748			5111-13				32	0	
									[10,517	80]									

TABLE I. - Seaward Migration of Young King Salmon at Benbow Dam (Fish Counted Through South Ladder), Season of 1938-39. (Cont'd.)

935 + 80 = 1,015 marked

52,504 + 10,517 = 63,021 unmarked
1,015 marked
64,036 total

Marked fish (935) form 1.8 per cent of unmarked fish (52,504).

Note: Fish not counted before April 1. No downstream migration in September. * Trap installed at noon. ** Several buckets counted, rest of fish estimated. 80 marked fish recorded.

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fish was counted through the dam, 810 unmarked King Salmon had been counted through (April 1-23). At this time a number of migrants was passing over the dam itself, so that the 810 fish counted represent an unknown proportion of the total number of fish that migrated past Benbow Dam up to and including April 23. There is no method of calculating this total number, but in any case the 810 fish that were counted should be subtracted from the total of 63,021 counted fish for the purpose of our present calculations.

Also, on June 13 the number of fish in the downstream trap was so great that several buckets were counted and the rest estimated. The total estimated number for the day, 10,517, also should be subtracted from the total of 63,021 counted fish. Likewise, the 80 marked fish recorded that day should be subtracted from the total of marked fish recorded, since they do not represent the total of marked fish for the day.

On the basis of the revised ratio of 935:41,112::51,694:x, we secure the figure of 2,272,988 as the number of unmarked King Salmon that migrated downstream past Benbow Dam during the time that the marked fish migrated downstream past the dam.

There might also be some justification for throwing out of the calculations the unmarked King Salmon that migrated past the dam during the period July 12-Sept. 12, i.e., after the last marked fish was taken, on the assumption that they were fish coming from points above the places of stocking with marked fish and therefore represent a different stock or group of fish. However, the ratio then secured, 935:41,112::50,868:x, would give us a total of 2,236,669 unmarked fish, a number not essentially at variance with the previously calculated total.

Of course, it must be recognized that in all of the calculations we have assumed that all of the 41,112 marked fish planted above Benbow Dam survived and migrated past the dam. It would probably be more correct to assume that 90 per cent, or 37,001 fish, survived. Leaving in our calculation the unmarked fish that migrated past the dam July 12-September 12, we secure a ratio of 935:37,001::51,694:x and 2,045,700 as the number of unmarked King Salmon that migrated downstream past the Benbow Dam during the time that the marked fish migrated downstream past the dam.

The question then arises, how many unmarked fish migrated past Benbow Dam before the count of marked fish was started, i.e., before April 24? As was stated previously, there is no way of calculating what proportion of this number the 810 fish recorded April 1-23 represent, so that our estimate can be little more than a guess. I believe that we would be quite

safe in saying that the number did not exceed a million fish, and fairly safe in saying that it did not exceed several hundred thousand fish.

As a result of our calculations and estimates we might say that between 2,000,000 and 3,000,000 naturally-propagated King Salmon fish of the season migrated downstream past Benbow Dam during the 1938-39 season, assuming that at least 90 per cent of the marked fish planted above the dam April 21-22 migrated past the dam. This latter assumption is not a certain one, but, nevertheless, a reasonable one.

The downstream migrations of recorded marked and unmarked fish are shown in the graphs, Figs. 1 and 2.

It is regrettable that the downstream trap was out of operation May 18-noon May 26, a period during which many marked fish were migrating past the dam. The absence of figures for this period reduces the size and therefore the accuracy of our sampling, but should not affect the proportions on which we have based our calculations, unless the proportion of marked to unmarked fish migrating past the dam during this period varied radically from that during the time that the counts were made. There appears to be no reason to assume that this was the case.

As a check on our calculations, we may also calculate the number of seaward migrants by the process of estimating the number of fish that resulted from the natural spawning of the adult females that passed over the dam on their upstream migration.

The total number of adult King Salmon that was counted through the Benbow Dam fishways during the 1938-39 season was 6,001. Of these, 2,571 were females, 1,319 large males (over 27 inches), and 2,111 grilse (males to 27 inches). I consider that the number of males was sufficient to fertilize all eggs spawned by females.

It is difficult to estimate how many of the females that passed over the dam succeeded in spawning, and how many were lost through various causes (fishermen, predators, old age, injuries, and disease). Also, it is not known how many eggs, on the average, are produced by the Eel River King Salmon.

McGregor (1923) found that Sacramento King Salmon contained an average of 7,422 eggs per female (study based on 50 female King Salmon taken in the Suisun portion of the Sacramento system). In an earlier paper, McGregor (1922) found that Klamath River King Salmon contained an average of 3,891 eggs per female (study based on 98 fish). During the fall of 1938, 2,171 female King Salmon spawned at the Klamathon Egg Collecting Station of the California Division of Fish and Game, located on the Klamath River near Hornbrook, yielded a total of 7,629,700 eggs, or an average of 3,514 per fish, a figure not differing greatly from McGregor's. The number of eggs contained by Eel River King Salmon is probably closer to that contained by Sacramento River fish than to that contained by Klamath River fish. It is likely that the average for Eel River King Salmon is between 4,000 and 7,000. Assuming that 5,000 eggs are produced, the female King Salmon that passed over the dam contained some 12,855,000 eggs (2,571 x 5,000).

My estimate is that over 50 per cent, and perhaps as high as 90 per cent, of the females succeeded in spawning. Assuming again that the fish spawned quite cleanly, which I believe is true, and that 90 per cent of the females succeeded in spawning, some 11,569,500 eggs were deposited.

Again we must make a calculation, and that is regarding the percentage of eggs that developed into fish which emerged from the gravel. The season of 1938-39 was a rather favorable one for the spawning of King Salmon in the Eel

River system, so we may assume that this percentage is around 70. On this basis, some 8,098,650 fish emerged from the gravel.

Since King Salmon as a rule migrate downstream soon after emerging from the gravel, we may assume that but a small percentage was lost between time of emergence and time of passing through the Benbow Dam fishways on the seaward migration. If 90 per cent survived this interval, then some 7,288,785 young King Salmon passed the Benbow Dam on their seaward migration during the 1938-39 season.

This figure is considerably higher than our estimate of 2,000,000 to 3,000,000, which was based on the ratio of marked to unmarked fish. It is therefore likely that one or more of the following estimates are too high: the number of eggs contained by Eel River King Salmon; the percentage of females that succeeded in spawning; the percentage of fish that emerged from the gravel; the percentage of emerging fish that survived to migrate past the Benbow Dam. Further investigations may be expected to clarify the latter three points only partially, but it is hoped that they will supply us with fairly accurate figures regarding the number of eggs contained.

Assuming that our calculation that approximately 11,569,500 eggs were deposited is correct, and also that our calculation (based on the ratio of marked to unmarked fish) that between 2,000,000 and 3,000,000 naturally-propagated King Salmon fish of the season migrated downstream past Benbow Dam is correct, we see that the migrating fish formed 17 to 26 per cent of the eggs deposited.

The statistics available are not complete and accurate enough to formulate a true evaluation of production of fish from natural and from artificial spawning. However, the available figures relating to the production

of the previously discussed marked fish will be presented for what they are worth.

According to the records of the Fall Creek Hatchery and the Ft. Seward Hatchery, the 500,000 eyed King Salmon eggs shipped to the Ft. Seward Hatchery from the Fall Creek Hatchery represented 541,454 eggs taken from the fish at the Klamathon Egg Collecting Station. Of the 500,000 shipped, 483,851 (including the marked fish) are recorded as surviving to time of planting. The latter number represents 89 per cent of the number of eggs taken from the fish, a remarkably high figure, considering that the fish when planted averaged approximately 23 per ounce. Of course, this percentage must be reduced to a slight but unknown extent, for the reason that in removal of the eggs from the fish some eggs are left in the fish. Also, some of the fish have lost or spawned a few of their eggs before stripping.

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