

SENSORY FACTORS IN THE HOMING OF ADULT CHINOOK SALMON
(SUMMARY)

by

Alan B. Groves

October 1964

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

INTRODUCTION

Adult salmon, after feeding in the vast areas of the North Pacific Ocean, migrate back to their home river and then return rather specifically to their stream of origin. Information is needed on this homing phenomenon, especially in relation to its directing sensory mechanisms. A favored hypothesis is that the final critical migratory movements are directed by odor and olfactory responses.

An experiment was conducted in the fall of 1960 to explore the possibility that the olfactory sense does play a key role in the final homing of adult chinook salmon. This consisted of blocking sensory receptors of fish which had attained a spawning goal, displacing them away from the site, and then observing their abilities to return.

MATERIALS AND METHODS

The work centered at the Spring Creek Hatchery, at Underwood, Washington (fig. 1). This station, currently a major return site for fall-run chinook salmon, is located on the main stem of the Columbia about 20 miles above Bonneville Dam. Though situated on the river, the hatchery water source is distinctly separate, deriving from a series of springs which supply the buildings and ponds. The same source fills the holding pond and flows out the entrance fishway abruptly into the Columbia--a physical arrangement which suggests that homing to this site may involve detection of a specific water quality.

The experimental fish were all males, excess to the number normally needed in the hatchery spawning operation. Four treatments were used on the fish. These were: (1) Olfactory occlusion, (2) visual occlusion, (3) olfactory & visual occlusion, and (4) controls--(no sensory occlusion, same handling procedure). Olfactory occlusion entailed insertion of a packing of petroleum jelly and cotton into the olfactory sac followed by sutures across the nares to retain the plugs. For visual occlusion, the optic lenses were removed surgically and replaced with a mixture of petroleum jelly and carbon black. These techniques were selected to minimize operative shock and the time required for treatment.

All fish were anesthetized with M.S. 222 prior to treatment, then marked with numbered Petersen disc tags. After treatment they were transported, still anesthetized, in units of four (treatments 1, 2, 3, 4) to selected release points away from Spring Creek.



Figure 1.--Spring Creek Hatchery on the Columbia River. Holding pond for returning adults is enclosed from the river within the earth dike. Opening to the entrance fishway is left of the turn in the roadway on the lower dike. Attraction water (arrow) is flowing from fishway into river at about 9 cubic feet per second.

Three release sites were used (fig. 2): (1) Downstream north shore (Stevenson, Washington), (2) downstream south shore (Cascade Locks, Oregon), and (3) upstream north shore (Lyle, Washington). A sample of 100 fish for each treatment at release points 1 and 2 was planned. A smaller sample of 50 in each category was attempted at site 3.

RESULTS

From 866 fish treated, tagged, and released between September 2 and September 21, 1960, tags recovered from September 5 through October 7 accounted for 348 fish or about 40 percent (table 1).

Returns to Spring Creek

Half of all recoveries were from fish returned to Spring Creek, where tags were collected individually as fish reentered the hatchery fishway, beginning September 5. After September 20, when the treatment and release work was terminated, the remainder of Spring Creek tag recoveries were gathered in groups as the fish were used in spawn taking.

Total returns to Spring Creek by treatment category from each release point are shown in figure 3. Approximately 50 percent of the control fish made their way back from the downstream releases and 37 percent from the upstream release. About half as many blind fish as controls returned from each point.

Six olfactory occluded fish returned--five from the north shore downstream release, and one from the south shore downstream release. These fish returned after September 20, and were not checked for adequacy of olfactory plugging. Two fish with visual-olfactory occlusion returned--one from each downstream release point. These also were taken after September 20, and not inspected. Of the total 176 fish that returned to Spring Creek, 95 percent did not have occluded olfactory structures, whereas 8 returning fish, or the remaining 5 percent, had received the olfactory blocking treatment.

Elapsed times between release and return were recorded for individual fish observed before September 20. These were in the control and visual occlusion categories only and are shown in table 2. The mean return time for visually blocked fish was 7 days compared to 5 days for control fish. No visually occluded fish returned in less than 4 days but ten control fish had appeared within 3 days.

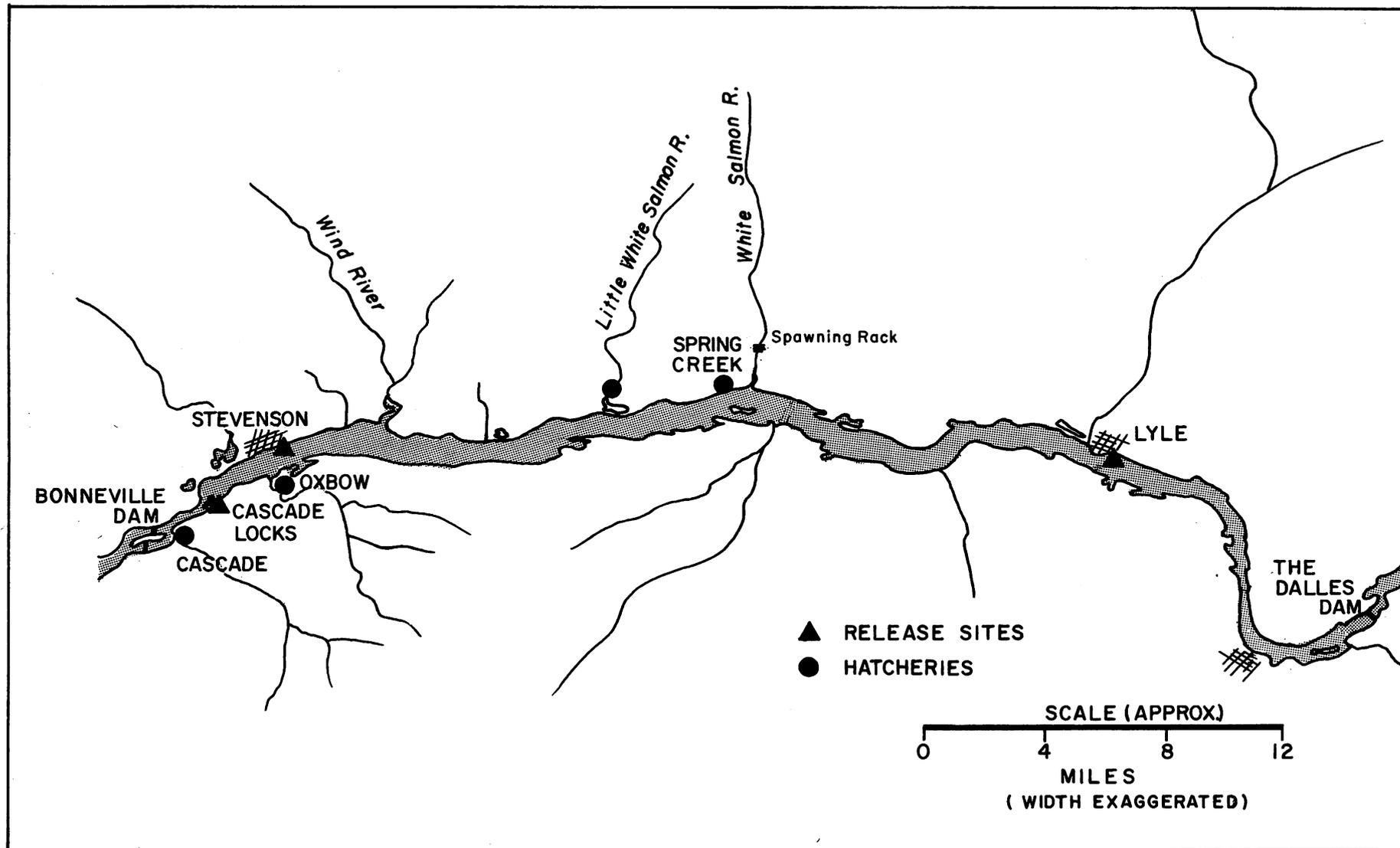


Figure 2.--Area of Columbia River where homing experiment was conducted. Fish were trucked from Spring Creek to release points. Other hatcheries are shown in relation to release points.

Table 1.--Summary of total tag recoveries from all fish released.

Release point	Recovery point	Control fish	EXPERIMENTAL TREATMENT			Total
			Visual occl.	Olfact. occl.	Vis-Olf. occl.	
		96 rel.	96 rel.	75 rel.	74 rel.	
Downstream	Spr. Cr.	48	22	5	1	76
No. Shore	Oxbow	9	11	1		21
(Stevenson)	Cascade	2	2	6		10
	Little					
	Wh.Salm.	5	1			6
	Big White					
	Salmon	1	7			8
	All other					
	spawn.					
	activ. ^{1/}		2	1		3
	Non-spawn. ^{2/}	1		8	7	16
Total recovered		66	45	21	8	140
		96 rel.	96 rel.	77 rel.	76 rel.	
Downstream	Spr. Cr.	46	24	1	1	72
So. Shore	Oxbow	23	14	3		40
(Cascade	Cascade	4	4	15	1	24
Locks)						
	Little					
	Wh.Salm.		2			2
	Big White					
	Salmon	1	4			5
	All other					
	spawning ^{1/}		4	1		5
	Non-spawn ^{2/}			8	8	16
Total recovered		74	52	28	10	164
		49 rel.	49 rel.	41 rel.	41 rel.	
Upstream	Spr. Cr.	18	10			28
No. Shore	Oxbow					0
(Lyle)	Cascade			1		1
	Little					
	Wh.Salm.					0
	Big White					
	Salmon	1	3			4
	All other					
	spawning ^{1/}	2	1			3
	Non-spawn ^{2/}	1	2	2	3	8
Total recovered		22	16	3	3	44
Grand totals		162	113	52	21	347

^{1/} artificial spawning activities; hatcheries and spawning rocks.

^{2/} includes fish taken by sport and commercial fishermen or found in river.

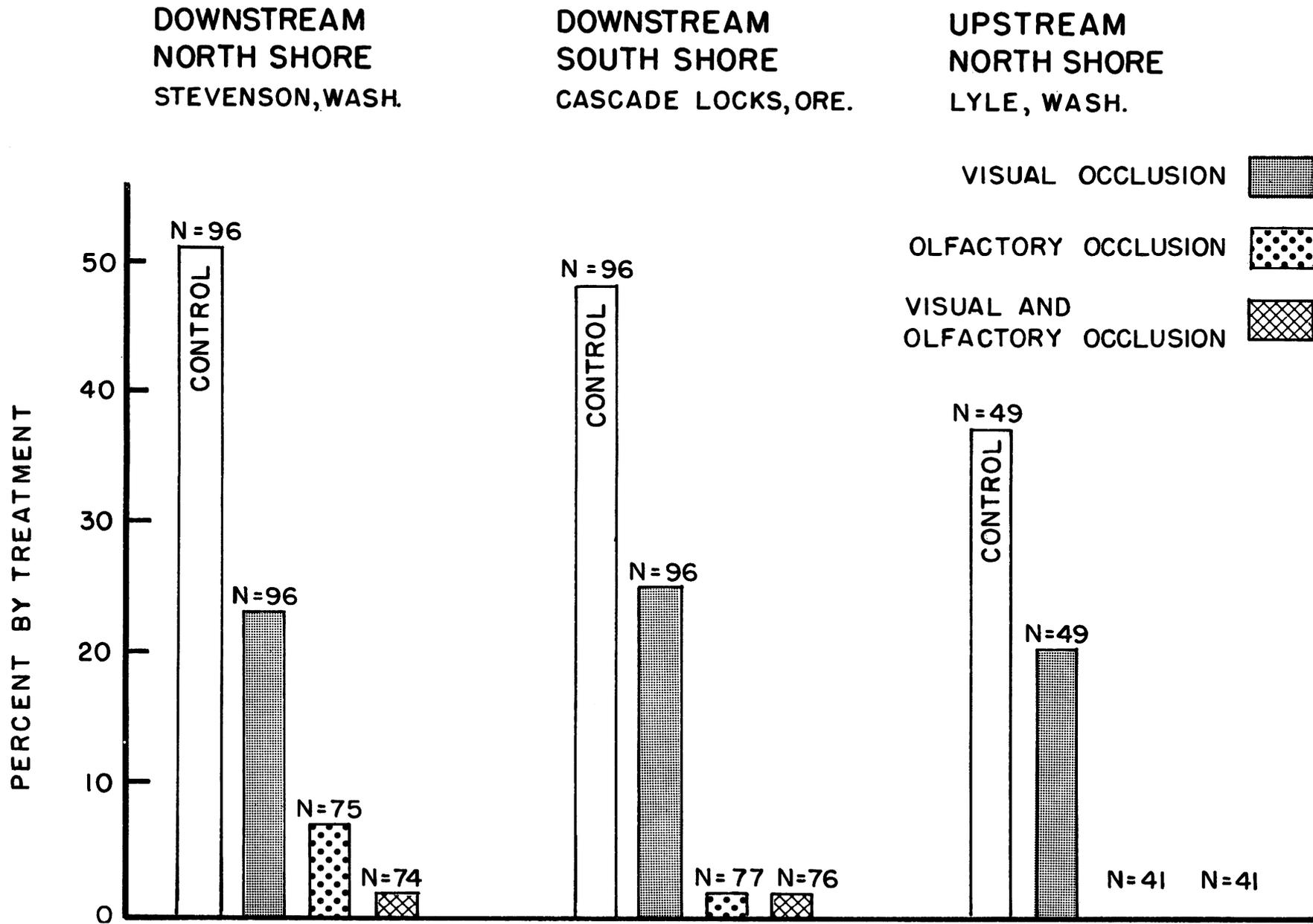


Figure 3.--Returns to Spring Creek by treatment category from each release point.

Table 2.--Days from release to return to Spring Creek--for individual fish observed between September 2 and September 21.

Treatment	RELEASE POINTS					
	Downstream North (Stevenson)		Downstream South (Cascade Locks)		Upstream North (Lyle)	
Control	Days to return	Number	Days to return	Number	Days to return	Number
	1		1	1	1	
	2		2	1	2	2
	3	4	3	2	3	
	4	6	4	4	4	
	5	2	5	5	5	1
	6	1	6	6	6	3
	7	2	7	3	7	
	8	2	8	1	8	
	9		9		9	
	10		10	1	10	
	11	1	11		11	
	12		12		12	1

Mean Time = 5 days

Visual occlusion	Days to return	Number	Days to return	Number	Days to return	Number
	1		1		1	
	2		2		2	
	3		3		3	
	4	2	4		4	
	5	1	5	1	5	
	6	2	6	1	6	2
	7	1	7	2	7	1
	8	2	8	3	8	
	9	1	9	1	9	
	10		10		10	1
	11		11	1	11	
	12		12		12	

Mean Time = 7 days

Olfactory
occlusion None returned

Olfactory
and visual
occlusion None returned

Recoveries Away from Spring Creek

Of the 172 tags recovered from points other than Spring Creek, 132 or 77 percent were from hatcheries and spawn-taking operations, and 40, or the remaining 23 percent, were from points or sources not associated with spawn-taking (table 1). The effect of treatment on this distribution is shown in figure 4. In both the control and visual occlusion groups about 96 percent were recovered from spawn-taking operations. In the olfactory occlusion category, 61 percent of recoveries were from spawn-taking sources. Though fewer were recovered from the combination sensory treatment groups, the ratio was reversed from control and visual occlusion recoveries, with 95 percent coming from sources that were not related to spawn taking.

As shown in table 1, 121 of the 132 tags from spawn-taking other than Spring Creek were from within a 15-mile portion of the Columbia above Bonneville Dam. Of this number, 96 were from the Oxbow and Cascade hatcheries--each respectively about 1 mile above and 1 mile below the downstream south shore release site at Cascade Locks. Ninety-three percent of the tags recovered from the Oxbow hatchery were from the control and visual occlusion groups. At the Cascade hatchery, 34 percent of the recoveries were from these categories with the remaining 66 percent made up of olfactory occluded fish. These two hatcheries accounted for nearly all of the olfactory occlusion returns from spawn-taking sites other than Spring Creek. Four were from Oxbow, and twenty-two from Cascade. The remaining two were from the Kalama hatchery about 90 miles downstream from Bonneville Dam.

Relation of Recovery Site to Fish Size and Release Time

Whether control fish returned to Spring Creek or were recovered from another spawning site was related to individual size and the period of release during the 18-day treatment interval. This is shown in figure 5 for the total of all control fish released in the experiment. From releases during the total 18 days, the return to Spring Creek was greater for fish over 32 inches in length. In releases of the first 8 days, all recoveries of larger fish were at Spring Creek. Despite a decline in the total recoveries from release days 9 to 13 and 14 to 18, the majority of the larger fish were recovered from Spring Creek. Fish under 32 inches, however, did not return as specifically. Some were recovered at alternate sites from all release intervals. In the last period, days 14 to 18, the majority of recoveries were from sites other than Spring Creek.

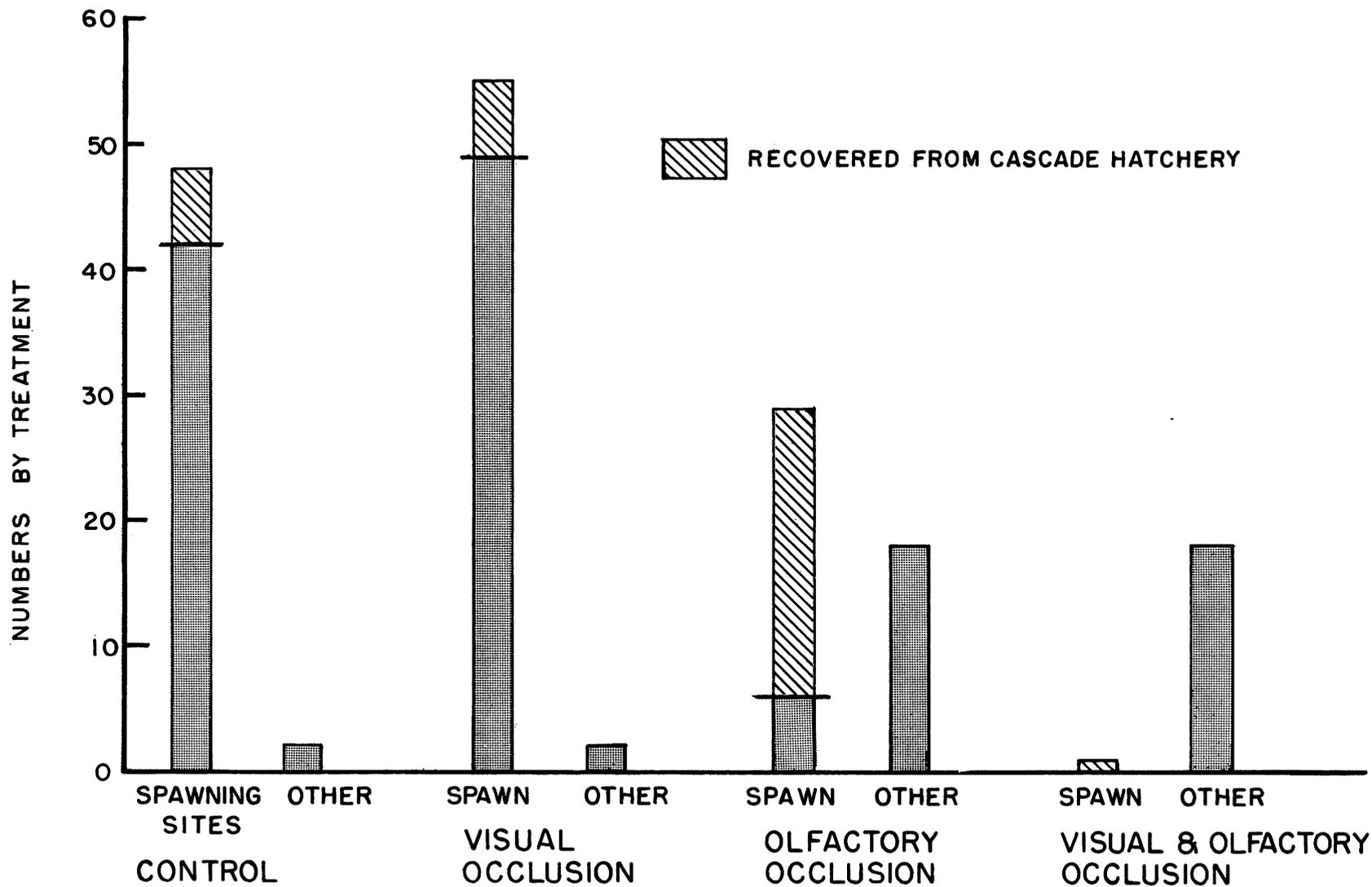


Figure 4.--Effect of treatment on type of recovery location for fish that did not return to Spring Creek. Recoveries from Cascade Hatchery show a disproportionate number of olfactory-occluded fish. Non-spawning recoveries were mostly from the commercial fishery below Bonneville.

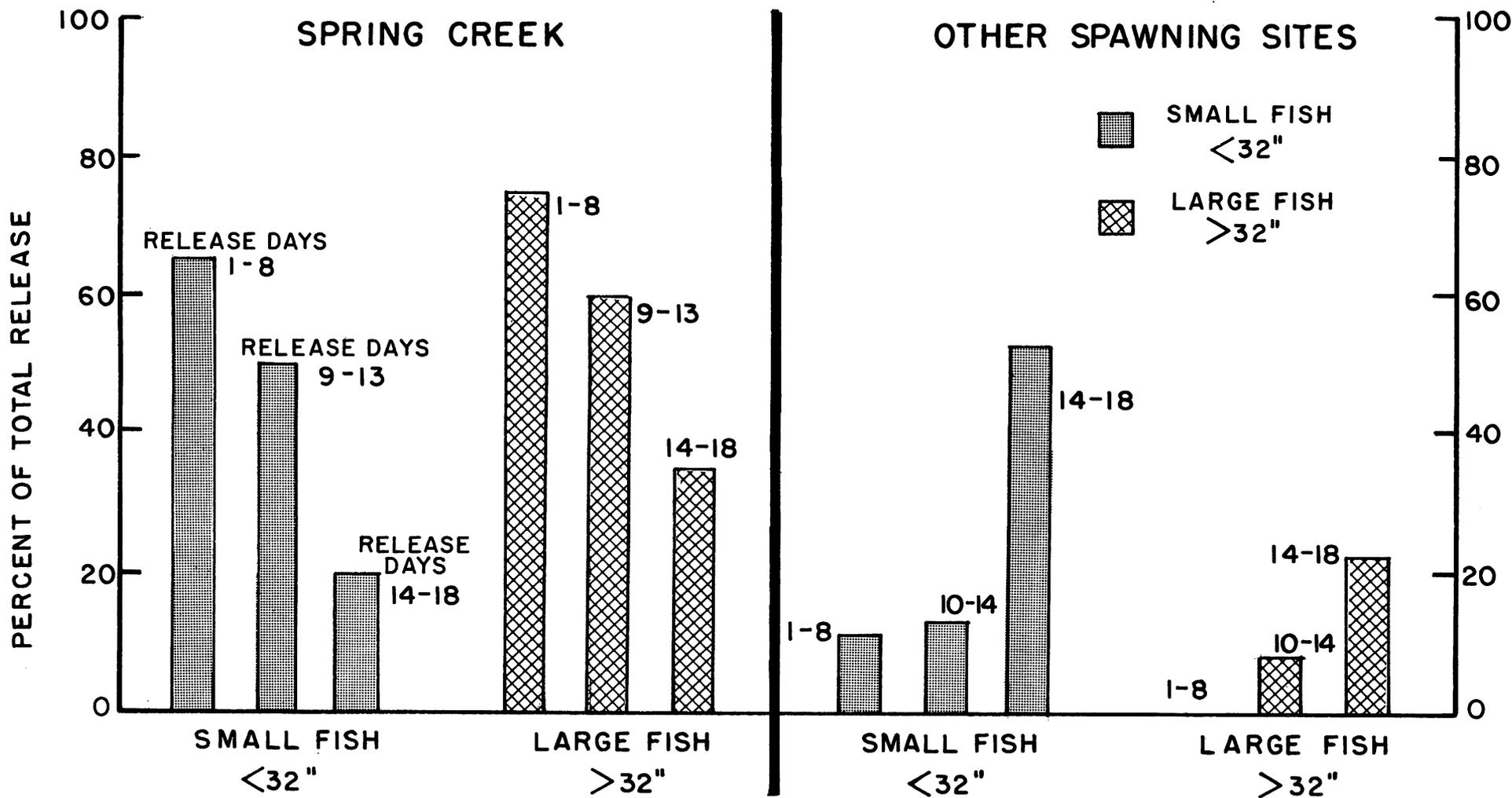


Figure 5.--Recovery pattern for untreated control fish. Fish size and period of release during the experiment affected whether fish returned to Spring Creek or were recovered at another spawning site.

DISCUSSION AND CONCLUSIONS

That final homing need not follow a fixed pathway was indicated by the numbers of control and visual occlusion fish returning from all release points. While such fish returning from upstream were proportionally fewer than from downstream releases, the absence of olfactory occlusion returnees from upriver suggests that some sort of odor recognition cued the unplugged fish back into Spring Creek. Perhaps as they moved down past the hatchery in a pattern of search, this cue was received. A search and return pattern from downstream is suggested by the proportionally larger but similar numbers of control and visual occlusion fish returning from each of the lower sites. Though the olfactory occlusion returnees may have reflected ineffective treatment, they also may have reflected the locations of the releases. All were from downstream, and six of the eight fish were from the north shore site on the same side of the river as Spring Creek.

The relatively constant ratios between control and visually occluded fish reappearing from each release suggest that sight played only a supporting role in the return. Though returning blinded fish were handicapped as shown by reduced numbers, delay, and a usually battered appearance on arrival, they did reappear in appreciable numbers. Sighted fish with blocked olfactory organs did not.

The primary directing role of olfaction in reattaining a spawning goal was indicated. However, the phasing appeared critical since time worked against the specificity of the response. Later in the experiment, when the fish were more mature, they increasingly appeared at the alternate spawning sites nearer to the release points. In part, this may have reflected diminishing physical capacities since smaller fish more often made such choices. Even in alternate spawning site choices, however, the importance of olfaction was apparent for when this sense was blocked, the fish evidently were less able to locate concentrations of potential spawners. In the one exception, where a significant number of olfactory occluded fish were recovered at the Cascade Hatchery, analysis indicated that this probably was related mostly to the location of this station with respect to the release points.

All the fish used in this test had once reached Spring Creek and the effect on return of this previous experience is not known. However, in view of the results, it seems highly probable that olfactory responses initially brought the fish into Spring Creek.