SEAWARD MIGRATION OF DWORSHAK HATCHERY STEELHEAD TROUT IN 1976

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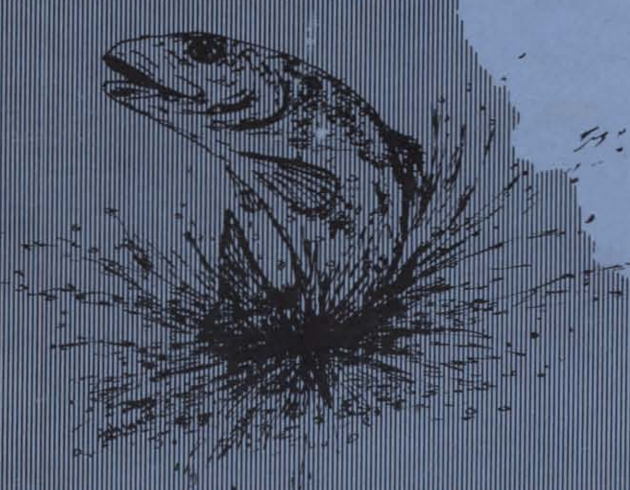

FOREST, WILDLIFE AND RANGE EXPERIMENT STATION

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SEAWARD MIGRATION OF DWORSHAK HATCHERY STEELHEAD TROUT IN 1976

by

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Idaho Cooperative Fishery Research Unit

Submitted to:

Dworshak National Fish Hatchery
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ABSTRACT

Studies were conducted during 1976 to evaluate the transformation from parr to smolt and seaward migration of steelhead trout (*Salmo gairdneri*) reared at Dworshak National Fish Hatchery. Fifteen groups of fish were branded and tagged and released to evaluate length at release, date of release, conditioning in cold water (5-10 C), incidence of fungus infection at the dams, saltwater tolerance and gill ATPase activity. Seaward migration was evaluated by recapturing marked fish at Lower Granite and Little Goose dams.

The marked groups of fish released in 1976 appeared to be in less than optimum health, but the number of fish recaptured at the dams was not clearly related to the indexes of health we used (mortality in the ponds and incidence of fungus at the dams). Pre-release mortality in the hatchery ponds and incidence of fungus infection at the dam was higher for all fish (test and productivity) from system II than from system III because the biofilters in the water reuse system did not keep metabolites at less than toxic concentrations.

Length at release was the single most important factor regulating the number of fish that migrated seaward and were recaptured at the dams. For steelhead between 150 and 205 mm in length, the number recaptured at the dam was a linear function of length.

Most steelhead trout at Dworshak Hatchery were ready to migrate seaward by mid-April. Large numbers of fish began leaving some ponds voluntarily in April, and more of the marked fish released April 14 were recaptured at the dams than those released May 5 or May 24.

Conditioning hatchery steelhead trout in cold water (5-10 C) for 3 or 6 weeks before release did not result in elevated gill ATPase activity or an obvious increase in the numbers of fish recaptured at the dams, but there was some evidence that a longer period of conditioning might be beneficial. Fish conditioned for 6 weeks and released April 14 were recaptured in relatively large numbers despite their smaller size and high pre-release mortality.

A relatively high percentage of the marked fish from Dworshak Hatchery was infected with fungus when recaptured at the dams. Fish released April 14 and recaptured April 20 to May 10 had infection rates of about 10 percent at Lower Granite Dam and nearly 25 percent at Little Goose Dam. The infection rate for wild fish was less than 2 percent throughout the season.

Gill ATPase activity of fish at the hatchery in mid-April was only slightly elevated, but doubled by mid-May and then declined. ATPase activity of hatchery fish collected at the dams was double that of fish held in the laboratory, but not as high as migrating wild fish.

Not all wild and hatchery steelhead trout collected at Lower Granite Dam May 12 survived when placed in seawater pens in Puget Sound. Only 10 percent of the wild fish and the large fish from Niagara Springs Hatchery (252 mm in length) did not survive the transfer to seawater, whereas 20-30 percent of the marked and unmarked steelhead from Dworshak Hatchery died within the first 6 days. The fish from Dworshak Hatchery were smaller and had not migrated as far, thus the transformation from parr to smolt was not as complete as in the other fish.

The percentage of the marked fish of each group released from the hatchery that migrated downstream and passed Lower Granite Dam ranged from 32 to 54 percent. The marked fish were probably representative of the other fish released from system II of the hatchery, thus half those fish, or more, did not get downstream as far as Lower Granite Dam. Fish from system III in the hatchery appeared to be in better health when released, had a lower incidence of fungus infection when examined at the dams, and a larger percentage may have migrated downstream.

INTRODUCTION

Juvenile steelhead trout reared at Dworshak National Fish Hatchery (DNFH) were studied in 1976 to assess their transformation from parr to smolt and seaward migration. We evaluated the effect of length at release, date of release, and conditioning in cool water (5-10 C) on the seaward migration of marked groups of hatchery steelhead trout to Lower Granite and Little Goose dams (Fig. 1). We also assessed the incidence of fungus infection, saltwater tolerance, and gill ATPase activity of wild and hatchery fish.

Hatchery personnel have reported that hatchery smolts were not in top health when released in some years and National Marine Fishery Service (NMFS) personnel operating collection facilities at the Snake River dams have reported that a high percentage of the hatchery fish observed at the dams in some years had fungus infections. The number of marked hatchery steelhead trout passing Lower Granite and Little Goose dams and the percentage which had fungus infections were monitored in 1976 to obtain a measure of the quality of the fish released from Dworshak Hatchery.

The facilities at Dworshak National Fish Hatchery were designed so that steelhead smolts could be produced in one year by using a water reuse system to maintain the water at an optimum temperature. The biofilters in the water reuse systems have not operated consistently or effectively every year and fish health deteriorated and growth slowed whenever toxic metabolytes accumulated in the water making it difficult to produce healthy fish of appropriate size.

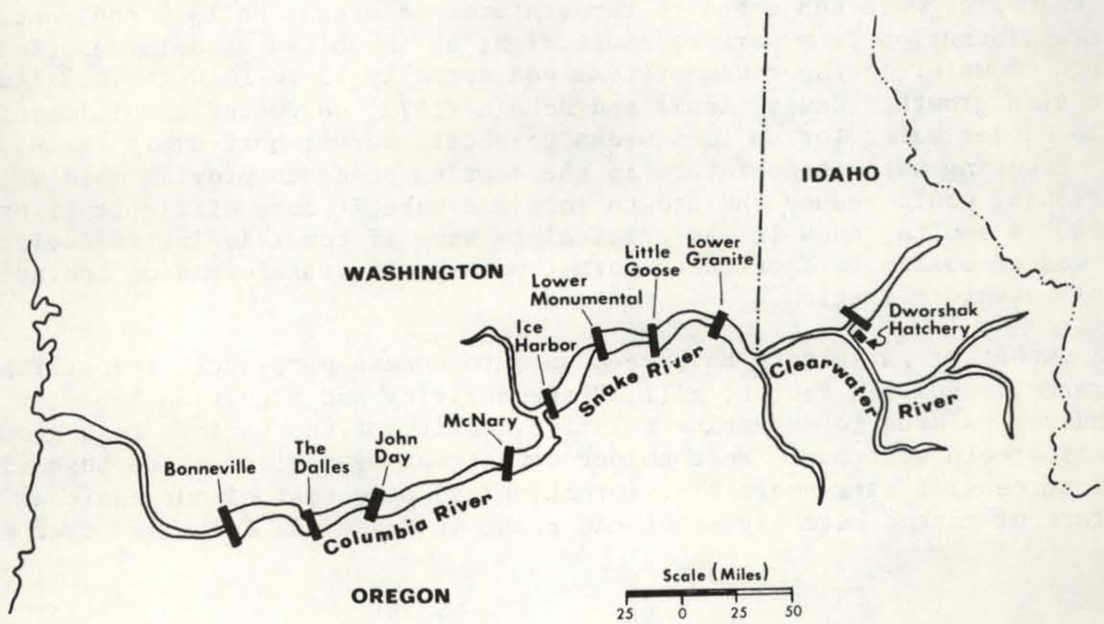

Figure 1. Location of Dworshak National Fish Hatchery and the dams on the Columbia and Snake rivers.

During the first few years, the smolts released from Dworshak Hatchery were supposed to average 180 mm total length. From the results of recent studies on the optimum size of hatchery reared summer steelhead trout (Chrisp and Bjornn 1978; Fessler 1974), we proposed that the target length should be 200 mm.

The need to produce 200 mm smolts has not gone unquestioned. Substantial numbers of adult steelhead trout had returned to Dworshak Hatchery from smolts released in earlier years that were shorter than 200 mm. An additional reason for evaluating the effect of length at release on parr-smolt transformation was the difficulty of rearing smolts to 200 mm in 1 year, especially if the biofilters did not operate effectively.

The optimum date to release hatchery smolts should probably coincide with the downstream migration of wild smolts. The peak of steelhead trout migration in the lower Snake River occurs consistently in mid-May (Raymond 1969). If hatchery fish, particularly those reared in the warm water of the reuse systems, needed time to acclimate to the river before they would migrate downstream, they should be released in April. Too early a release, however, would shorten the time for reaching the target length, and too late a release may result in some fish not migrating at all or reaching the ocean at a less than optimum time. Zaugg, Adams, and McLain (1972) postulated that the warmer water (higher than 13 C) in the rivers during late May and June may retard or even reverse the parr-smolt transformation of late migrating fish.

Adams, Zaugg and McLain (1972), in their work with winter and summer steelhead trout, observed that gill ATPase activity did not increase normally when fish were subjected to temperatures in excess of 13 C and concluded that transformation from parr to smolt might be inhibited or delayed. Temperature of water in the reuse systems was normally 12 to 16 C to facilitate faster fish growth. Zaugg, Adams and McLain (1972) suggested conditioning fish in cooler water for up to 6 weeks to obtain normal parr-smolt transformation. Lowering water temperature in the rearing ponds to provide cold water conditioning would reduce the growth rate and make it more difficult to produce 200 mm smolts, thus it was critical to know if conditioning in cooler water was necessary to facilitate normal parr-smolt transformation and successful seaward migration.

A number of parameters have been used to assess parr-smolt transformation. Appearance, condition factor, gill ATPase activity and migration behavior were the indexes we used to determine relative quality of the various test groups of hatchery steelhead trout. We consider downstream migration as the best indicator of successful parr-smolt transformation and base most of our analyses on recapture of marked hatchery steelhead trout at Snake and Columbia river dams.

METHODS

Recapture of marked fish at Snake River dams was the primary method of evaluating optimum length at release, date of release, and weeks of cold water conditioning. Gill ATPase activity, salt water tolerance, condition factors, and rates of fungus infection at the dams were also used to evaluate quality of the various test groups of steelhead trout released from DNFH in 1976.

Fifteen separate groups of steelhead trout with distinctive marks or tags were released from DNFH in 1976 (Table 1). Thirteen groups were used to evaluate the three major factors tested in 1976 (length at release, date of release, and cold water conditioning). The other two groups were used to assess timing of voluntary migration and as an additional evaluation of optimum smolt length.

Table 1. Test groups of steelhead trout marked and released from DNFH in 1976 with length at release, weeks of conditioning in 5-10 C of water, date of release, abbreviated description of group for use elsewhere in this report, brand applied to the left dorsal (LD) side of the fish and number released in each group. All fish were age I except group 14.

Group number	Description of group: Total length (mm)	Weeks of conditioning	Date of release	Abbreviated description	Brand applied	Number released
1	Large (192.5)	0	April 14	L-0-A	LD NI	10864
2	Small (177.1)	0	April 14	S-0-A	LD ⊔	13149
3	Large (197.7)	0	May 5	L-0-M	LD ≷	10164
4	Small (177.1)	0	May 5	S-0-M	LD ⊏	17888
5	Large (200.2)	3	April 14	L-3-A	LD IN	12955
6	Small (168.2)	3	April 14	S-3-A	LD ⊓	14227
7	Large (198.5)	0[a]	May 5	L-0'-M	LD ≷	12685
8	Small (179.5)	0[a]	May 5	S-0'-M	LD ⊐	12214
9	Large (190.8)	6	April 14	L-6-A	LD IT	10989
10	Small (166.7)	6	April 14	S-6-A	LD ∇I	10055
11	Large (190.0)[b]	6	May 3	L-6-M	LD ⫤	8880
12	Small (180.5)[b]	6	May 3	S-6-M	LD IΔ	10948
13	Large (199.9)	13	May 24	L-13-M'	LD ⊥I	6004
14	Age II fish placed in sluiceway		March 16, April 5 and 29	–	Jaw tags	1491
15	Age I fish placed in sluiceway		March 31	–	Jaw tags	673

a/ Originally scheduled for 3 weeks of cold water conditioning, but water temperature control was inadequate.

b/ Fish not measured when released. Length at release based on measurements of fish that died in pond the week before release.

Length at Release

Two methods were used to evaluate optimum length of hatchery steelhead at time of release: (1) 12 groups of fish, half referred to as large fish (190-200 mm total length at release) and half small fish (170-180 mm in length), were marked for later recapture at the dams, and (2) we tagged 2,164 fish with monel metal jaw tags, recorded the length of each fish, and released them into a sluiceway at the hatchery where they could leave via a trap to migrate downstream whenever they desired.

Fish marked in February, 1976 were those that we anticipated would average about 180 mm (the small size group) or 200 mm (the large size group) in length when released. These two lengths were selected for testing because they represented what appeared to be the optimum length and a smaller length that is more easily attained by fish at Dworshak Hatchery. The large sized fish were about 20 mm longer than the small sized fish when branded and slightly less when released (Table 2). Average lengths of small sized fish ranged from 167 to 181 mm when released and for large sized fish, 190 to 200 mm. Average length of the fish increased 7 to 20 mm from branding to release with the amount of increase dependent primarily on date of release and length of cold water conditioning (Table 2).

Table 2. Number of fish branded in each test group, number released, mean length when branded, mean length when released, length increase between branding and release, percentage mortality in the ponds between branding and release and for the last 23 days before release in 1976.

Group number	Abbreviated description[a]	Date branded	Number branded	Number released	Percentage mortality Total	Percentage mortality Last 23 days	Mean total length When branded	Mean total length When released	Length increase (mm) Total	Length increase (mm) Per day
1	L-0-A	Feb 13 & 18	13587	10864	13.9	9.1	174.1	192.5	18.4	0.32
2	S-0-A	Feb 25 & 26	14327	13149	8.2	4.6	158.7	177.1	18.4	0.38
3	L-0-A	Feb 19	14127	10164	28.1	9.5	177.9	197.7	19.8	0.26
4	S-0-M	Feb 26	20162	17888	12.7	5.3	161.0	177.1	16.1	0.23
5	L-3-A	Feb 20	15044	12955	13.9	5.6	183.7	200.2	16.5	0.31
6	S-3-A	Feb 27	15620	14227	8.9	3.2	155.6	168.2	12.6	0.27
7	L-0'-M	Feb 23	15650	12685	18.9	3.6	184.6	198.5	13.9	0.19
8	S-0'-M	Feb 27	15244	12214	19.9	7.9	160.1	179.5	19.4	0.29
9	L-6-A	Feb 24	13400	10989	18.0	10.4	183.9	190.8	6.9	0.14
10	S-6-A	March 2	13342	10055	22.7	17.2	160.2	166.7	6.5	0.15
11	L-6-M	Feb 25 & 26	11566	8880	23.2	10.7	181.3	190.0	8.7	0.13
12	S-6-M	March 1	13796	10948	21.0	4.4	159.7	180.5	20.8	0.33
13	L-13-M'	May 22	6059	6044	-	-	-	200.2	-	-

[a] Refer to Table 1 for full description of test groups if needed.

The four groups of jaw-tagged steelhead trout released into a sluiceway at DNFH included one group of age I fish (130 to 250 mm in length) placed in the channel on March 31, and three groups of age II fish (130 to 350 mm in length) released on March 16, April 5, and April 29 (Table 3). Fish migrating downstream out of the sluiceway entered a trap placed at the lower end where they were measured, the tag number recorded, and then released to continue their migration. Jaw-tagged fish were also recaptured at the Snake River dams, but because of the small number tagged, the number of recaptures was relatively small.

Table 3. The number of jaw-tagged steelhead trout in each length group released into the sluiceway at DNFH in 1976.

Length group	Age I fish March 31	Age II fish March 16	Age II fish April 5	Age II fish April 29
130-39	11			1
140-49	28	4	2	1
150-59	43	6	2	3
160-69	89	10	7	6
170-79	123	12	12	8
180-89	119	36	21	10
190-99	112	48	44	24
200-09	90	76	52	60
210-19	35	65	73	68
220-29	17	63	58	59
230-39	5	55	60	55
240-49		39	47	64
250-59	1	36	32	38
260-69		26	34	26
270-79		12	22	30
280-89		9	13	15
290-99		5	11	14
300-09		2	5	6
310-19			4	1
320-29				2
330-39				
340-49			1	
350-59				
Totals	673	504	500	491

Date of Release

Release dates of April 14 and May 5 were selected so the hatchery fish would be placed in the river 20-25 and 0-5 days, respectively, before the peak of the wild steelhead trout migration in May. Six of the 12 test groups of fish were released on April 14 and 2 on May 3, and 4 on May 5 (Table 1). A third date of release was added to the studies when we branded and released on May 24 a group of large sized fish that had been held in raw water for 13 weeks. Timing of migration of fish allowed to leave three hatchery rearing ponds whenever they chose was assessed with traps installed on the outlets. Pond trapping plus the trapping of fish leaving the sluiceway was undertaken to help us determine when fish were ready to migrate.

Cold Water Conditioning

To determine the length of time juvenile steelhead must be conditioned in cold water (less than 10 C) before release, we conditioned the 12 groups of fish for 0, 3, or 6 weeks. We selected 6 weeks as the maximum length of conditioning because of the suggestion of Zaugg, Adams and McLain (1972) and because of reluctance to give up more growing time in warmer water than was absolutely necessary. Four of the 12 test groups received no conditioning. Four of the groups were scheduled to receive 3 weeks of conditioning, but we were unable to reduce the temperature sufficiently for groups 7 and 8 so only two groups had 3 weeks of conditioning, and 4 groups received 6 weeks (Table 1).

All test groups were reared initially in reuse water (12 C or warmer) of system II. Fish scheduled for 6 weeks of conditioning were moved 6 weeks before the scheduled release date to ponds of system I supplied with cold (less than 10 C) untreated river water. The water supply in system II was changed from reuse to cold untreated river water (single pass through the ponds) on March 19 to start the cold water conditioning of groups 5 and 6 (Table 1). Groups 1, 2, 3, 4, 7, and 8, scheduled for later release than groups 5 and 6 or 0 weeks of conditioning, were moved on March 19 to system III which was supplied with reuse water. By mid-April, groups 3 and 4 and groups 7 and 8, scheduled for release May 5, were the only test fish left in system III. We attempted to condition fish in groups 7 and 8 by running untreated river water down the pipe to their pond and at the same time supply reuse water in the same pipe but from the opposite direction to the adjacent pond containing groups 3 and 4, but were unable to cool the water in the group 7 and 8 pond sufficiently to provide bonafide cold water conditioning. Thus, none of the fish released on May 5 had been conditioned for 3 weeks (Table 1). We could have shifted groups 7 and 8 from system III to system I to achieve the cold water conditioning but decided against that option because of the additional handling involved.

A pond of fish moved from system II to system I in mid-February provided an opportunity to mark a group of fish that had been in cold water for many weeks. These fish were some of the largest fish in system II when transferred to system I and we monitored their voluntary migration out of the pond through May 22. At that time, 6,059 of the remaining fish were branded and then re-released on May 24. This group of fish cannot be compared directly with other groups of fish without some caution because of the late date of release.

Timing of Voluntary Migration

To determine when fish would leave DNFH, if not detained, we removed the vertical plates from the outlet at the end of one pond in each of the three systems and attached spill type traps to collect the fish as they left the ponds. We also tagged age I and age II fish and placed them in a sluiceway (as stated previously) with a spill trap at one end and allowed them to migrate freely.

Traps were installed on ponds 43 (system I), 34 (system II) and 52 (system III) and fish were allowed to migrate beginning in mid-March. We continued trap operation through April 30 on pond 34, May 20 on pond 52 and May 21 on pond 43. The number of fish which entered the trap each day was recorded and we noted whether the fish were healthy and had a smolt appearance or were sick fish and had merely drifted rather than migrated into the trap.

Fish tagged with monel metal jaw tags and released into the sluiceway were: (1) the remaining age II fish from a group of 161,000 fish held over from the previous year, and (2) age I fish from pond 20 in system II. The age II fish were not representative of hatchery fish on a properly run schedule of two year rearing, but were the only such fish available for testing. They were originally scheduled for release after 1 year of rearing and thus were in heated reuse water all during their first year. After 1 year of rearing, they were not quite large enough to release but larger than fish on a scheduled two year rearing program. After an additional summer and fall of rearing in an adult holding pond supplied with untreated river water, the fish were transferred to pond 49 and averaged nearly 220 mm in length (range: 140 to 300 mm). Most of the 161,000 fish placed in the adult pond in June escaped and only 2,500 were transferred to pond 49 in November, 1975. Fish transferred to pond 49 may have been atypical of even the 161,000 fish put in the adult pond because a large proportion (one-third) of the fish were precocious males. We did not tag any fish that had visible signs of being a maturing male.

Age II fish were tagged and released into the sluiceway on March 16-17 (499 fish) and on April 5 (500 fish) and age I fish were tagged and released on March 31 (673 fish). On April 29, the sluiceway had to be cleared so we moved the remaining fish to pond 49. An additional 491 age II fish were tagged and left in pond 49 with the fish from the sluiceway. On May 5, the fish in pond 49 were moved to pond 41 to accommodate other needs at the hatchery and held there until May 24 when they were released. Traps were operated on ponds 49 and 41 and fish were allowed to leave those ponds. The tag number, length, and date of migration of all fish that left the ponds or sluiceway were recorded.

Gill ATPase Activity

To assess the gill ATPase of DNFH and wild steelhead trout in 1976, we collected fish at the hatchery and at Lower Granite and John Day dams and transported them to Dr. W. S. Zaugg at the Western Fish Nutrition Lab at Cook, Washington for analysis. Live fish of all test groups were sent to the lab at the time they were released from the hatchery. Dr. Zaugg periodically measured the ATPase activity of fish from the original shipments. Nearly all test groups, along with wild smolts, were represented in the samples sent to the lab from the two dams. The gill ATPase activity was expressed as μ moles of ATP hydrolyzed per hour per milligram of protein.

Saltwater Tolerance Tests

We evaluated the ability of Dworshak Hatchery and other Snake River steelhead trout to survive in seawater by transporting 100 fish of four different groups from Lower Granite Dam to Manchester, Washington and placing them in holding pens in Puget Sound. We also held 100 fish of each group in a raceway at Lower Granite Dam to assess mortality of fish not subjected to the hauling and seawater.

The four groups of Snake River steelhead trout collected at Lower Granite Dam for these tests were:

1. Branded smolts from Dworshak Hatchery (reared originally in system II).
2. Unbranded hatchery fish that we believe were almost entirely from system III at DNFH on the basis of their time of arrival at the dam, length distribution, and unique fin deformities.
3. Large smolts (longer than 220 mm) that we believed were from Niagara Springs Hatchery via the Pahsimeroi River on the basis of their length distribution, fin deformitites, and appearance of marked fish.
4. Wild smolts as distinguished by their lack of fin deformities and general appearance.

Fish with any evidence of fungus infection or other illness were not used in the saltwater tests.

We measured and examined large numbers of fish in system III at DNFH just prior to their release so we were familiar with their appearance. They ranged from 170 to 210 mm in length, had erosion of the dorsal and ventral fins, and minimal descaling. They were released April 28 and 29, and were passing the dam in large numbers when the fish for these tests were selected.

Marked fish from Niagara Springs Hatchery were large (longer than 210 mm), had erosion of the dorsal and pectoral fins, substantial descaling on many fish and a notable lack of slime when handled. We used marked fish from Niagara Springs to the extent available and similar appearing unmarked fish for the Niagara Springs Hatchery group.

On May 12, we selected 200 fish for each of the four groups from fish collected at Lower Granite Dam. We placed 100 fish of each group in a tank truck and 100 in a vacant raceway at the dams. Water in the fish tank had a salinity of 10 ppt with sufficient potassium added to maintain a proper chemical balance. The trip to Manchester began at 1700 hours on May 12 and ended at 0900 hours the next morning. Salinity in the tank was increased to 20 ppt by 1000 hours on May 13 after arrival at Manchester and to 23 ppt at 2200 hours, an hour before releasing the fish into the holding pen. Salinity of the seawater in that area of Puget Sound was 27 ppt.

Mortality among the fish was negligible while enroute to Manchester but increased when salinity was raised to 20 ppt. Nearly all fish that died during the first six days in 20 ppt or more seawater had the usual symptoms of seawater dehydration. Dead fish were removed daily from the pen at Manchester by NMFS personnel and frozen for our examination and identification at a later date. We discontinued holding fish at Manchester on May 25. By that time fish that could not handle the initial challenge of seawater had died. The surviving fish in the pen appeared healthy but longer term testing may be warranted.

Mortality among fish placed in the raceway at Lower Granite Dam was negligible during the first week but then increased. Dead fish were removed and identified every 1 or 2 days. At the end of the test, all fish remaining in the raceway were examined, identified, and the incidence of fungus infection noted.

Marking and Monitoring of the Fish at the Hatchery

Branding of the fish at Dworshak Hatchery began February 13 and ended March 2, 1976. In 12 days, 176,135 fish were branded by a crew operating four marking stations (15,700 fish per day, 3,700 fish per station per day, Table 2). Hatchery personnel transferred fish from the ponds to the marking stations inside the main building via a fish pump and pipes. Fish were pumped into a holding tank and then netted into the anesthetic trough at the marking stations. The brands (6 and 10 mm high) were made of silver and attached to a copper rod which extended into a pot containing liquid nitrogen to keep the brands cold. The left dorsal side of the fish was held against the brand for about 1 second. Branded fish of the large and small size groups that were to be cold water conditioned for the same length of time and released on the same date were then placed in the same pond.

Dead fish were removed from each pond daily by hatchery personnel. We examined the dead fish removed from ponds containing marked fish on a regular basis to determine the proportion from each marked group. The number of marked fish released was determined by subtracting the number of dead marked fish removed from the ponds from the total number marked.

A sample of fish from each group (usually 300 fish) was measured (total length) and weighed when marked and again when released. All of the marked groups of fish were pumped from the ponds and piped to the North Fork of the Clearwater River near the entrance to the hatchery fish ladder.

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Recovery of Marked Fish at the Dams

Marked fish from Dworshak Hatchery were recaptured in downstream migrant collection facilities operated by NMFS personnel at the Snake and Columbia river dams after they had migrated downstream. Fish entering collection facilities at Lower Granite and Little Goose dams were automatically sorted into raceways according to size. Numbers of fish entering each raceway were recorded electronically each day. Most of the collected fish were loaded directly from raceways into tank trucks for transportation to the lower Columbia River.

Each working day NMFS personnel moved fish from one or more raceways into the marking building for examination, sorting and marking. As fish were examined and sorted, marked fish from DNFH were set aside in a holding tank where we then recorded the brand, total length of the fish, and on many days, the presence or absence of fungus infection. We examined 54 to 848 branded fish from each of the 13 marked groups of steelhead trout released from the hatchery (Table 4).

Table 4. Number of marked DNFH steelhead trout smolts examined at Lower Granite and Little Goose dams in 1976, estimated number collected in all raceways of the collection facility, and the estimated number from each group which would have been collected if river discharge had remained constant and thus collection efficiency at each dam had remained constant.

		Recaptures-Lower Granite			Recaptures-Little Goose		
Group number	Abbreviated descriptions[a/]	Number examined	Estimated number collected	Number with constant efficiency	Number examined	Estimated number collected	Number with constant efficiency
1	L-0-A	603	675	892	533	1213	1699
2	S-0-A	848	923	1189	485	1089	1514
3	L-0-A	431	468	892	70	203	398
4	S-0-M	569	665	1276	95	329	648
5	L-3-A	782	911	1283	664	1634	2506
6	S-3-A	522	635	902	279	648	1007
7	L-0'-M	554	638	1214	190	540	1058
8	S-0'-M	376	426	810	54	206	413
9	L-6-A	682	778	1103	467	1119	1737
10	S-6-A	396	500	763	289	544	883
11	L-6-M	298	315	574	168	280	501
12	S-6-M	429	476	852	251	381	671
13	L-13-M'	367	367	620	267	282	443

[a/] Refer to Table 1 for full descriptions of test groups if needed.

Analysis of the Recapture Data

Before we could make valid comparisons between groups, the number of branded fish we examined from each test group had to be adjusted for the following factors: (1) unequal sampling from raceways, (2) variable collection efficiency at the dams due to fluctuation in river discharge, and (3) unequal numbers released in each group.

NMFS personnel kept daily records of the number of fish entering the raceways and the number they moved into the marking house for examination. With this data we could estimate the total number of branded fish collected at Lower Granite Dam on a daily basis (Table 4). At Little Goose Dam we estimated the total number of marked fish collected at that facility by multiplying the number of marked fish we examined by an expansion factor developed by NMFS personnel.

The smolt migration season in 1976 extended from mid-April to mid-June. During that period, discharge from turbines at Snake River dams was relatively constant while discharge over spillways was governed by total river discharge and fluctuated significantly during the migration season (Fig. 2). With increased discharge over spillways, a larger proportion of migrating fish passed the dams over the spillways and a smaller proportion passed through the turbine intake collection system.

We adjusted the estimated number of marked fish collected at each dam for the variable percentage passing through the turbine collection system by: (1) multiplying the daily number collected by a factor related to river discharge, or (2) by collection efficiency rates based on the NMFS mark-recapture data for

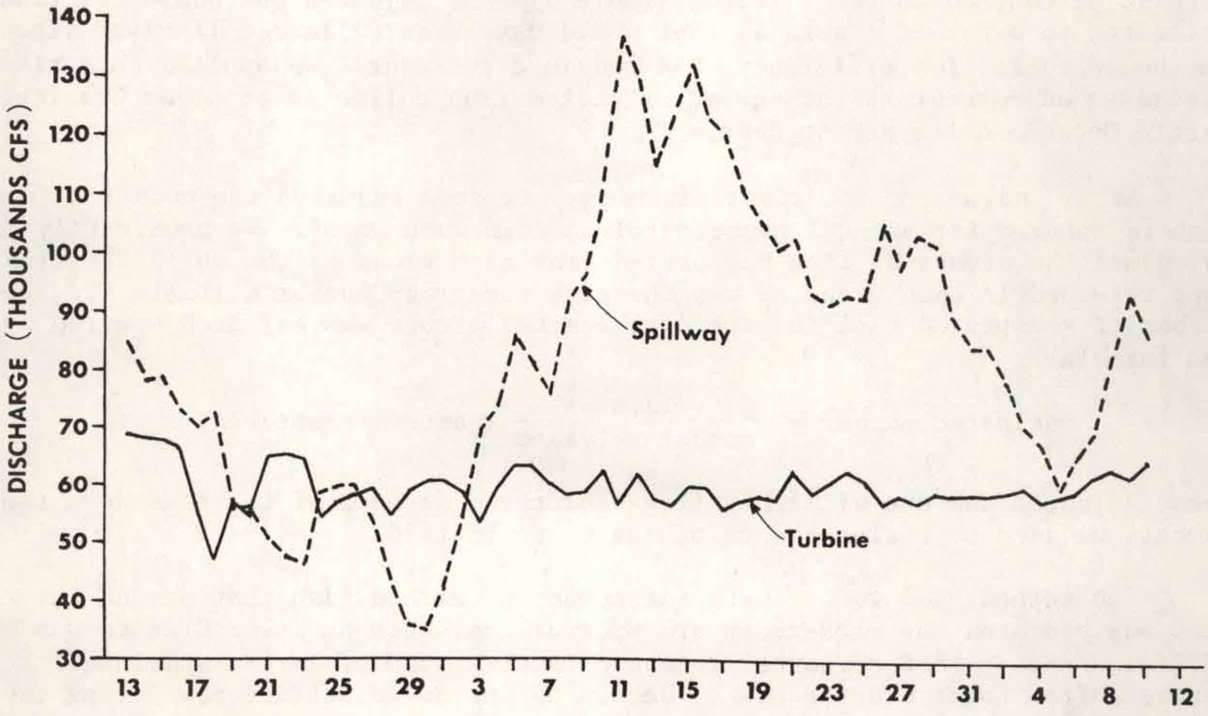

Figure 2. Turbine and spillway discharge at Lower Granite Dam on Snake River, 1976.

Lower Granite Dam. The first method did not allow us to estimate the percentage of DNFH fish that passed the dams, but provided the best data for comparisons between groups of the relative number recaptured and the timing of migration. The second method allowed us to estimate the number of DNFH marked fish that passed the dams, but we believe the estimates were less useful for comparison between groups than the first method because of inherent assumptions of the method.

With the first method, the number of marked fish collected each day was adjusted for variations in river discharge with a river discharge-collection efficiency curve developed by Raymond, et al. (1975). As river discharge increased (more water over the spillways relative to the turbines) a decreasing percentage of the marked fish released upstream from Ice Harbor Dam were recaptured. The equation, $Y = 359.3/(X-12.8)$, described the relationship between discharge and percentage of fish captured at Ice Harbor Dam and we have assumed that similar relationships between river discharge and fish collection efficiency existed at other lower Snake River dams because of similarity in design and each had three operating turbines.

Using the equation from Ice Harbor data, we calculated percentage recovery rates (Y) for each day of the migration season in 1976 with river discharge as the X value in the equation. We then divided each of these percentages by the largest percentage to get a factor (Table 5) that adjusted the number of fish collected to a number (Table 4) that would have been collected if river discharge, and hence collection efficiency, had remained constant. We applied this river discharge adjustment to the number of marked fish collected at Lower Granite, Little Goose and Ice Harbor dams.

After adjusting for river discharge, we then adjusted the number of marked fish recaptured for unequal numbers released in each group. We arbitrarily chose to adjust the number of fish recaptured from each group as though 17,888 fish had been released in each group as was the case for group number 4 (Table 6). The number of recaptured fish in each of the other groups was adjusted upwards by the formula:

$$\text{Adjusted number} = \frac{17{,}888}{\text{number released}} \text{(number recaptured)}$$

These adjusted numbers of marked fish recaptured at each of the dams were the numbers we used to evaluate each of the tests in 1976.

The method used to estimate the number of marked fish that passed the dams was based on the mark-recapture program conducted at Lower Granite Dam by NMFS personnel. NMFS personnel released three groups of marked steelhead trout upstream from Lower Granite Dam to determine collection efficiency during the 1976 migration season. The first group of 7,923 steelhead trout smolts was collected, marked and released between April 13 and 24, the second group of 32,769 fish between April 28 and May 14 and the third group of 10,295 fish between May 17 and 24. Fish from all three of these groups were recaptured throughout the remainder of the migration season at Lower Granite Dam, but most were recaptured within the release period plus 8 days (Fig. 3). The timing of release and recapture of the three marked groups roughly coincided with the period of low discharges in the early part of the migration season, the period with peak discharges during the middle of the season, and the latter part of the season with intermediate discharges (Fig. 2).

Table 5. Snake River discharge at Lower Granite Dam in 1976 and marked fish recovery factors (from Raymond et al. 1975 for Ice Harbor Dam) for each day.

Date	Discharge	Factor	Date	Discharge	Factor
April 13	153,800	2.55	May 12	191,400	2.01
14	146,700	2.68	13	172,500	2.25
15	146,700	2.68	14	179,900	2.15
16	139,100	2.84	15	191,700	2.01
17	125,200	3.20	16	182,100	2.12
18	120,100	3.35	17	175,400	2.21
19	114,100	3.55	18	168,300	2.31
20	112,400	3.61	19	163,900	2.38
21	115,800	3.49	20	158,300	2.47
22	112,900	3.59	21	164,700	2.37
23	110,700	3.67	22	151,900	2.58
24	113,400	3.57	23	150,500	2.61
25	117,700	3.43	24	155,400	2.52
26	117,100	3.44	25	153,500	2.55
27	113,200	3.58	26	162,400	2.40
28	110,300	3.69	27	156,200	2.51
29	94,800	4.38	28	160,500	2.43
30	95,400	4.35	29	159,700	2.45
May 1	102,400	4.01	30	147,200	2.67
2	113,300	3.58	31	142,800	2.76
3	123,600	3.24	June 1	142,100	2.78
4	133,900	2.97	2	137,000	2.89
5	148,200	2.65	3	130,300	3.06
6	144,200	2.73	4	125,000	3.20
7	136,100	2.91	5	118,100	3.41
8	149,900	2.62	6	123,900	3.23
9	155,600	2.52	7	131,200	3.03
10	173,900	2.23	8	145,800	2.70
11	192,800	2.00	9	155,700	2.51
			10	150,500	2.61

Using the NMFS mark-recapture data, we calculated recapture percentages (collection efficiencies) for a 3 time periods (April 13-May 2, May 3-May 20, and May 21-June 8) that corresponded with periods of low, peak, and intermediate discharges (Fig. 2) and the periods of release and recapture of the three marked fish groups (Fig. 3). Fish of the first release group were recaptured during all three time periods, but were not recaptured during the second and third time periods at the same rate as during the first time period because of the changes in river discharge.

To determine the recapture rate during each of the three time periods, we used the fish recaptured during the release period plus 8 days for the first and second release groups, and all the fish recaptured from the third group. Fish of the first group recaptured after the first time period and fish of the second group recaptured after the second time period were not used to calculate recapture rates. The number of fish released had to be adjusted downward for fish that did not migrate back down to the dam until after the time period in which each group was released.

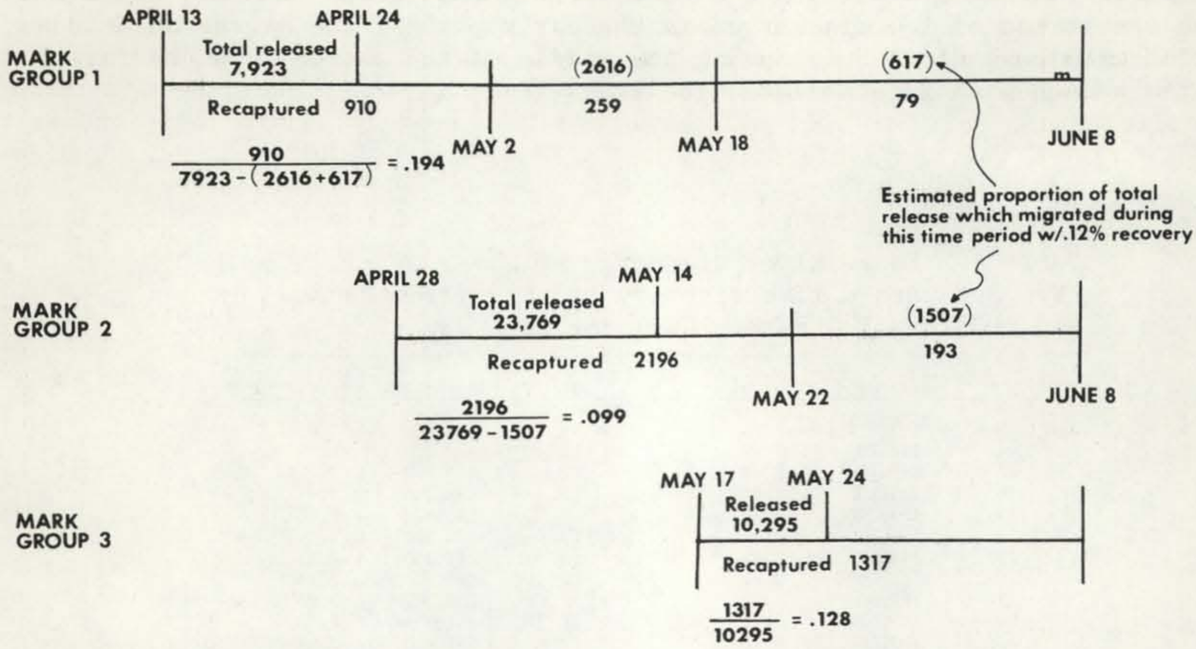

Figure 3. Timing of marked steelhead smolt releases and recovery at Lower Granite Dam by NMFS personnel in 1976 and proportion recovered for each period of the migration season. Assumes all marked fish returned to the dam.

We worked backwards timewise in calculating recapture rates because the third group of fish did not have to be adjusted for later time periods. Of the 10,295 fish of the third group released during the third time period, 1,317 were recaptured for a recapture rate of 12.8 percent (Fig. 3).

To calculate recapture rate for the second time period, we subtracted from the second release group the estimated number of fish that migrated downstream during the third time period. During the third time period, 193 marked fish of the second group were recaptured and assuming a 12.8 percent recapture rate for those fish, an estimated 1,507 of the 23,769 fish released in the second group did not migrate back down to the dam until the third time period. The recapture rate for the second time period was then estimated to be 9.9 percent (Fig. 3):

$$0.999 = \frac{\text{fish recaptured} = 2{,}196}{\text{fish released} = 23{,}769 - 1{,}507}$$

Using the same logic for the first group of fish released, the recapture rate for the first time period was 19.4 percent (Fig. 3):

$$0.194 = \frac{\text{fish recaptured} = 910}{\text{fish released} = 7{,}923 - (2{,}616 + 617)}$$

The recapture rates listed for each time period in Fig. 3 are based on the assumption that all marked fish returned to the dam. On the basis of other work (Chrisp and Bjornn 1978; Wagner[1], personal communication), we suspect that some of the smolts hauled back upstream and released did not return back to Lower Granite Dam. If 80 percent of the marked fish returned to the dam, rather than 100 percent, the recapture rates for the three time periods would have been 24, 12, and 16 percent, respectively, rather than 19, 10, and 13 percent. By assuming that all marked fish return to the dam, we are probably overestimating the number of marked fish from any marked group that passed the dam.

Using the recapture rates for each of the three time periods, we estimated the number of marked fish from DNFH that passed Lower Granite Dam during 1976. The estimated number of fish collected in the trapping facility during each time period was multiplied by the ratio: 100/percentage recapture rate.

RESULTS

Fish of the test groups were recovered at each of the dams in a consistent pattern (Fig. 4). Groups with the largest or smallest number of recaptures at the upper dams were recaptured at about the same relative abundance at the downstream dams, even though the absolute number recaptured varied at each dam. When the number of fish of each group recaptured at Lower Granite and Little Goose dams was adjusted for changes in collection efficiency and for unequal numbers released, the differences in recapture between groups were more pronounced at Little Goose Dam than at Lower Granite (Table 6, Fig. 5). We believe many smolts in the less fit groups did not migrate the additional distance down to Little Goose Dam.

All age I test groups were started in system II and their health was impaired to a variable degree because the biofilter did not function properly. Groups of fish with extended periods of cold water conditioning were moved from system II (reuse water) to system I (untreated river water) in early March and early April while the other groups remained in system II or were transferred to system III (reuse water) until release.

Our first task in evaluating the recapture data was to determine if significant differences in health existed between the test groups, and if so, did the differences in health mask differences expected from the test conditions? Clinical examination of some test groups before release from the hatchery did not reveal any major differences in health with all groups having a low incidence of fungus infection (less than 2%) when released. Fish transferred to system I (untreated river water) prior to release appeared to be in slightly better health than those kept in system II (reuse water), but we did not have any quantitative assessment from the laboratory examinations.

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[1] Harry H. Wagner, Oregon Department of Fish & Wildlife, Corvallis, Oregon

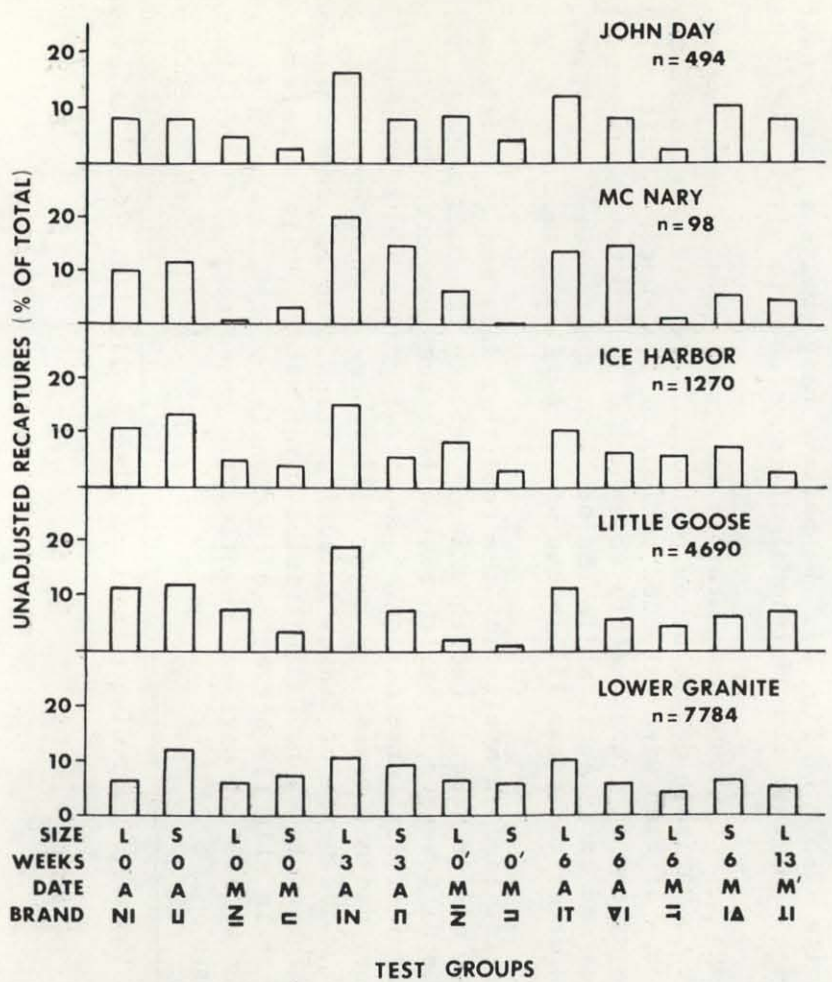

Figure 4. Relative abundance of DNFH steelhead trout of each test group recaptured at each dam by NMFS personnel in 1976, expressed as percentage of total recaptures at each dam. Recaptures adjusted only for sampling at each dam; not for collection efficiency or number released.

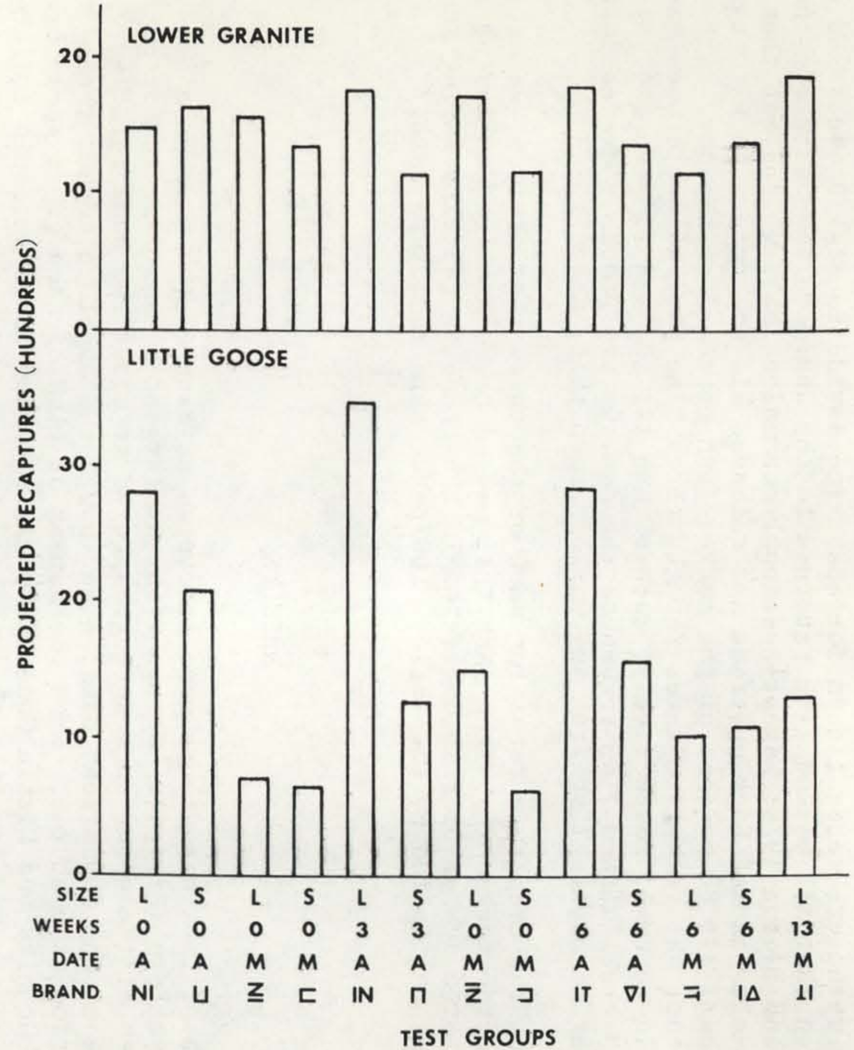

Figure 5. Projected recaptures of each test group of DNFH steelhead trout at Lower Granite and Little Goose dams in 1976 adjusted for sampling at the dam, collection efficiency and number released.

Table 6. Projected number of marked DNFH steelhead trout which would have been collected at Lower Granite and Little Goose dams in 1976 with constant collection efficiency and when adjusted as if 17,888 marked fish had been released in each group.

Group number	Abbreviated descriptions[a/]	Number released	Projected recaptures-Lower Granite W/constant efficiency	Projected recaptures-Lower Granite W/17,888 fish released	Projected recaptures-Little Goose W/constant efficiency	Projected recaptures-Little Goose W/17,888 fish released
1	L-0-A	10864	892	1468	1699	2797
2	S-0-A	13149	1189	1618	1514	2060
3	L-0-M	10164	892	1570	398	700
4	S-0-M	17888	1276	1276	648	648
5	L-3-A	12955	1283	1772	2506	3460
6	S-3-A	14227	902	1134	1007	1266
7	L-0'-M	12685	1214	1712	1058	1492
8	S-0'-M	12214	810	1186	413	605
9	L-6-A	10989	1103	1795	1737	2828
10	S-6-A	10055	763	1357	883	1571
11	L-6-M	8880	574	1156	501	1009
12	S-6-M	10948	852	1392	671	1096
13	L-13-M'	6004	620	1847	443	1320

[a/] Refer to Table 1 for full descriptions of test groups if needed.

Theoretically, groups of fish with higher mortalities, particularly during the last few weeks before release, should have been the least healthy fish. Fish in system II had a higher daily mortality rate than fish in either system I or III (Fig. 6). The test groups of fish released May 5 with 0 weeks of cold water conditioning and those released April 14 with 6 weeks of conditioning had relatively high daily mortality rates just before release (Fig. 6).

Test groups of large sized fish with the highest mortalities in the ponds before release had the smallest number of recaptures at the dams (Figs. 7 and 8). An inverse relationship between the number of recaptures at the dams and mortality in the ponds was consistent for all the test groups of large sized fish, but was confounded and weakened by other factors such as length variations between the groups and date of release. No such inverse relationship was evident for the test groups of small sized fish.

Another potential index of fish health was the incidence of fungus infection on fish of the test groups when recaptured at the dams. The incidence of fungus infection was not correlated with mortality in the hatchery ponds (Fig. 9), or with the number of recaptures at either dam (Fig. 10).

After evaluating mortaltiy of fish in hatchery ponds, incidence of fungus infection, and number of fish recaptured, we concluded that differences between groups in the number of fish recaptured were primarily the result of differences

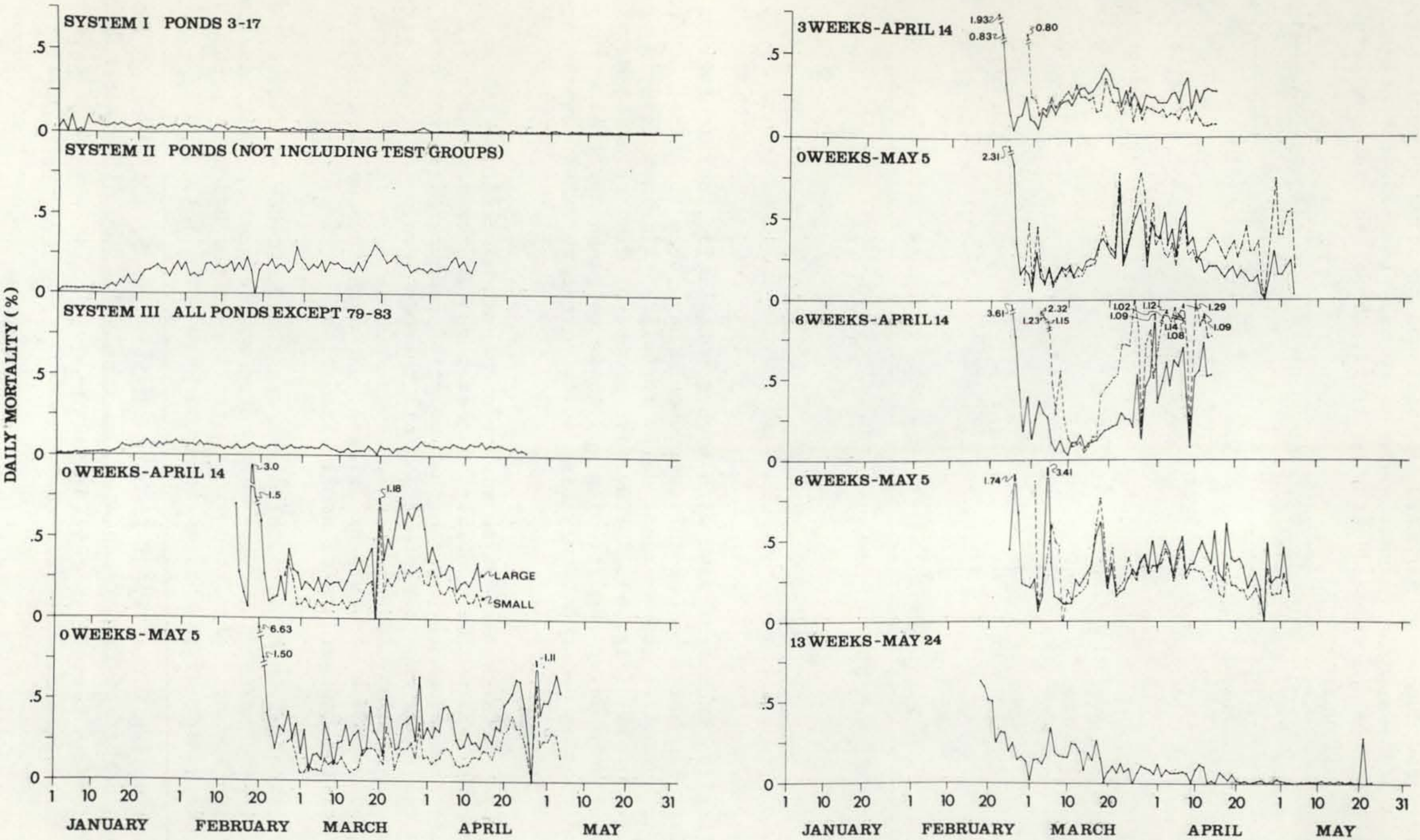

Figure 6. Daily mortality rate (percentage of fish in pond) of steelhead trout at DNFH starting in January for the three systems and when marked for the test groups. Weeks refers to weeks of cold water conditioning, date to date of release and large or small to length at release (refer to Table 1 for complete description of groups).

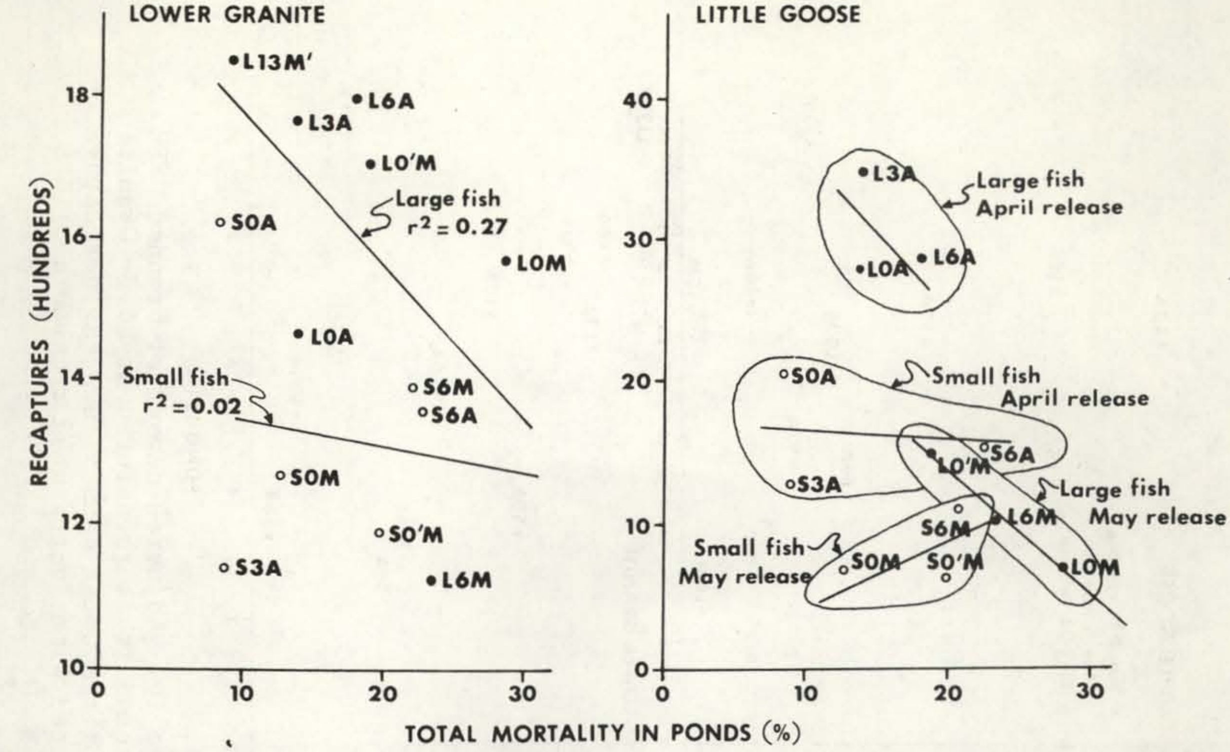

Figure 7. Percentage mortality of fish of each test group between marking and release and the projected number of recaptures at Lower Granite and Little Goose dams, 1976. The encircled data points are test groups of similar size and date of release. Refer to Table 1 for explanation of abbreviated descriptions.

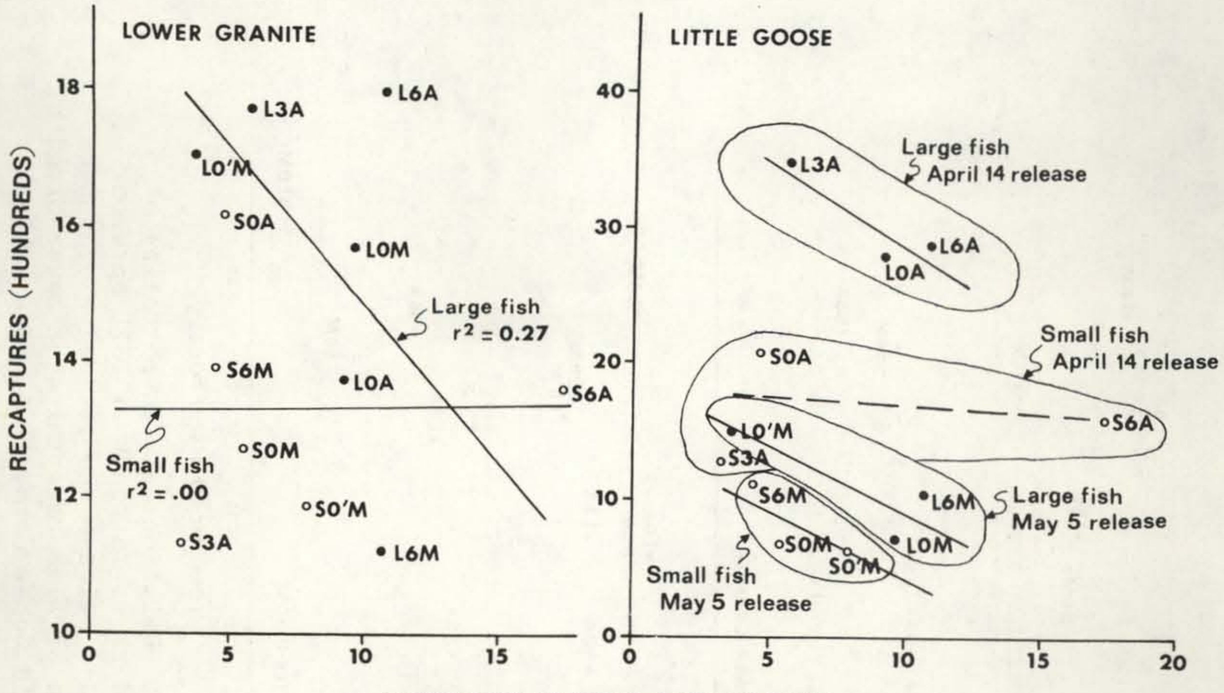

Figure 8. Percentage mortality of steelhead trout of each group the last 23 days before release from DNFH and the projected recaptures at Lower Granite and Little Goose dams, 1976. Encircled data points are test groups of similar size and date of release. Refer to Table 1 for explanation of abbreviated descriptions.

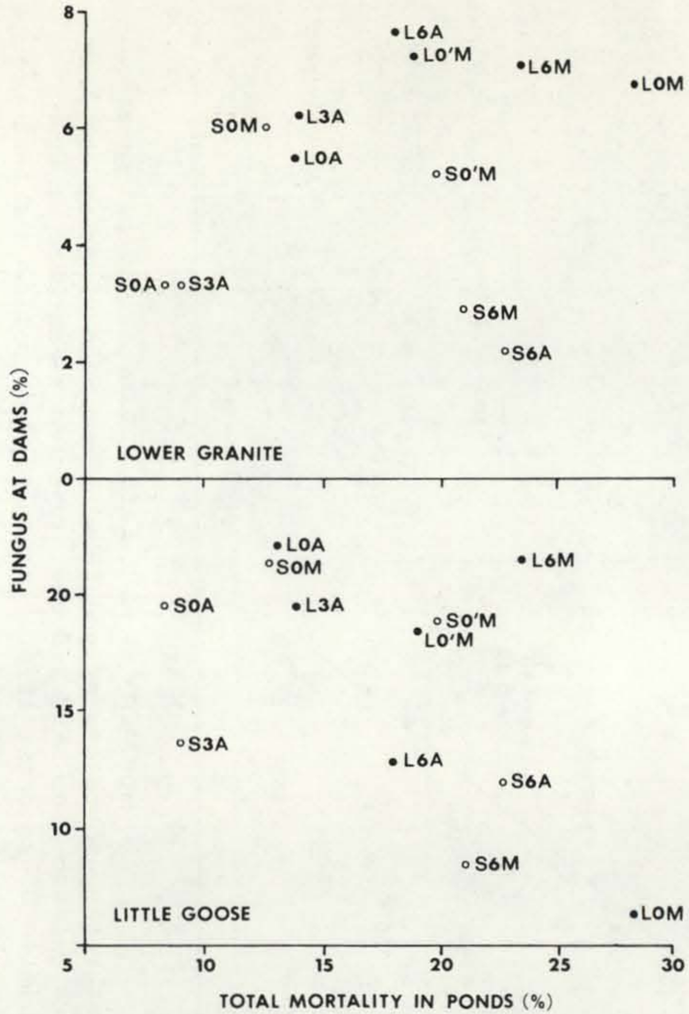

Figure 9. Relation between mortality of steelhead trout in ponds at DNFH between marking and release and incidence of fungus infection of fish recaptures at Lower Granite and Little Goose dams, 1976. See Table 1 for explanation of abbreviated descriptions.

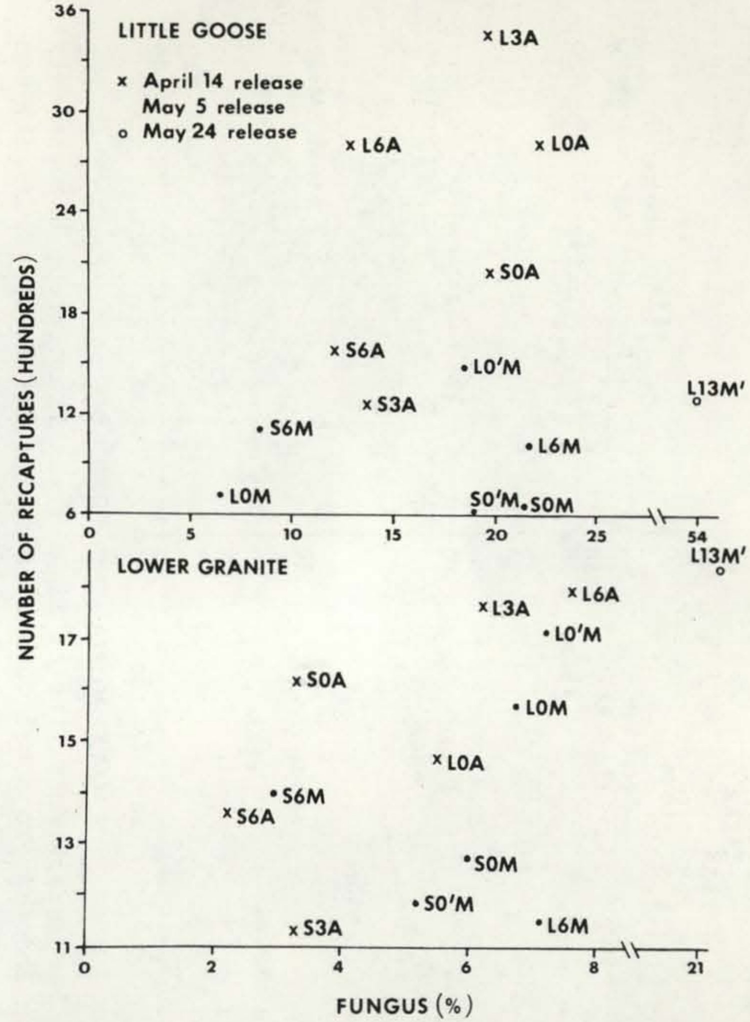

Figure 10. Adjusted number of branded DNFH steelhead trout recaptured at Lower Granite and Little Goose dams versus the percentage infected with fungus when recaptured, 1976.

in length at release and date of release (Table 7). Large sized fish had mortalities in the ponds and fungus infection rates similar to those of small sized fish, but more of the large sized fish were recaptured at the dams. The difference in number of fish recaptured between groups of large sized and small sized fish, released on the same date, reflects the effect of length on successful parr-smolt transformation. The differences in number of fish recaptured from groups released April 14 and those released May 5 may have been caused by the following:

1. The fish released May 5 may have been released too near the peak of migration and many of the fish may not have had sufficient time to migrate before the river warmed and they reverted to parr.

2. Although not strongly supported by the pond mortality and fungus infection data, the fish released May 5 may have been less healthy because of their longer stay in the reuse water systems.

3. The longer retention in the hatchery of fish released May 5 may have made them less fit because confinement of migrating smolts or smolts ready to migrate seems to be stressful. Wild and hatchery smolts deteriorate in health when captured during seaward migration and held in raceways.

Table 7. Mortality of steelhead trout in ponds at DNFH for the last 23 days before release and for the total time since marking, the percentage of fish observed at the dams with fungus infection, and the number of fish recaptured at the dams adjusted for sample taken at the dams, flows in river (percentage fish entering collection facility) and number released in each group, 1976.

Date of release	Size of fish	Weeks of conditioning	Mortality in ponds (%)				Fungus at dams (% of fish examined)				Recaptures at dams			
			Since marking	Mean	Last 23 days	Mean	Lower Granite	Mean	Little Goose	Mean	Lower Granite	Mean	Little Goose	Mean
Apr 14	Large	0	13.9		9.1		5.5		22.1		1468		2797	
		3	13.9	15.3	5.6	8.4	6.2	6.4	19.6	18.2	1772	1678	3460	3028
		6	18.0		10.4		7.6		12.8		1795		2828	
	Small	0	8.2		4.6		3.3		19.7		1618		2060	
		3	8.9	13.3	3.2	8.3	3.3	2.9	13.8	15.1	1134	1370	1266	1632
		6	22.7		17.2		2.2		11.9		1357		1571	
May 5	Large	0	28.1		9.5		6.7		6.3		1570		700	
		0	18.9	23.4	3.6	7.9	7.2	7.0	18.5	15.4	1712	1462	1492	1067
		6	23.2		10.7		7.1		21.5		1104		1009	
	Small	0	12.7		5.3		6.0		21.3		1276		648	
		0	19.9	17.9	7.9	5.9	5.2	4.7	18.9	16.2	1186	1284	605	783
		6	21.0		4.4		2.9		8.4		1392		1096	
May 24	Large	13	9.1		0.4		21.3		53.9		1847	1847	1320	1320

Length at Release

Length of the fish when released in 1976 was an important factor regulating the number of DNFH steelhead trout that became smolts and migrated to the sea. The number of DNFH steelhead recaptured at Lower Granite Dam was correlated ($r = 0.66$) with mean length of the fish in each group when released (Fig. 11). No correlation existed between length at release and fish recaptured at Little Goose Dam when all groups were combined, but when separated into April versus May releases, strong correlations existed, especially for the fish released in April ($r = 0.98$; Fig. 11).

Using the regression line for fish released in April and recaptured at Little Goose Dam (Fig. 11), we would expect to recapture 1,880 fish if they were 175 mm in length when released compared to 3,370 fish that were 200 mm. For fish released in May and recaptured at Little Goose Dam, we would expect to recapture 680 of the 175 mm fish versus 1,217 of the 200 mm fish. Using the regression line for all fish released and recaptured at Lower Granite Dam, we would expect to recapture 1,320 of the 175 mm fish and 1,683 of the 200 mm fish.

The importance of length at release was clearly evident in the number of fish from each group that were recaptured at the dams (Fig. 11), and also in the length-frequencies of the fish in some groups when released and when recaptured at the dams (Fig. 12). The length-frequency curves for the fish when released were usually to the left of the curves for recaptured fish, and mean lengths of fish recaptured at the dams were longer than lengths of each group when released, in most cases (Table 8). Fish recaptured at dams averaged as much as 10.9 mm longer than the fish released. The longer mean length of fish recaptured at the dams was a result of: (1) many of the smaller fish failing to become smolts, and (2) growth of the fish while in the rivers and reservoirs.

The fish tagged with mandible tags at the hatchery and recaptured later at the dams provided a minimum estimate of growth while the fish were migrating downstream (Fig. 13). The tagged fish grew an average of about 0.2 mm per day between the dates of release from the hatchery and recapture at the dams.

The number of days from date of release for 50 percent of the migrants from each group to pass Little Goose Dam ranged from 10 to 24 days (Table 8). For some groups, therefore, most of the difference in mean length between fish at release and those recaptured could have been growth after leaving the hatchery. In some cases, however, the length differences were large (groups 1 and 2; Table 8) and the time between release and passage at the dams relatively short (14 days) and thus most of the length difference was a result of more of the larger fish becoming smolts and migrating past the dams.

The mean length of recaptured DNFH steelhead trout was longer at each succeeding downstream dam (Fig. 14). Fish from both the large and small size groups recaptured at Ice Harbor Dam averaged about 10 mm longer than those

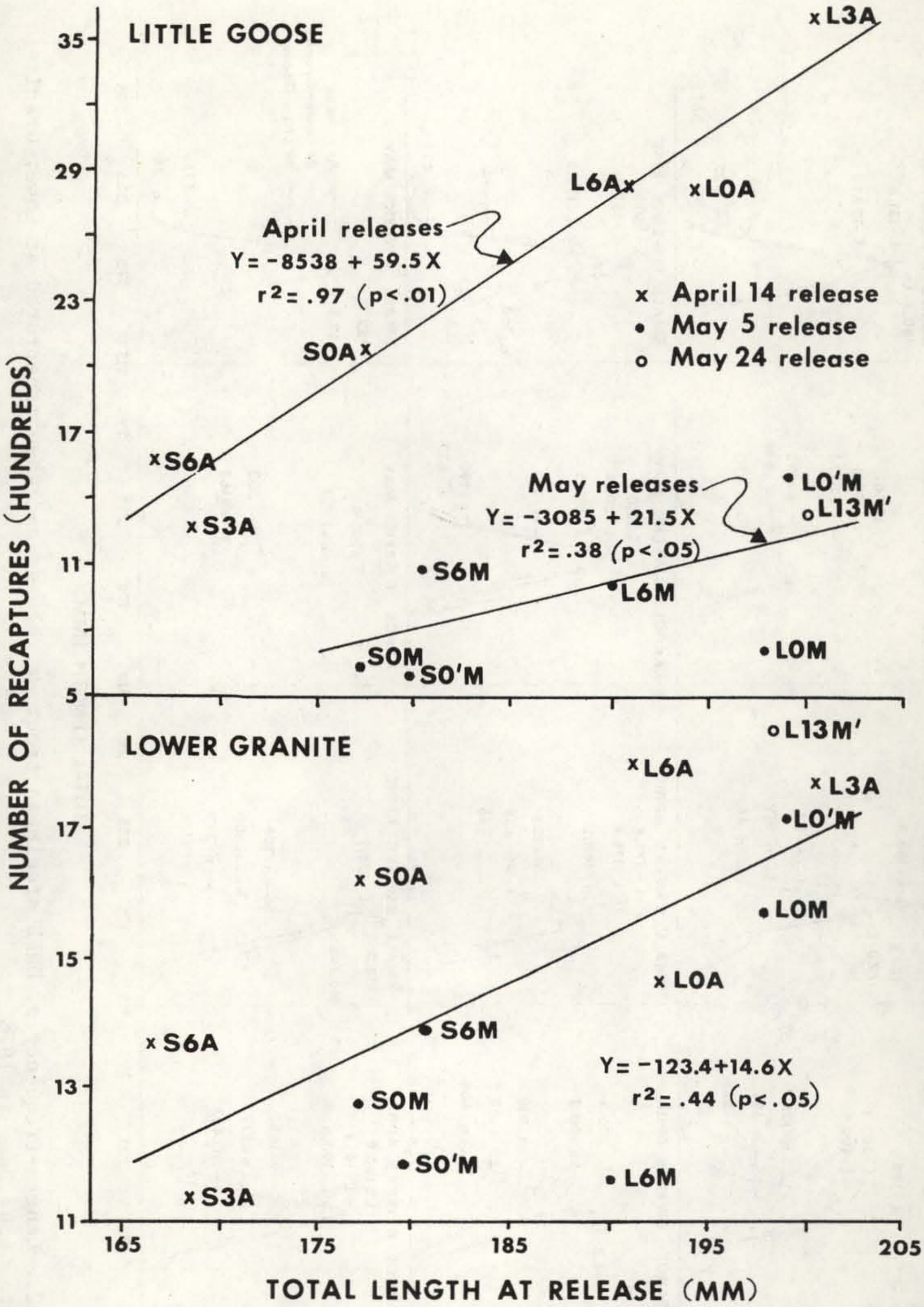

Figure 11. Adjusted number of branded DNFH steelhead trout recaptured at Lower Granite and Little Goose dams versus length at release, 1976.

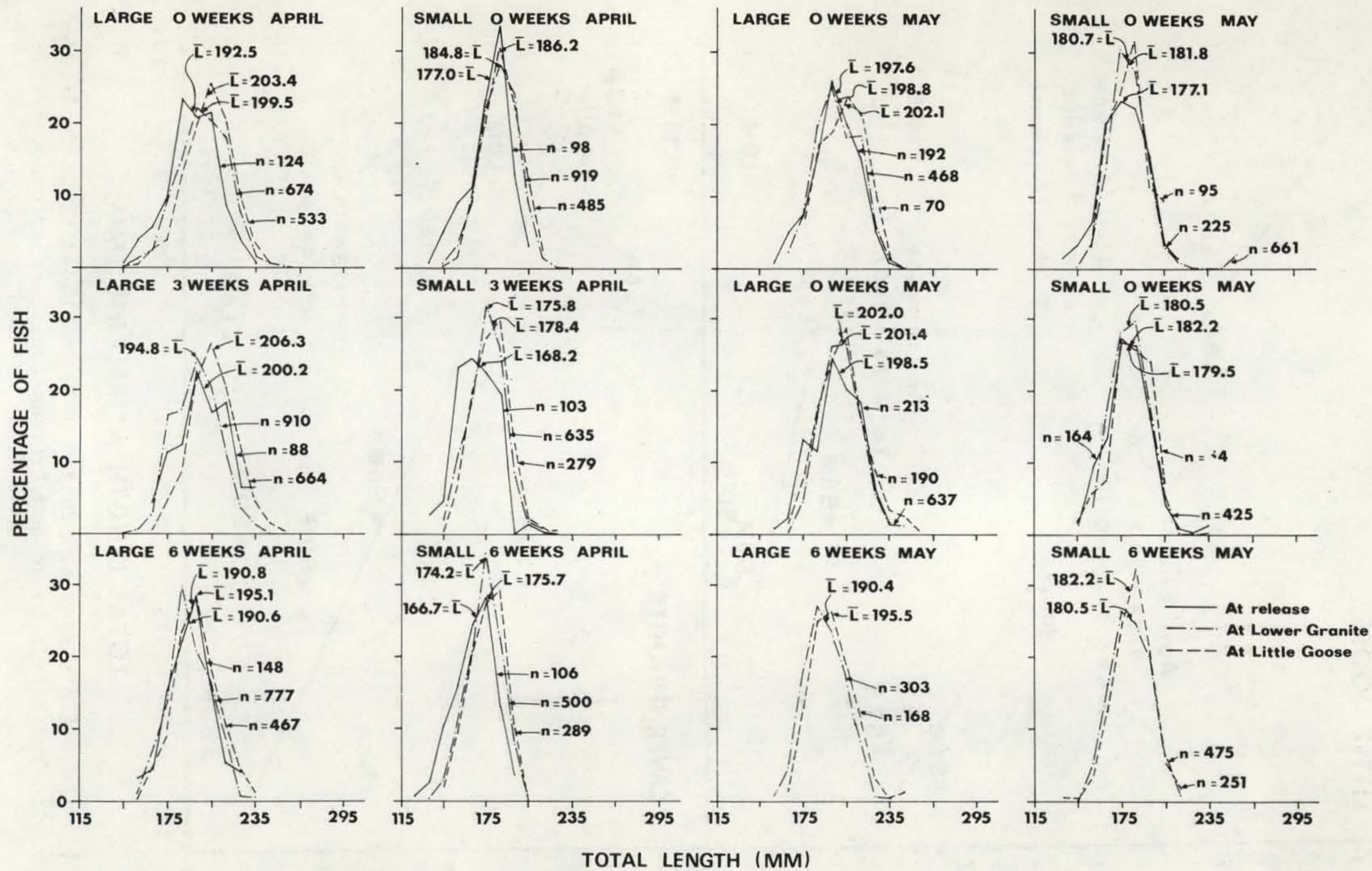

Figure 12. Length-frequency of DNFH steelhead trout at release and when recaptured at Lower Granite and Little Goose dams in 1976.

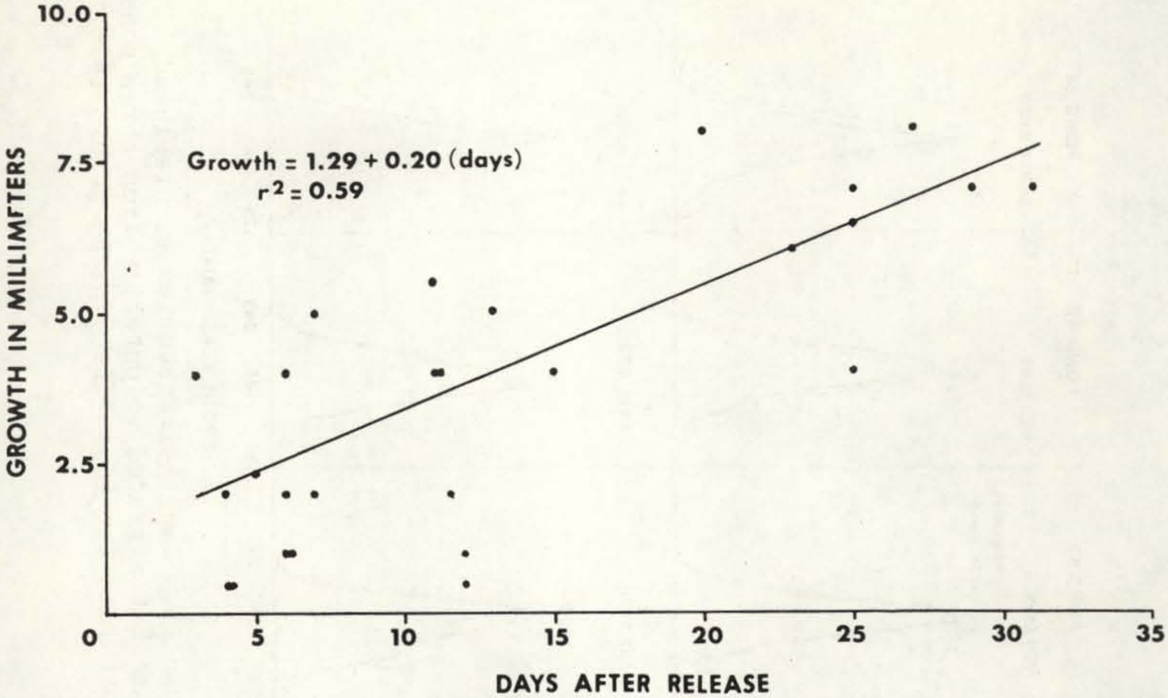

Figure 13. Growth of jaw-tagged steelhead trout smolts released from DNFH and recaptured at Lower Granite and Little Goose dams, 1976.

Table 8. The mean lengths of DNFH steelhead trout at release and when recaptured at Lower Granite and Little Goose dams in 1976, and the number of days from release until 50 percent of the migrants had passed each dam.

Group number	Abbreviated description[a]	At release: Number in sample	At release: Mean length (mm)	At Lower Granite Dam: Number in sample	At Lower Granite Dam: Mean length (mm)	At Lower Granite Dam: Migration days	At Little Goose Dam: Number in sample	At Little Goose Dam: Mean length (mm)	At Little Goose Dam: Migration days
1	L-O-A	124	192.5	675	199.5	11	533	203.4	14
2	S-O-A	98	177.1	923	184.8	13	485	186.2	14
3	L-O-M	192	197.7	468	198.9	5	70	202.1	12
4	S-O-M	225	177.1	665	181.9	6	95	180.7	10
5	L-3-A	88	200.2	911	194.8	16	664	206.3	18
6	S-3-A	103	168.2	635	175.8	17	279	178.3	21
7	L-O'-M	213	198.5	638	201.4	7	169	201.9	12
8	S-O'-M	164	179.5	426	180.5	6	54	182.2	10
9	L-6-A	148	190.8	778	190.6	15	467	195.1	23
10	S-6-A	106	166.7	500	174.2	27	289	175.7	44
11	L-6-M	---	≈190.4[b]	303	190.4	14	168	195.5	28
12	S-6-M	---	≈180.5[b]	476	180.5	15	251	182.2	28
13	L-13-M'	235	199.9	367	200.4	4	267	201.5	10

[a]See Table 1 for full description of test groups.

[b]Estimated from mortalities.

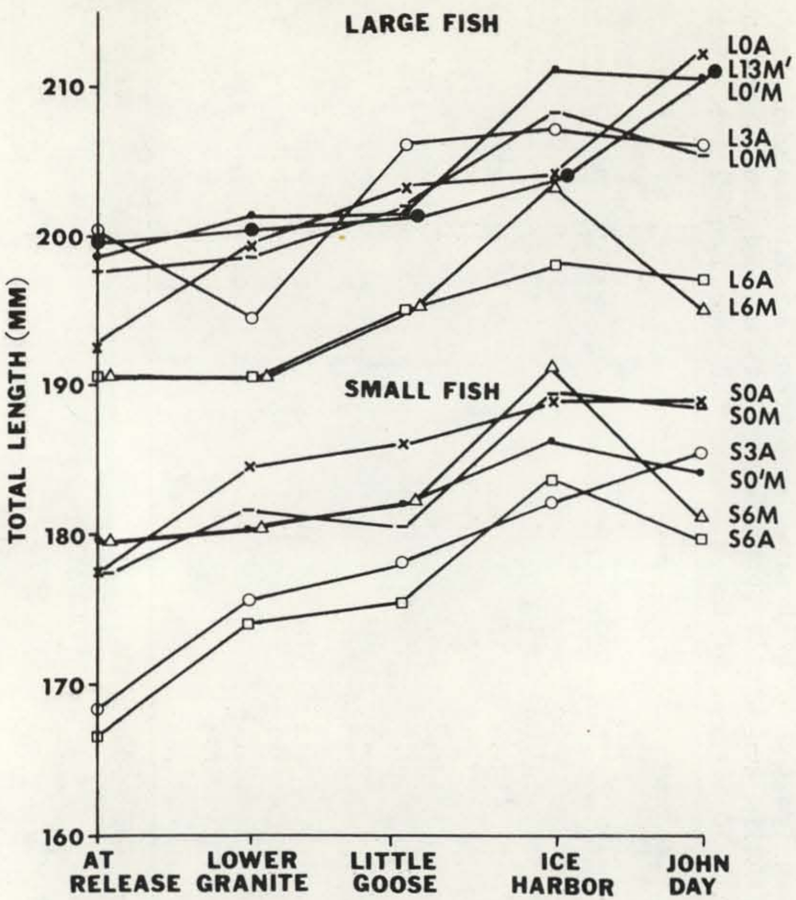

Figure 14. Mean length of marked steelhead trout released from DNFH when recaptured at dams on the Snake and Columbia rivers, 1976.

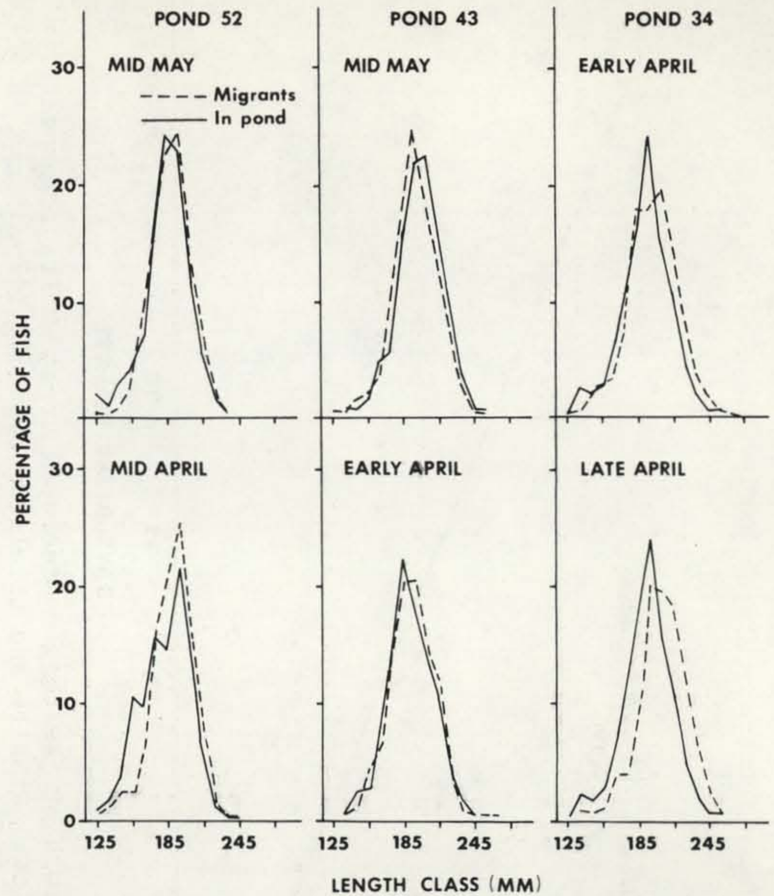

Figure 15. Length-frequencies of steelhead trout that migrated voluntarily from three ponds at DNFH and for those fish in the ponds, 1976.

released. Growth while migrating to Ice Harbor Dam might have accounted for half the length difference, but the other half is likely the result of small fish failing to migrate seaward.

The differences between length-frequencies of fish migrating voluntarily from hatchery ponds 34, 43, and 52 versus those of all fish in the ponds provided some additional evidence that length was an important factor in seaward migration (Fig. 15). The frequency curves for the migrants were usually a little to the right of the curve for fish in the pond, an indication that the larger fish were the ones migrating from the ponds.

Jaw-tagged fish that migrated from the sluiceway (or ponds 49 and 41 after the fish were transferred from the sluiceway) differed only slightly in length from all fish released into the sluiceway (Fig. 16). Because three of the four groups released into the sluiceway were relatively large age II fish, we expected most of those fish to migrate, including the smaller fish.

Another measure of the importance of length of hatchery steelhead trout in controlling seaward migration was the percentage of jaw-tagged fish in each 10 mm length group that voluntarily migrated from the sluiceway (Fig. 17). For age I fish placed in the sluiceway March 31, nearly equal and relatively high percentages of the fish in the 160-169 mm and larger classes migrated, whereas, smaller percentages of the fish in the smaller length classes migrated. For age II fish, the pattern was similar for all three groups; smaller fish in the groups (180-199 mm) migrated best and progressively fewer migrants from the larger fish.

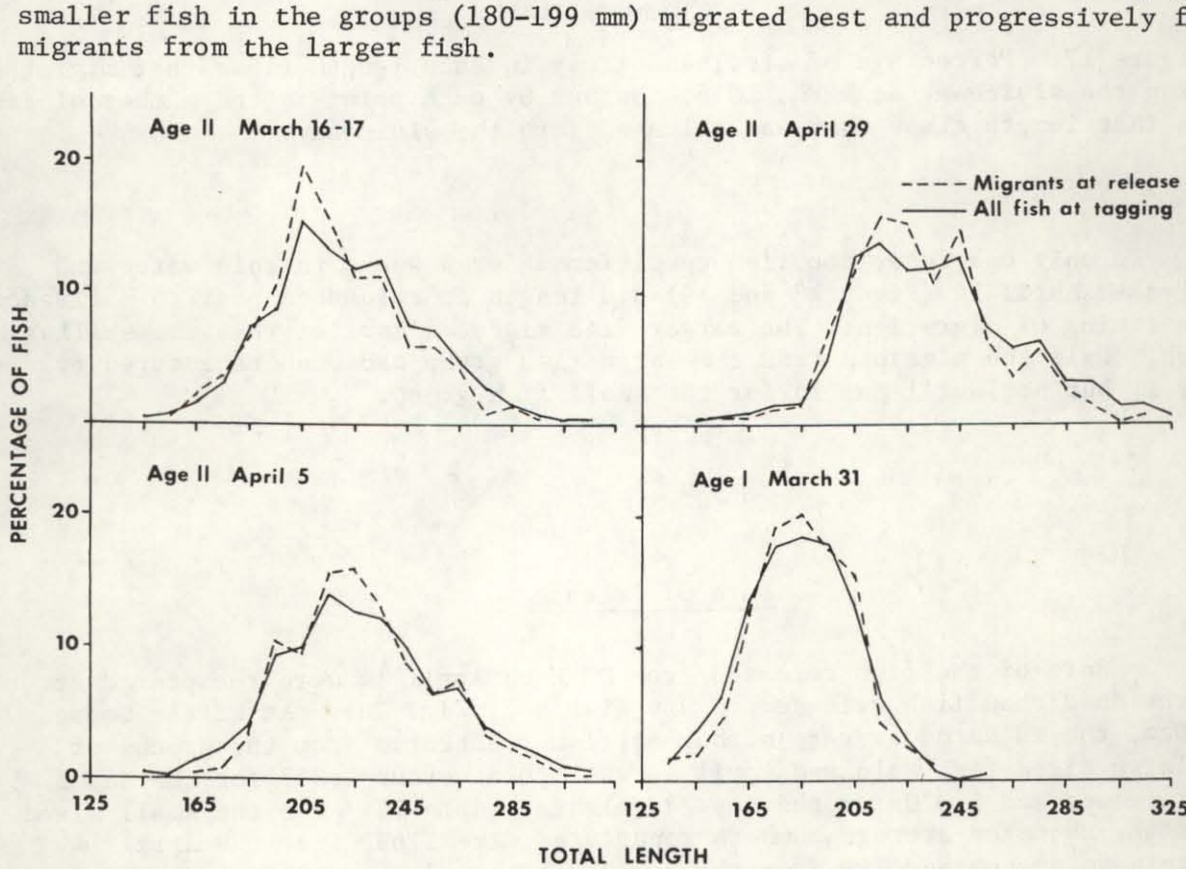

Figure 16. Length-frequency of steelhead trout tagged and released into the sluiceway at DNFH and of the migrants when released into the sluiceway, 1976.

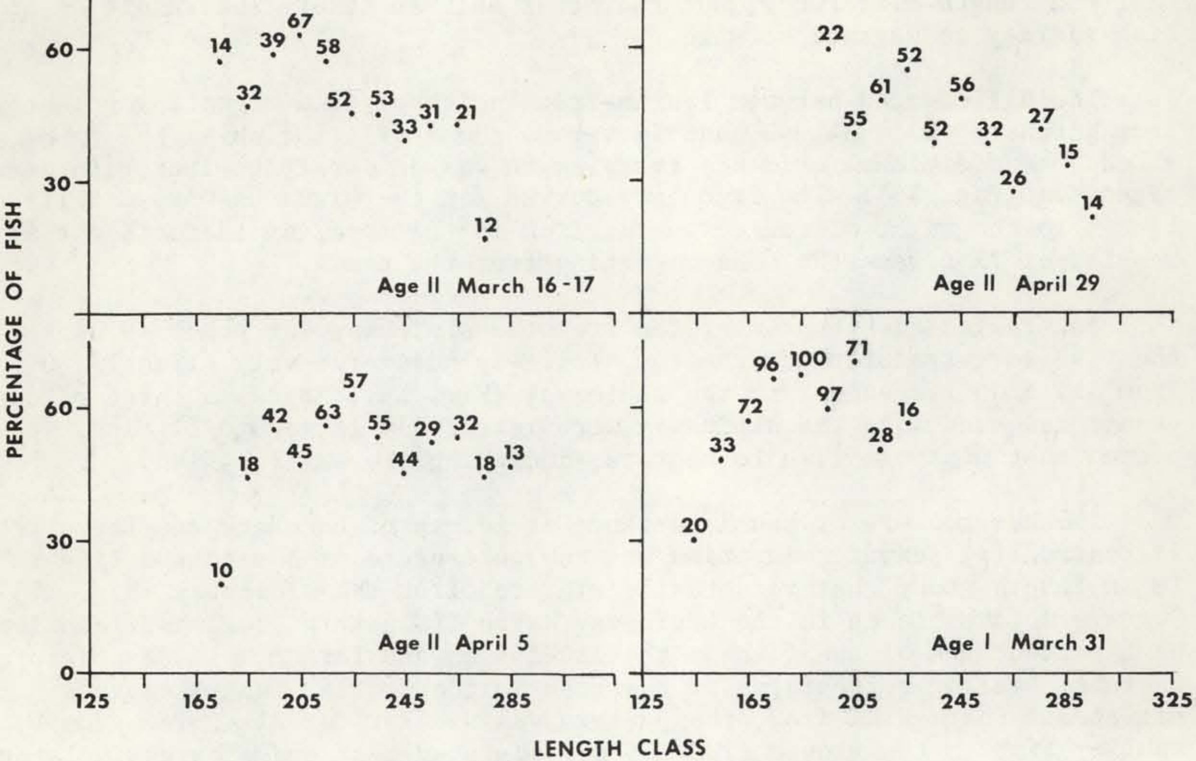

Figure 17. Percentage of steelhead trout in each length class that migrated from the sluiceway at DNFH, 1976. Number by each point is the number of fish in that length class that was released into the sluiceway.

In only one case, the fish conditioned for 6 weeks in cold water and released April 14 (Figs. 18 and 19) did length at release appear to influence the timing of migration. The larger fish migrated earlier than the smaller fish. Half the migrants from the large fish group had been recaptured by May 1, but not until May 15 for the small fish group.

Date of Release

More of the fish released from DNFH on April 14 were recaptured at the dams than fish released in May (Table 7; Fig. 20). At Little Goose Dam, the adjusted average number of fish recaptured from the groups of large sized fish released April 14 was 3,028 versus 1,067 for the May 5 releases and 1,320 for the May 24 release (Table 7). For the small sized fish, adjusted average numbers recaptured were 1,632 from the April 14 release groups and 783 from the May 5 releases.

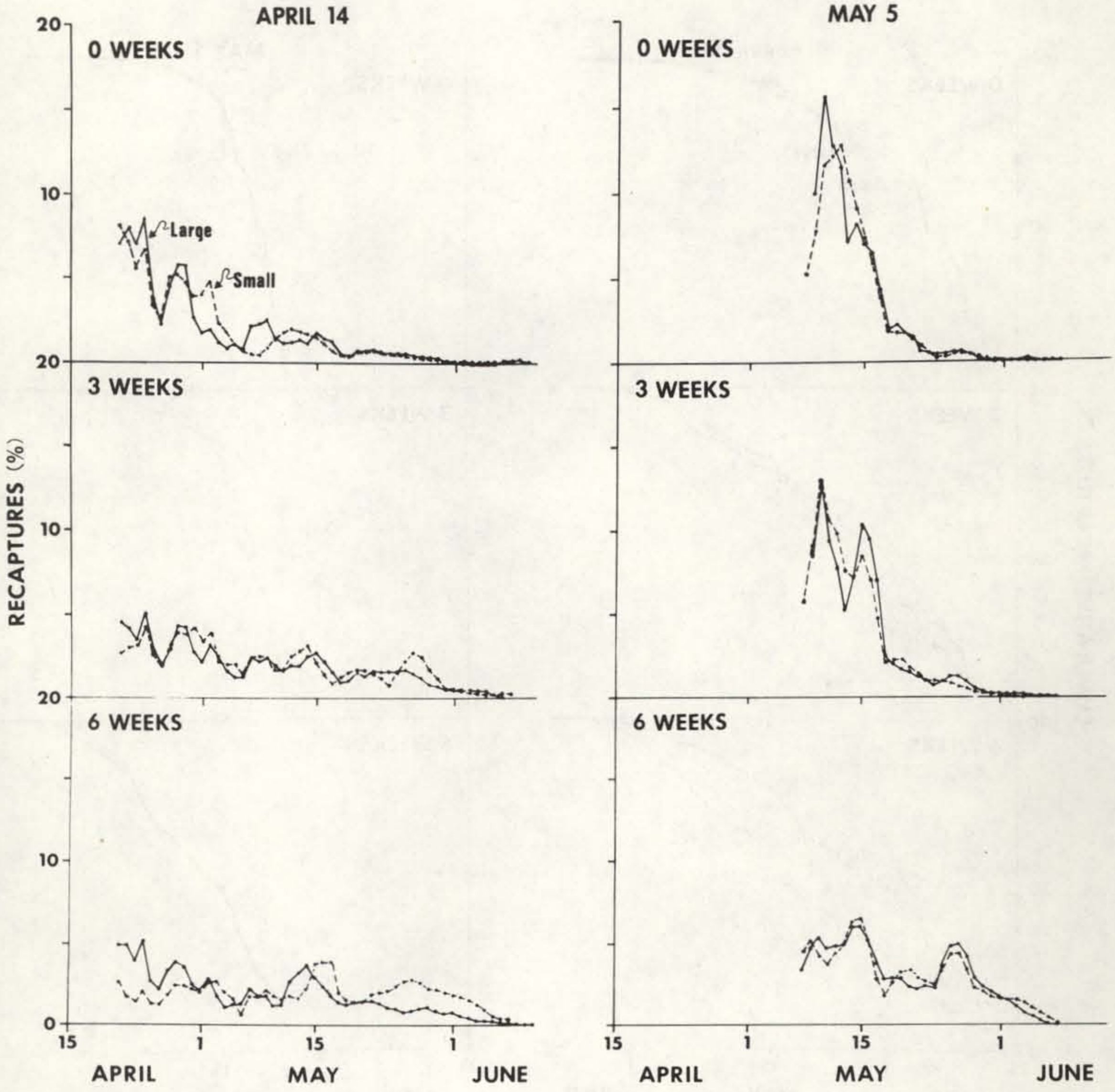

Figure 18. Timing of recapture at Lower Granite Dam of large and small size steelhead trout conditioned for 0, 3, and 6 weeks and released April 14 and May 5 from DNFH, 1976. The group released May 5 and labeled 3 weeks conditioning were not conditioned in cold water.

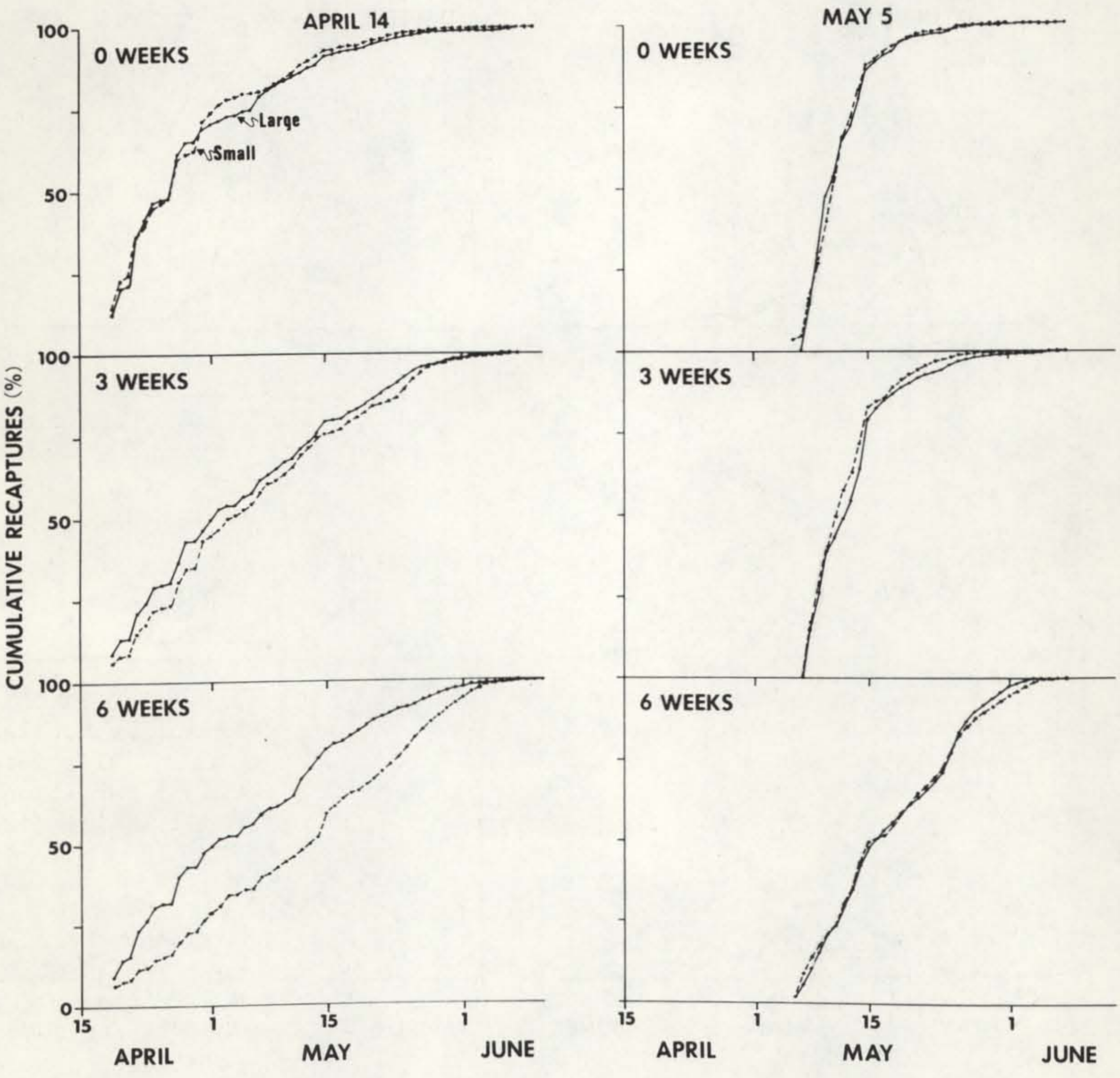

Figure 19. Cumulative percentage recapture at Lower Granite Dam of large and small size steelhead trout conditioned for 0, 3, and 6 weeks and released April 14 or May 5 from DNFH, 1976,

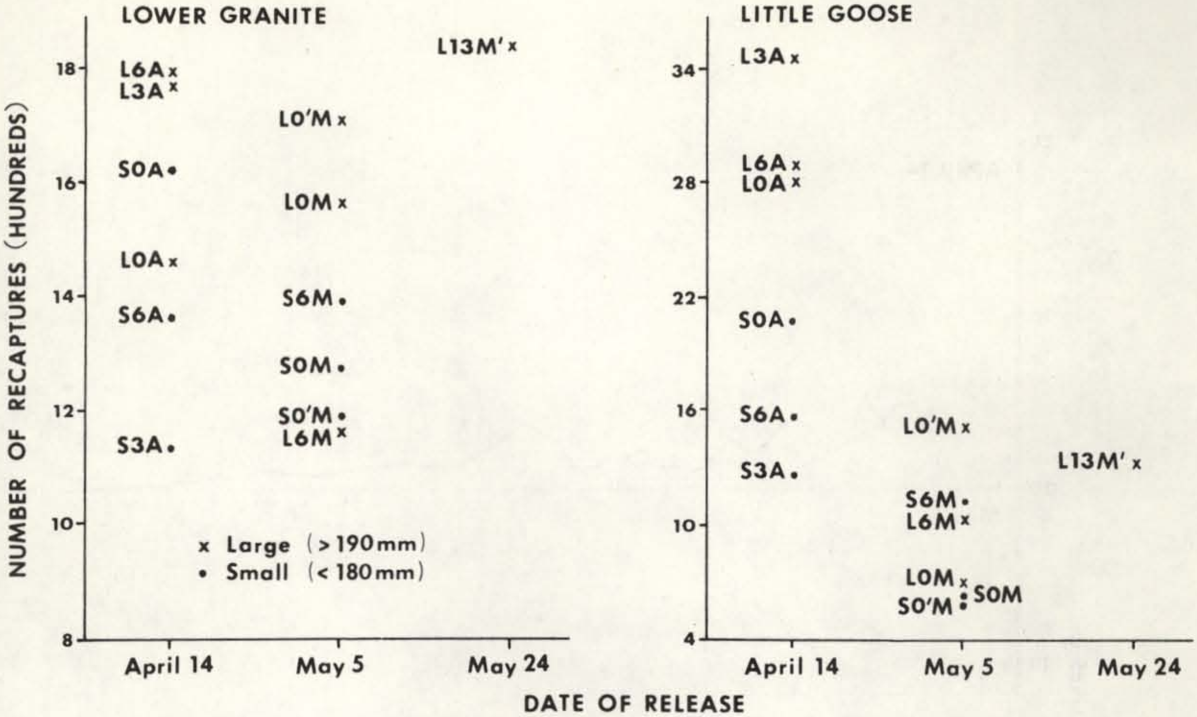

Figure 20. Adjusted number of branded DNFH steelhead trout recaptured at Lower Granite and Little Goose dams from each date of release and for large and small size fish, 1976.

The reasons for the smaller number of recaptures from the May releases are not readily apparent. At the time of release, the fish released in May appeared less healthy to us than the fish released in April, but the only quantitative measure of poorer health was the increase in daily mortality just before release May 5 of the groups with 0 weeks of conditioning (Fig. 6). The groups released April 14 with 6 weeks of conditioning also had high daily mortalities in the 3 weeks before release.

The timing of migration was different for fish released on April 14, May 5 and May 24 (Fig. 21). Fish in the April 14 release passed the dams over a prolonged period with 50 percent of the migrants having passed Lower Granite Dam by May 1 (Fig. 19). A large percentage of the fish released May 5 migrated soon after release - 50 percent of the migrants passing Lower Granite Dam by May 10-15. The fish released May 24 migrated immediately with 50 percent of the migrants having passed Lower Granite Dam 5 days after release (Fig. 21).

The May 24 release date was 1 to 2 weeks after the normal peak of steelhead migration at the lower Snake River dams, yet a higher percentage of fish released on that date were recaptured at Lower Granite Dam than any other group (Table 7). At Little Goose Dam, a smaller number of the May 24 fish were recaptured, perhaps because of the high incidence of fungus infection (Table 7). The incidence of fungus infection of the fish released May 24 (21% at Lower Granite Dam and 54% at Little Goose Dam) was higher than expected since mortality of these fish in the hatchery pond had been nil before release (Fig. 6).

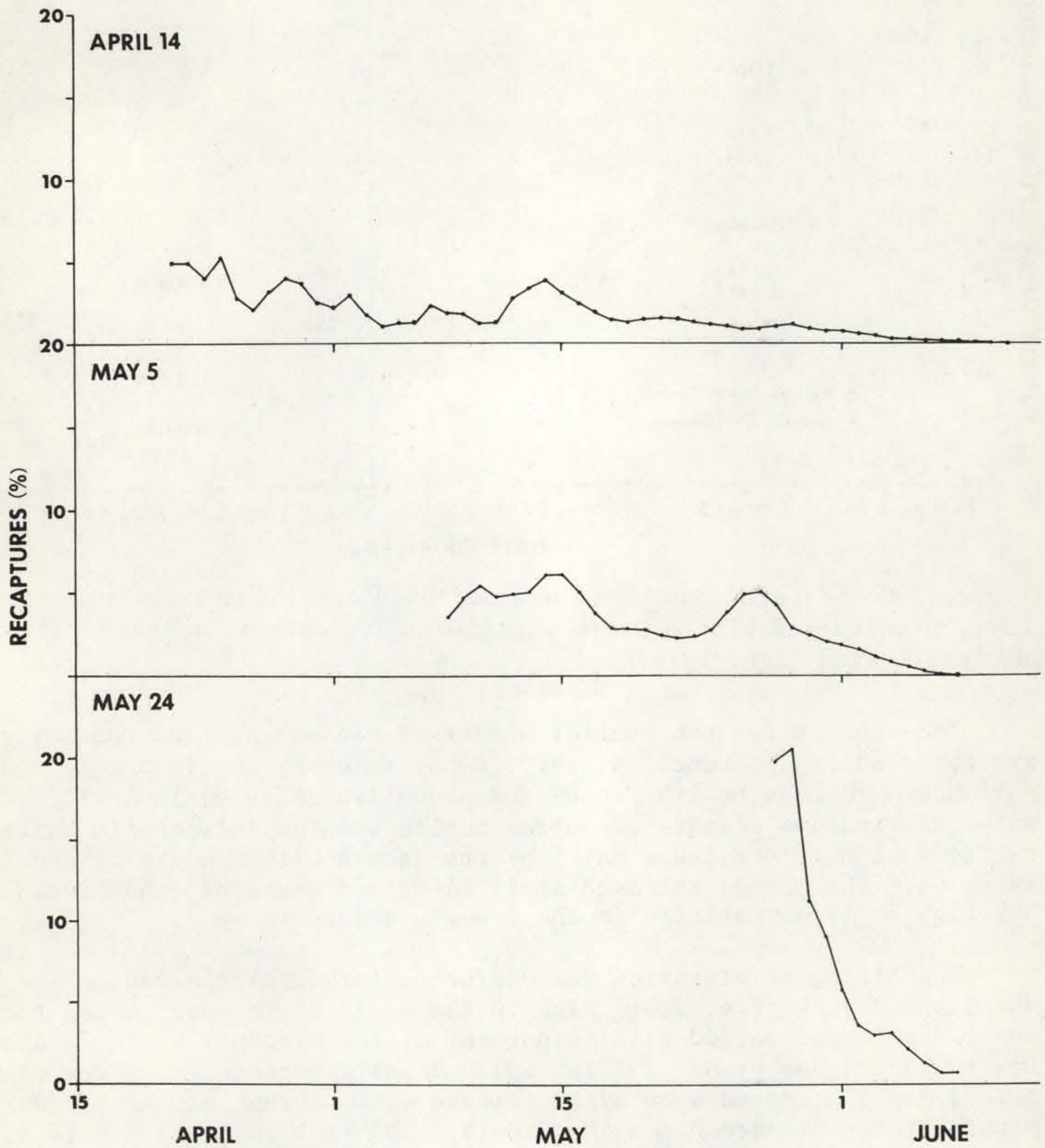

Figure 21. Timing of recapture at Lower Granite dams of large sized steelhead trout conditioned for 6 weeks and released April 14 and May 5 and conditioned 13 weeks and released May 24, 1976 from DNFH.

The pattern of DNFH steelhead trout at Little Goose Dam was similar to that at Lower Granite Dam, except the timing of the initial peak was 4-6 days later at Little Goose Dam, and a larger percentage of the fish moved past Little Goose Dam during May 1-15, the normal peak period of migration (Fig. 22).

We released four groups of jaw-tagged fish into a sluiceway at the hatchery (Table 9) and operated traps on the outlets of three hatchery ponds and the sluiceway to determine when the fish would voluntarily migrate if allowed to do so. With the exception of pond 52, the steelhead trout did not readily leave either the sluiceway or the ponds via the spill traps we installed. Without traps in the outlets, a larger percentage of the fish might have migrated voluntarily.

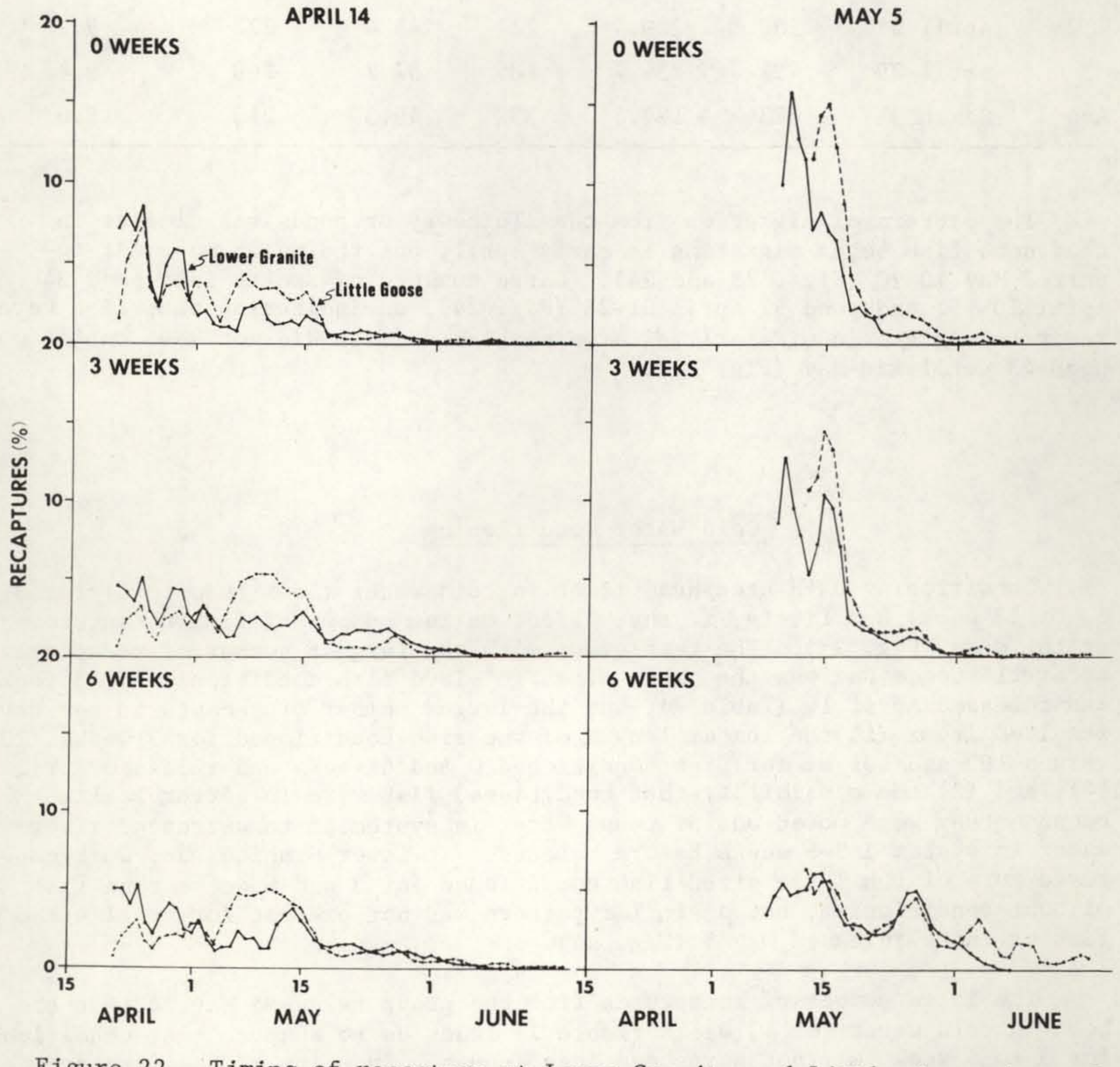

Figure 22. Timing of recapture at Lower Granite and Little Goose dams of large sized steelhead trout conditioned 0, 3, and 6 weeks and released April 14 and May 5, 1976 from DNFH.

Table 9. Number and mean total length of age II and age I steelhead trout tagged and released into sluiceway at DNFH, number recaptured in sluiceway or pond traps, number released from the pond May 24 and the percentage of the fish initially released that were not accounted for. The fish were moved from the sluiceway to ponds on April 29 and all remaining fish were released from the pond May 24, 1976,

Group of fish	Date tagged	Number tagged	Mean length at tagging	Fish recaptured in traps		Number released from pond May 24	Percentage unaccounted for
				Number	(%)		
Age II	March 16	499	221.6	216	43.2	218	13.0
	April 5	500	229.4	227	45.4	227	9.2
	April 29	491	234.7	185	37.7	260	9.4
Age I	March 31	673	184.6	332	49.3	213	19.0

The pattern of migration from the sluiceway or ponds was similar in that some fish began migrating in early April, but the major movement occurred May 10-20 (Figs. 23 and 24). Large numbers of smolts left pond 34 April 10-15, and pond 52 April 21-26 (Fig. 24), an indication that fish were ready to migrate in mid-April. Large numbers of fish did not move out of pond 43 until mid-May (Fig. 24).

Cold Water Conditioning

Conditioning DNFH steelhead trout in cold water (less than 10 C) for 3, 6, or 13 weeks had little, if any, effect on the number of fish recaptured at the dams (Fig. 25). The test group with the largest number of recaptures at Little Goose Dam was the group of large sized fish conditioned for 3 weeks and released April 14 (Table 7), but the larger number of recaptures may have resulted from: (1) the longer length of the fish conditioned for 3 weeks (200 versus 193 and 191 mm for fish conditioned 0 and 6 weeks and released April 14), and (2) the possibility that conditioned fish were in better health because they were moved out of reuse water in system II to untreated river water in system I 3-6 weeks before release. At Lower Granite Dam, we recaptured more of the large sized fish conditioned for 3 and 6 weeks than fish without conditioning, but a similar pattern was not present for small sized fish or those released May 5 (Fig. 25).

The large number of recaptures from the group released May 24 that had been in cold water for 13 weeks (Table 7) leads us to suspect that conditioning for 3 to 6 weeks may not have been long enough. In spite of the late date of release and high incidence of fungus infection when recaptured at the dams, a relatively large proportion of the fish conditioned for 13 weeks were recaptured.

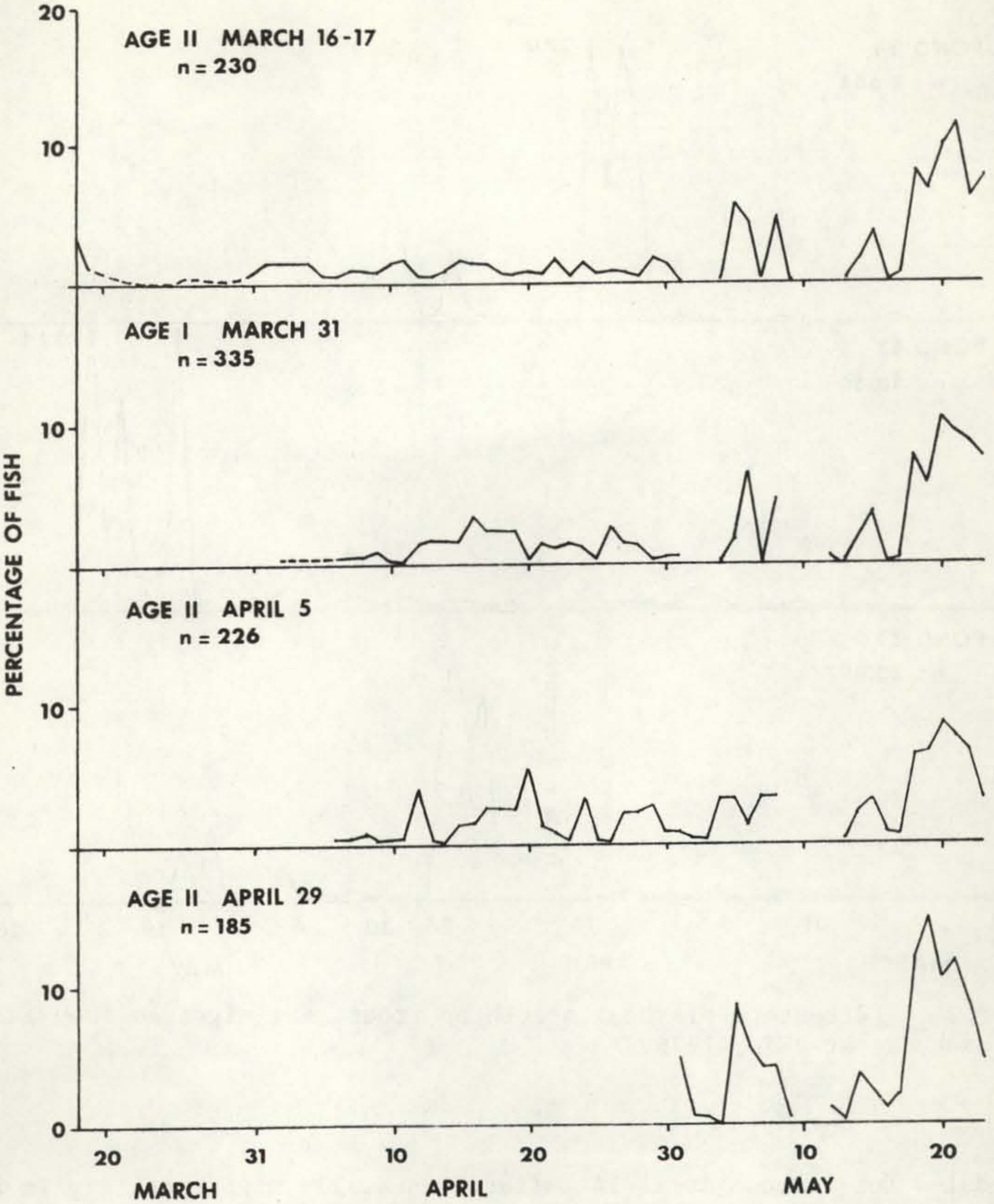

Figure 23. Percentage of total steelhead trout migrants from each group that migrated each day from the sluiceway (March 18-April 30) and from ponds 49 and 41 (May 1-23) at DNFH in 1976.

Conditioning the fish for 3 and 6 weeks in cold water appeared, at first glance, to delay the migration of some fish (Fig. 18). However, the large sized fish, conditioned for 3 and 6 weeks and released April 14, had more migrants than any other group (Table 7) which leads us to believe that at least some of the fish that migrated later may not have migrated at all without the cold water conditioning. Unfortunately, the fish being conditioned for 6 weeks

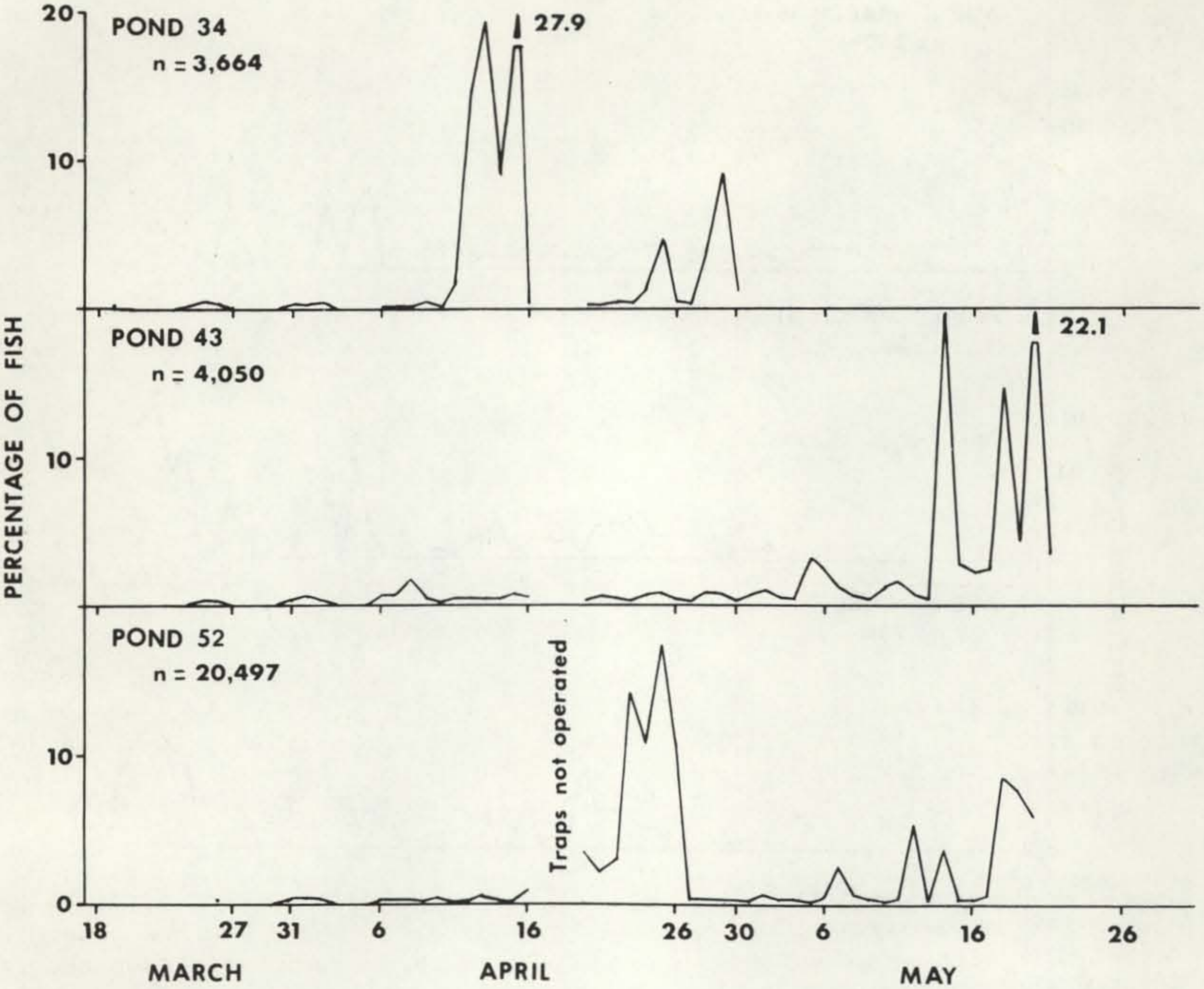

Figure 24. Percentage of total steelhead trout that migrated from each pond each day at DNFH, 1976.

and scheduled for release April 14 suffered unusually high mortality in the pond during the 3-4 weeks before release (Fig. 6), and thus they may have been less healthy when released than fish conditioned 0 to 3 weeks. Despite the potential health problems of the fish conditioned for 6 weeks, and their smaller size when released than fish conditioned for 0 and 3 weeks (Table 8), the large sized fish with 6 weeks of conditioning had the second largest number of migrants at both dams (Table 7), an indication that cold water conditioning may be more beneficial than appears obvious from these tests.

The timing of migration of the fish conditioned in cold water was significantly later than those without conditioning (Fig. 19). Half the migrants from the April 14 release with 0 weeks of conditioning had passed Lower Granite Dam by April 26, 50 percent of the migrants with 3 weeks of conditioning and the large sized fish conditioned for 6 weeks had passed by May 1-2, but half the migrants from the small sized fish conditioned for 6 weeks had not passed the dam until May 13.

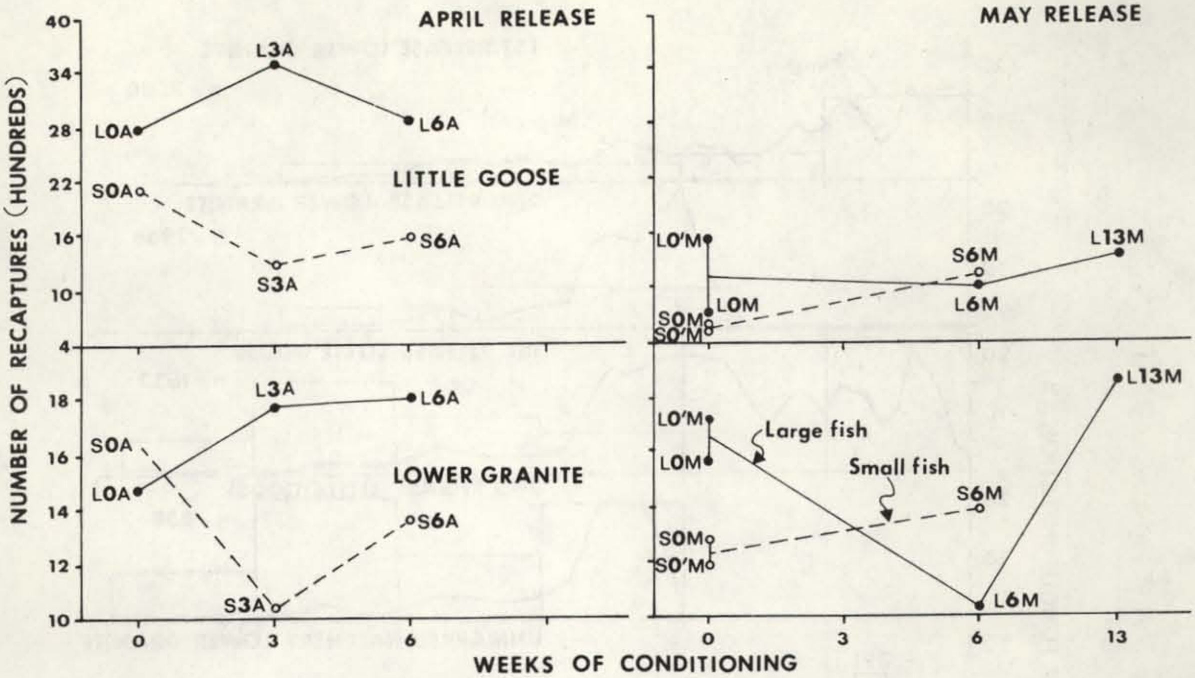

Figure 25. Adjusted number of branded DNFH steelhead trout recaptured at Lower Granite and Little Goose dams after 0, 3, 6, or 13 weeks of conditioning in cold (<10 C) water and released April 14, May 5 and 24, 1976. Refer to Table 1 for explanation of abbreviations (LOA, etc) for groups.

The small sized fish conditioned for 6 weeks and released April 14 had the third largest number of migrants at Lower Granite Dam and the second highest at Little Goose Dam (Table 7). The number of migrants from the group conditioned for 6 weeks may have been larger had they not had high mortalities in the pond just before release (Fig. 6) and they had been longer than 167 mm when released. If the small sized fish conditioned for 6 weeks had been the same length as the fish conditioned for 0 weeks (177 mm), an additional 500 fish would have been recaptured (using the regression in Fig. 11) making a total of about 2100 fish recaptured, the largest number of any of the small sized fish groups (Table 7).

Incidence of Fungus Infection

The percentage of DNFH smolts with fungus infections when recaptured at the dams was highest among the early migrants (Fig. 26). At both Lower Granite and Little Goose dams, the fish released April 14 that passed the dam in late April and early May had the highest rate of fungus infection (up to 25%). The incidence of infection was higher among fish examined at Little Goose Dam than among those at Lower Granite Dam.

At Lower Granite Dam, the early migrants from the April 14 release of marked fish had an infection rate of 14 percent compared to 26 percent at Little Goose Dam and 22 percent for a mixed group of branded fish examined at Ice Harbor Dam (Fig. 26). Unbranded hatchery smolts passing Lower Granite

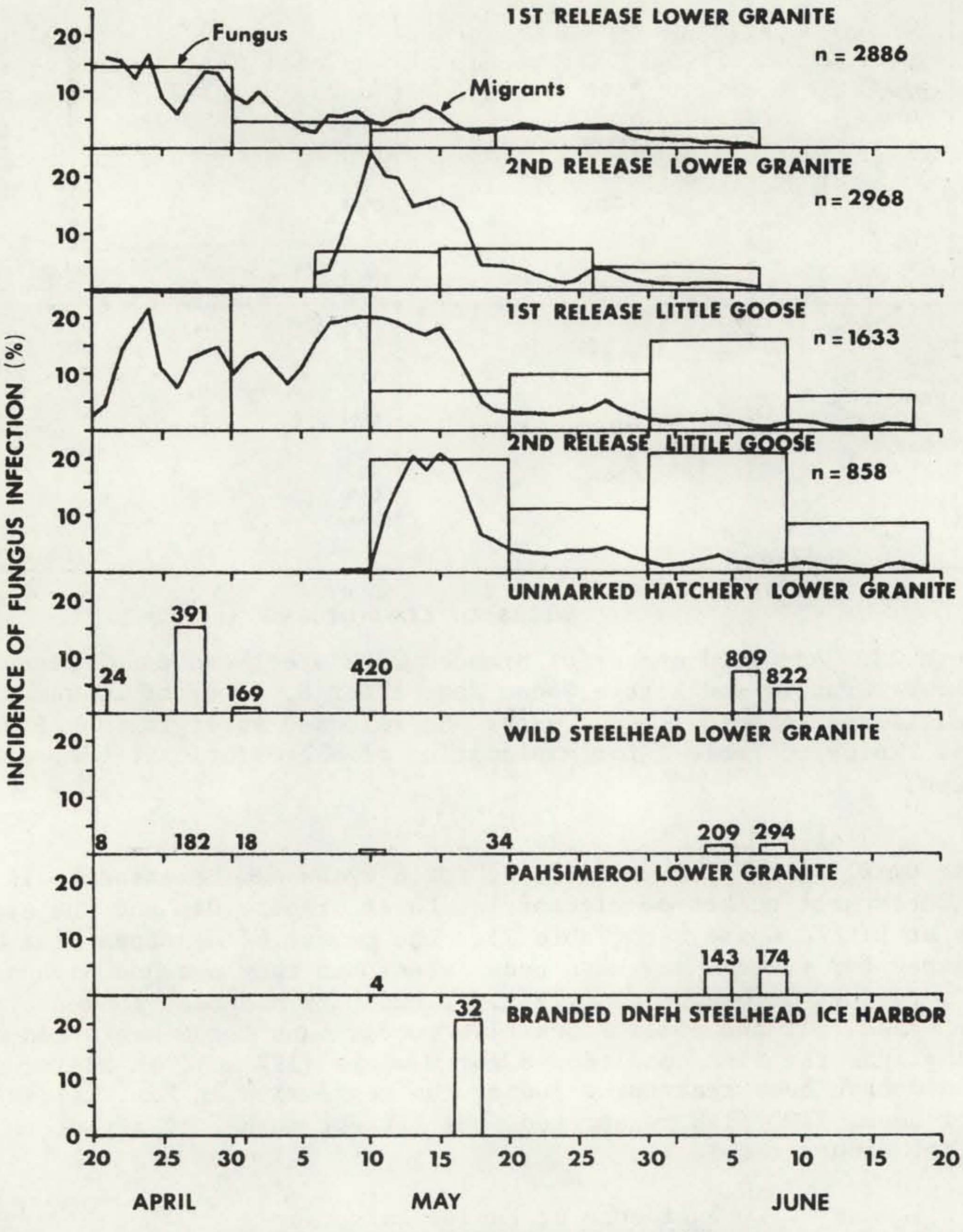

Figure 26. Timing of migration of marked DNFH steelhead trout and incidence of fungus infection (% of fish examined) among marked and unmarked fish from DNFH, hatchery fish from Pahsimeroi River (Niagara Springs State Hatchery), and wild fish, 1976. Numbers of fish examined on top of histograms.

Dam in late April (probably from DNFH system II) had an infection rate of 15 percent, similar to the rate for branded fish released April 14. Branded and unbranded hatchery smolts examined at Lower Granite Dam May 10-20 had infection rates of 6-7 percent.

Wild steelhead smolts had infection rates of 2 percent or less throughout the migration season (Fig. 26). Niagara Springs Hatchery-Pahsimeroi River smolts examined at Lower Granite Dam June 4 and 8 had fungus infection rates of 4-5 percent.

Gill ATPase Activity

Gill ATPase activity of DNFH steelhead was only slightly elevated when measured April 15 on fish taken from the hatchery (Fig. 27). Large sized fish had higher activity levels than the small sized fish (Table 10). The ATPase activity level of fish held at the hatchery or in the lab increased during May to a peak of about 25 μ moles and then declined in early June.

The ATPase activity level in branded DNFH steelhead collected at the dams after they had migrated downstream was higher than in fish taken from the hatchery on similar dates (Fig. 27). Fish collected at Lower Granite Dam on April 27 averaged 27 μ moles compared to 20 for fish at the hatchery, and fish collected May 13 at the dam averaged 34 μ moles versus 26 for fish at the hatchery. Hatchery fish collected at John Day Dam had ATPase activities of about 50 μ moles in mid-May.

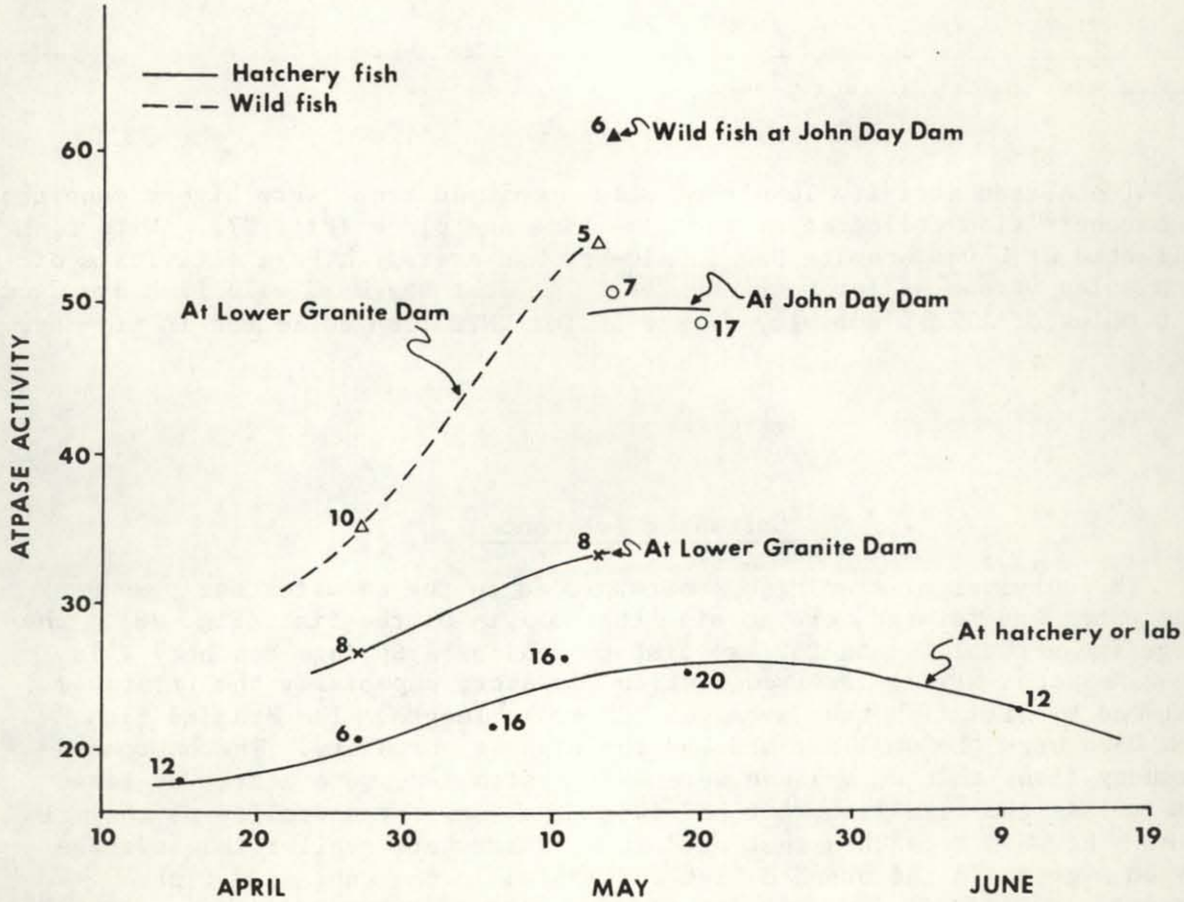

Figure 27. Gill ATPase activity level of wild and marked DNFH steelhead trout held at the hatchery or in laboratory or collected at dams, 1976.

Table 10. Gill ATPase activity (micro moles ATP hydrolyzed/hr/mg protein) of wild and hatchery steelhead trout sampled while at the hatchery and while migrating past Lower Granite and John Day dams in 1976. Fish in sample in parantheses.

		While at hatchery or lab						Migrants at Lower Granite		Migrants at John Day	
Group number	Abbreviated description[a]	April 15	April 27	May 6	May 10-12	May 17-21	June 8-14	April 27	May 13	May 14	May 20
1	L-0-A	20.0(2)	22.5(2)	-	-	-	-	31.3(3)	-	52.0(1)	44.0(2)
2	S-0-A	13.5(2)	-	-	-	-	-	22.0(1)	-	-	-
3	L-0-M	-	-	19.5(2)	20.0(2)	30.0(2)	28.0(3)	-	-	-	55.5(2)
4	S-0-M	-	-	19.5(2)	21.5(4)	19.0(2)	20.7(3)	-	37.3(3)	-	43.0(2)
5	L-3-A	22.0(2)	20.5(2)	-	-	17.5(2)	-	23.5(2)	-	51.5(2)	40.0(2)
6	S-3-A	16.5(2)				20.0(3)		-	-	49.0(1)	54.0(2)
7	L-0'-M	-	-	22.0(2)	31.0(4)	33.5(2)	21.5(2)	-	33.0(2)	-	67.0(2)
8	S-0'-M	-	-	18.5(2)	20.0(2)	28.5(2)	-	-	30.3(3)	-	49.0(2)
9	L-6-A	18.5(2)	19.0(2)	-	-	29.0(3)	-	25.5(2)	-	47.5(2)	38.0(1)
10	S-6-A	16.5(2)	-	-	-	25.8(4)	-	-	-	55.0(1)	50.5(2)
13	L-13-M'	-	-	24.5(4)	32.0(2)	-	23.5(2)				
	Wild	-	-	-	-	-	-	35.4(10)	54.4(5)	61.3(6)	-
	Pond 52	-	-	23.5(4)	29.8(4)	-	19.0(2)	-	-	-	-

[a]See table 1 for full description of test groups.

The ATPase activity levels of wild steelhead trout were higher than those of hatchery fish collected at the same time and place (Fig. 27). Wild fish collected at Lower Granite Dam in mid-May had average ATPase activities of 54 μ moles versus 34 for hatchery fish. At John Day Dam, wild fish averaged 61 μ moles of ATPase activity versus 50 for DNFH fish collected in mid-May.

Saltwater Tolerance

The survival of steelhead smolts placed in the seawater net pens at Manchester was related more to size than origin of the fish (Fig. 28). The large (mean total length 252 mm) fish from Niagara Springs Hatchery (via the Pahsimeroi River) survived best in seawater, especially the first week, followed by wild fish that averaged 202 mm in length. The branded fish from DNFH were the smallest and had the highest mortality. The unbranded hatchery fish, that we believe were DNFH system III, were nearly as large (198 mm) as the wild fish, but had twice the seawater mortality of the wild fish. The DNFH steelehad that died in seawater were smaller than average -- 175 mm average in the branded fish and 185 mm in the unbranded fish.

Most of the fish that could not handle seawater had died by May 19 (Fig. 28). Mortality among control fish held in the raceway at Lower Granite Dam was minimal up to that time, but increased rapidly during the next 2 weeks. Fish in all four groups had fungus infections and significant numbers died.

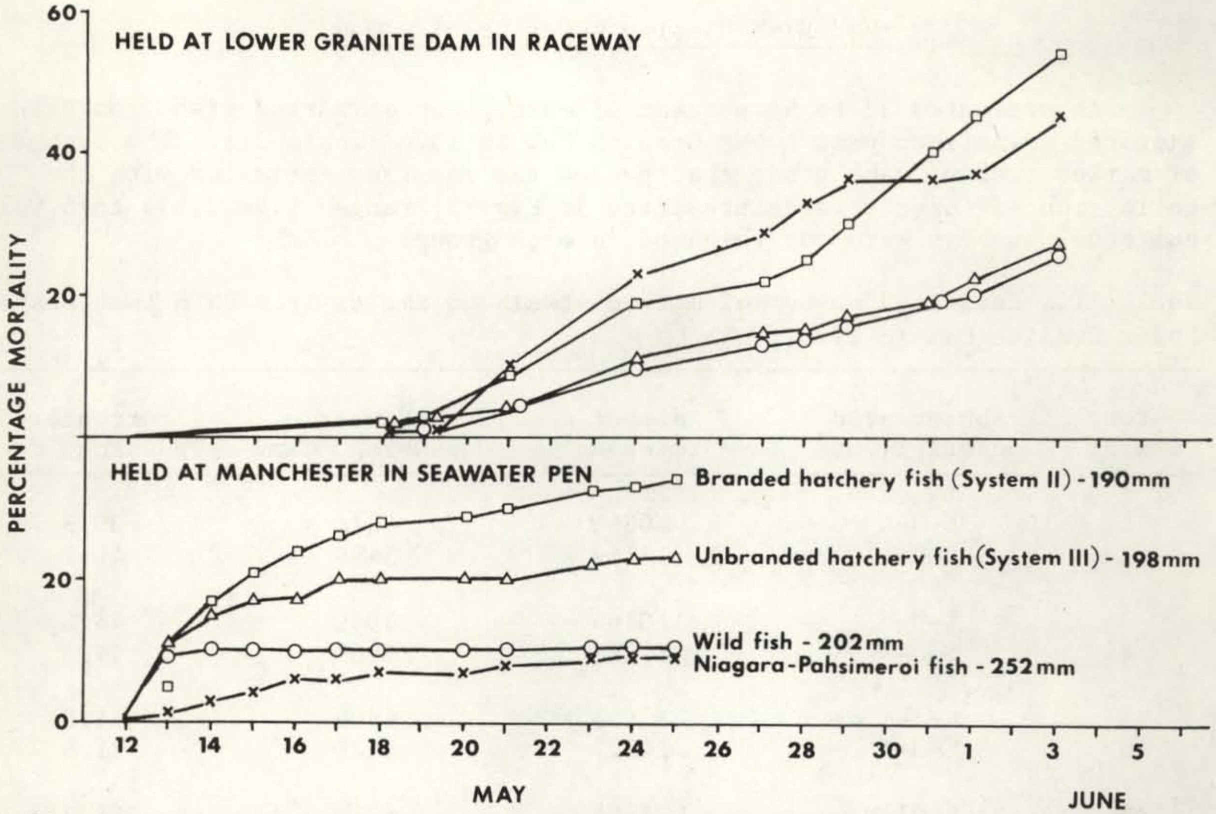

Figure 28. Cumulative percentage mortality of wild and hatchery (DNFH from systems II and III, and Niagara Springs via the Pahsimeroi River) steelhead trout collected at Lower Granite Dam May 12 placed in a raceway at the dam (100 fish of each group), and hauled to Manchester and placed in net pens in saltwater (100 fish in each group).

The wild fish and the unbranded hatchery fish (from DNFH system III) were the healthiest looking fish when they were placed in the raceway, and these two groups had the least mortality (about 26%) and the lowest rate of fungus infection; 9-11 percent of the fish remaining on June 3. The Niagara-Pahsimeroi fish had considerable descaling and seemed devoid of mucous when placed in the raceway, conditions that might have led to the high mortality (45%) and fungus infection rate (23%) among those fish. The high mortality rate among the branded fish from DNFH system II (54%) and the 21 percent fungus infection rate is evidence that the health of fish from system II was less than desired.

Marked Fish Passing Lower Granite Dam

An estimated 32 to 54 percent of each group of marked fish from DNFH migrated downstream past Lower Granite Dam in 1976 (Table 11). The number of marked fish of each group that passed the dams, as estimated with the collection efficiency rates presented in Fig. 3, ranged from 2,834 to 6,967, but equal numbers were not released in each group.

Table 11. Estimated number of marked steelhead smolts from DNFH that passed Lower Granite Dam in 1976.

Group number	Abbreviated descriptions[a]	Number released	Number passing dam	Percentage passing dam
1	L-0-A	10864	4271	39.3
2	S-0-A	13149	5489	41.7
3	L-0-M	10164	4939	48.6
4	S-0-M	17888	6967	44.6
5	L-3-A	12955	6606	51.0
6	S-3-A	14227	4520	31.8
7	L-0'-M	12685	6870	54.2
8	S-0'-M	12214	4481	36.7
9	L-6-A	10989	5398	49.1
10	S-6-A	10055	3944	39.2
11	L-6-M	8880	2834	31.9
12	S-6-M	10948	4449	40.6
13	L-13-M'	6004	2866	47.3

a/ Refer to Table 1 for full description.

The relative abundance between groups of migrants versus adjusted number of fish recaptured at the dam had a similar pattern (Fig. 29). The groups with largest numbers of adjusted recaptures also had the largest percentages of the fish in the group that migrated past the dam. The adjusted number of fish recaptured from each group at Little Goose Dam did not have the same relative abundance pattern as adjusted recaptures or percentage passing Lower Granite Dam (Fig. 29). Some groups that were relatively abundant at Lower Granite Dam (the LOM and SOM groups, for example) were notably less abundant at Little Goose Dam.

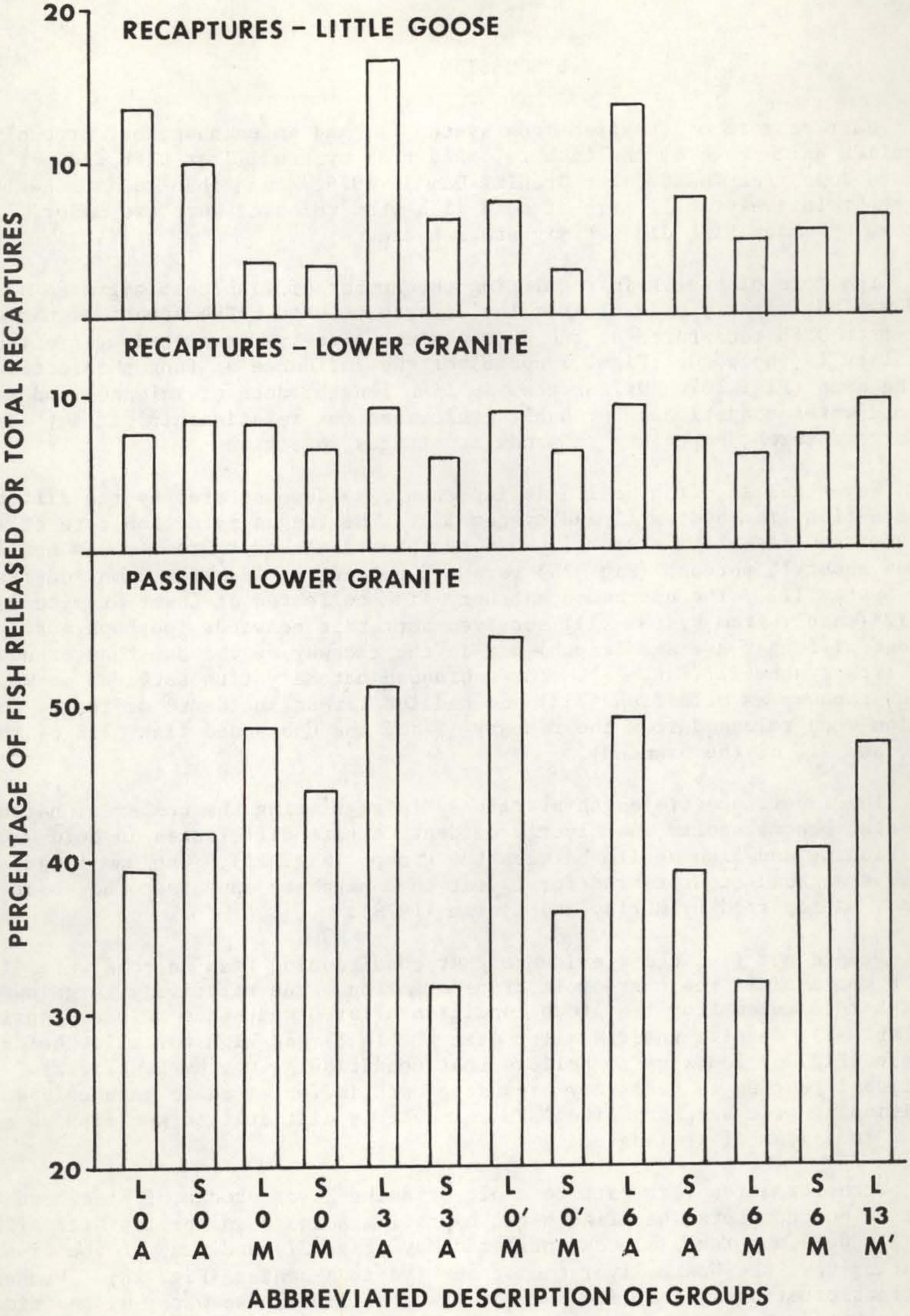

Figure 29. Estimated percentage of each group of steelhead trout released from DNFH that passed Lower Granite Dam and the adjusted number recaptured expressed as a percentage of the total number recaptured at Lower Granite and Little Goose dams, 1976.

DISCUSSION

Half or more of the fish from system II, and an unknown, but probably a smaller percentage of the fish released from system III at DNFH did not migrate downstream past Lower Granite Dam in 1976. Less than optimum health and the relatively small size of some fish when released were two major reasons why many fish did not migrate seaward.

The role of health in regulating the number of fish that migrated seaward was not clearly evident from the indexes we used. The number of marked fish from DNFH recaptured at the dams was not closely correlated with either mortality in the ponds (Figs. 7 and 8) or the incidence of fungus infection at the dams (Fig. 10). Differences in fish length, date of release, and weeks of cold water conditioning probably confounded the relationship, if any, between recaptures, mortality in ponds and fungus infection.

Nevertheless, fish health is important, as demonstrated by the differences between fish from system II and system III. The fungus infection rate of marked and unmarked fish from system II when recaptured at Lower Granite Dam April 20-30 was about 15 percent (Fig. 26) versus 6 percent or less for unmarked fish from System III. The unbranded hatchery fish collected at Lower Granite Dam May 12 (mostly from system III) survived better in seawater (perhaps mostly because of longer average length) and in the raceway at the dam than branded fish from system II (Fig. 28). The unbranded hatchery fish survived as well in the raceway as wild fish (75%) and had the lowest incidence of fungus infection when released from the raceway (9% of the unbranded fish, 11% of the wild, and 21% of the branded).

The importance of length at release in regulating the number of hatchery fish that become smolts was clearly evident despite differences in cold water conditioning and fish health between the groups (Fig. 11). Optimum length for summer steelhead trout reared for 1 year in a hatchery appears to be about 200 mm, as reported by Chrisp and Bjornn (1978).

We did not find clear evidence that conditioning fish in cold water for 3 or 6 weeks aided the parr-smolt transformation. The relatively large number of fish recaptured from the group conditioned for 6 weeks and released April 14 (Table 7), despite their smaller size (Table 8) and high mortality before release (Fig. 6) leads us to believe that conditioning may be beneficial. Additional testing is necessary because growth is forfeited to gain cold water conditioning at a hatchery like DNFH where it is difficult to get fish up to 200 mm in 1 year of rearing.

Transformation form parr to smolt of Snake River stocks of steelhead trout is not complete when fish begin migrating seaward in April. Gill ATPase activity does not reach a peak until mid-May (Fig. 27) and many of the fish migrating down the Snake River cannot survive in seawater (Fig. 28). Presumably the transformation is complete and the fish can live in seawater by the time the migrants reach the estuary.

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